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7

8 UNITED STATES DISTRICT COURT
9 SOUTHERN DISTRICT OF CALIFORNIA
10

11 BEATBOT TECHNOLOGY (USA)
CO. LTD., DEEPWATER
12 INNOVATION
TECHNOLOGY (HONG KONG)
13 LIMITED, and XINGMAI
INNOVATION TECHNOLOGY
14 (SUZHOU) CO., LTD.,

15 Plaintiffs,

16 v.

17 ZODIAC POOL SYSTEMS LLC

18 Defendant.
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Case No. **'25CV1946 GPC JLB**

**COMPLAINT FOR DECLARATORY
JUDGMENT OF NON-
INFRINGEMENT**

JURY TRIAL DEMANDED

1 Plaintiffs Beatbot Technology (USA) Co. Ltd., Deepwater Innovation
2 Technology (Hong Kong) Limited (f/k/a Xingmai Innovation Technology (Hong
3 Kong) Limited), and Xingmai Innovation Technology (Suzhou) Co., Ltd.
4 (collectively, “Beatbot”) seeks a declaration that Beatbot does not directly or
5 indirectly infringe United States Patent Nos. 11,880,207 (“the ’207 Patent”);
6 11,262,766 (“the ’766 Patent”); and 11,003,191 (“the ’191 Patent”) (collectively,
7 the “Patents-in-Suit”), either literally or under the doctrine of equivalents, and in
8 support of its Complaint alleges as follows:

9 **NATURE OF THE ACTION**

10 1. This is an action for a declaratory judgment of noninfringement arising
11 under the patent laws of the United States, Title 35 of the United States Code.
12 Beatbot seeks this relief because Defendant Zodiac Pool Systems LLC (“Zodiac”)
13 has accused Beatbot of infringing the Patents-in-Suit.

14 2. An immediate, real, and justiciable controversy exists between Beatbot
15 and Zodiac as to whether the Patents-in-Suit have been infringed by Beatbot.

16 3. Beatbot is a manufacturer and seller of robotic pool cleaners, such as
17 Beatbot AquaSense 2 Ultra Robotic Pool Cleaner (“Beatbot Products”).

18 4. Zodiac through its prior actions and statements has created a
19 substantial controversy of sufficient immediacy and reality to warrant the issuance
20 of a declaratory judgment of non-infringement as to whether the Beatbot Products
21 infringe the Patents-In-Suit, which are attached hereto as Exhibits 1–3.

22 5. Specifically, by a letter dated July 17, 2025, attached hereto as Exhibit
23 4, Zodiac, through its counsel, expressly accused Beatbot’s Beatbot Aquasense 2
24 Ultra Robotic Pool Cleaner of infringing the Patents-in-Suit. In this letter, Zodiac
25 demanded that Beatbot immediately cease all allegedly infringing conduct and
26 threatened to “enforce its intellectual property rights” if its demands were not met
27 within ten business days, creating a substantial, immediate, and real controversy
28 between the parties. This action is necessary to resolve the controversy created by

1 Zodiac's accusations and threats. Beatbot brings this action to obtain a declaratory
2 judgment that Beatbot does not infringe at least the claims of the Patents-in-Suit
3 identified below, directly or indirectly, literally or under the doctrine of equivalents.

4 **THE PARTIES**

5 6. Beatbot Technology (USA) Co. Ltd. is a Texas company having an
6 address at 7307 Peek Rd., Richmond, Texas, 77407.

7 7. Deepwater Innovation Technology (Hong Kong) Limited (f/k/a
8 Xingmai Innovation Technology (Hong Kong) Limited) is a company organized
9 and existing under the laws of Hong Kong having an address at Flat/Room 185
10 G/F, Hang Wai Ind Centre, No. 6 Kin Tai St, Tuen Mun Nt, Hong Kong .

11 8. Xingmai Innovation Technology (Suzhou) Co., Ltd. is a company
12 organized and existing under the laws of China having an address at 12 F, Bldg. 5,
13 Tianyun Plaza, No.111, Wusongjiang Ave., Guoxiang St., Wuzhong District,
14 Suzhou, 215124, Jiangsu, China.

15 9. On information and belief, Zodiac is a Delaware limited liability
16 company with its principal place of business at 2882 Whiptail Loop # 100,
17 Carlsbad, California, 92010.

18 **JURISDICTION AND VENUE**

19 10. The Court has subject matter jurisdiction over this action pursuant the
20 Federal Declaratory Judgment Act, 28 U.S.C. §§ 2201 and 2202, and pursuant to 28
21 U.S.C. §§ 1331 and 1338(a) because this action involves claims arising under the
22 patent laws of the United States, 35 U.S.C. § 1, et seq. Jurisdiction is also proper
23 because Beatbot and Zodiac are citizens of different states and the value of the
24 controversy exceeds \$75,000.

25 11. Venue is proper in this District pursuant to at least 28 U.S.C.
26 § 1391(b), because a substantial part of the events at issue in this action is whether
27 Beatbot commits acts of infringement in this and other districts in the United States,
28

1 and because Zodiac is subject to the Court's personal jurisdiction and thus resides
2 in this District, pursuant to § 1391(c).

3 12. The Court's exercise of jurisdiction over Zodiac will not offend
4 traditional notions of fair play and substantial justice.

5 13. An actual controversy exists between Beatbot and Zodiac because, as
6 described in the Nature of the Action above, Zodiac through its statements has
7 created a substantial controversy as to whether the Beatbot Products infringe the
8 Patents-in-Suit that is of sufficient immediacy and reality to warrant the issuance of
9 a declaratory judgment as to the controversy.

10 **THE PATENTS-IN-SUIT**

11 14. On May 11, 2021, the U.S. Patent and Trademark Office issued U.S.
12 Patent No. 11,003,191 ("the '191 Patent"), titled "Pool Cleaning System and
13 Method to Automatically Clean Surfaces of a Pool Using Images from a Camera"
14 to assignee Zodiac Pool Systems LLC. A true and correct copy of the '191 Patent
15 is attached to this Complaint as Exhibit 1. Upon further information and belief,
16 Zodiac Pool Systems LLC purports to hold by assignment and/or by license all
17 substantive rights to assert the '191 Patent.

18 15. On March 1, 2022, the U.S. Patent and Trademark Office issued U.S.
19 Patent No. 11,262,766 ("the '766 Patent"), titled "Pool Cleaning System and
20 Method to Automatically Clean Surfaces of a Pool Using Images from a Camera"
21 to assignee Zodiac Pool Systems LLC. A true and correct copy of the '766 Patent
22 is attached to this Complaint as Exhibit 2. Upon further information and belief,
23 Zodiac Pool Systems LLC purports to hold by assignment and/or by license all
24 substantive rights to assert the '766 Patent.

25 16. On January 23, 2024, the U.S. Patent and Trademark Office issued
26 U.S. Patent No. 11,880,207 ("the '207 Patent"), titled "Pool Cleaning System and
27 Method to Automatically Clean Surfaces of a Pool Using Images from a Camera"
28 to assignee Zodiac Pool Systems LLC. A true and correct copy of the '207 Patent

1 is attached to this Complaint as Exhibit 3. Upon further information and belief,
 2 Zodiac Pool Systems LLC purports to hold by assignment and/or by license all
 3 substantive rights to assert the '207 Patent.

4 **COUNT ONE**

5 **Non-Infringement of U.S. Patent No. 11,003,191**

6 17. Beatbot incorporates by reference the preceding allegations of this
 7 Complaint.

8 18. Beatbot has not infringed and does not infringe at least claim 1 of the
 9 '191 Patent, either directly or indirectly, literally or under the doctrine of
 10 equivalents, including through its making, use, sale or offer for sale in, or
 11 importation into the United States of the Beatbot Products.

12 19. The Beatbot Products also do not perform substantially the same
 13 function, in substantially the way, to obtain substantially the same result as claim 1
 14 of the '191 Patent.

15 20. By way of example, claim 1 of the '191 Patent is directed to self-
 16 propelled pool cleaner for cleaning debris from a submerged surface of a swimming
 17 pool. *See* Exhibit 1, Claim 1, at 10:50–65. Claim 1 recites numerous limitations,
 18 including: “at least one camera positioned on or in the body for capturing an image
 19 of at least a first portion of the submerged surface” and “a controller (i) positioned
 20 on or in the body, (ii) in electronic communication with the at least one camera, and
 21 (iii) configured to generate, in response to the captured image, at least one control
 22 signal to cause movement of the body within the swimming pool to, or away from,
 23 the first portion of the submerged surface.” *Id.* The Beatbot Products do not
 24 infringe claim 1, at least because they do not practice these claim limitations. For
 25 example, the Beatbot Products do not include “at least one camera positioned on or
 26 in the body for capturing an image of at least a first portion of the submerged
 27 surface” or “a controller (i) positioned on or in the body, (ii) in electronic
 28 communication with the at least one camera, and (iii) configured to generate, in

1 response to the captured image, at least one control signal to cause movement of the
2 body within the swimming pool to, or away from, the first portion of the submerged
3 surface” as recited in claim 1.

4 21. Accordingly, at least for the above reasons, Beatbot does not directly
5 infringe at least claim 1 of the ’191 Patent, either literally or under the doctrine of
6 equivalents, because the Beatbot Products do not practice all elements of that claim.

7 22. Beatbot also does not indirectly infringe the ’191 Patent for at least the
8 reasons stated above and because there is no direct infringement of the ’191 Patent,
9 either literally or under the doctrine of equivalents.

10 23. As set forth above, an actual controversy exists between Beatbot and
11 Zodiac with respect to alleged infringement of the ’191 Patent, and this controversy
12 is likely to continue. Accordingly, Beatbot desires a judicial determination and
13 declaration of the respective rights and duties of the parties with respect to the ’191
14 Patent.

15 24. A judicial declaration is necessary and appropriate so that Beatbot may
16 ascertain its rights regarding the claims of the ’191 Patent.

17 **COUNT TWO**

18 **Non-Infringement of U.S. Patent No. 11,262,766**

19 25. Beatbot incorporates by reference the preceding allegations of this
20 Complaint.

21 26. Beatbot has not infringed and does not infringe at least claim 1 of the
22 ’766 Patent, either directly or indirectly, literally or under the doctrine of
23 equivalents, including through its making, use, sale or offer for sale in, or
24 importation into the United States of the Beatbot Products.

25 27. The Beatbot Products also do not perform substantially the same
26 function, in substantially the way, to obtain substantially the same result as claim 1
27 of the ’766 Patent.

1 28. By way of example, claim 1 of the '766 Patent is directed to a self-
2 propelled pool cleaner for cleaning debris from a submerged surface of a swimming
3 pool. *See* Exhibit 2, claim 1, at 10:47–62. Claim 1 recites numerous limitations,
4 including: “at least one camera mounted directly or indirectly to the body for
5 capturing an image of at least a first portion of the submerged surface” and “a
6 controller (i) positioned on or in the body, (ii) in electronic communication with the
7 at least one camera, and (iii) configured to generate, in response to the captured
8 image, at least one control signal to cause movement of the body within the
9 swimming pool to, or away from, the first portion of the submerged surface.” *Id.*
10 The Beatbot Products do not infringe claim 1, at least because they do not practice
11 these claim limitations. For example, the Beatbot Products do not include “at least
12 one camera mounted directly or indirectly to the body for capturing an image of at
13 least a first portion of the submerged surface” or “a controller (i) positioned on or in
14 the body, (ii) in electronic communication with the at least one camera, and (iii)
15 configured to generate, in response to the captured image, at least one control signal
16 to cause movement of the body within the swimming pool to, or away from, the
17 first portion of the submerged surface,” as required in claim 1. Beatbot also does
18 not infringe the other claims of the '766 Patent.

19 29. Accordingly, at least for the above reasons, Beatbot does not directly
20 infringe the claims of the '766 Patent, either literally or under the doctrine of
21 equivalents, because the Beatbot Products do not practice all elements of those
22 claims.

23 30. Beatbot also does not indirectly infringe the '766 Patent for at least the
24 reasons stated above and because there is no direct infringement of the '766 Patent,
25 either literally or under the doctrine of equivalents.

26 31. As set forth above, an actual controversy exists between Beatbot and
27 Zodiac with respect to alleged infringement of the '766 Patent, and this controversy
28 is likely to continue. Accordingly, Beatbot desires a judicial determination and

1 declaration of the respective rights and duties of the parties with respect to the '766
2 Patent.

3 32. A judicial declaration is necessary and appropriate so that Beatbot may
4 ascertain its rights regarding the claims of the '766 Patent.

5 **COUNT THREE**

6 **Non-Infringement of U.S. Patent No. 11,880,207**

7 33. Beatbot incorporates by reference the preceding allegations of this
8 Complaint.

9 34. Beatbot has not infringed and does not infringe at least claim 1 of the
10 '207 Patent, either directly or indirectly, literally or under the doctrine of
11 equivalents, including through its making, use, sale or offer for sale in, or
12 importation into the United States of the Beatbot Products.

13 35. The Beatbot Products also do not perform substantially the same
14 function, in substantially the way, to obtain substantially the same result as claim 1
15 of the '207 Patent.

16 36. By way of example, claim 1 of the '207 Patent is directed to a self-
17 propelled pool cleaning system for cleaning debris from a submerged surface of a
18 swimming pool. *See* Exhibit 3, claim 1, at 10:50–64. Claim 1 recites numerous
19 limitations, including: “at least one camera for capturing an image of at least a first
20 object within the swimming pool” and “a controller (i) in electronic communication
21 with the at least one camera and (ii) configured to generate, in response to the
22 captured image, at least one control signal to cause movement of the body within
23 the swimming pool to, or away from, the first object.” *Id.* The Beatbot Products do
24 not infringe claim 1, at least because they do not practice these claim limitations.
25 For example, the Beatbot Products do not include “at least one camera for capturing
26 an image of at least a first object within the swimming pool” or “a controller (i) in
27 electronic communication with the at least one camera and (ii) configured to
28 generate, in response to the captured image, at least one control signal to cause

1 movement of the body within the swimming pool to, or away from, the first object”
2 as required in claim 1. Beatbot also does not infringe the other claims of the '207
3 Patent.

4 37. Accordingly, at least for the above reasons, Beatbot does not directly
5 infringe the claims of the '207 Patent, either literally or under the doctrine of
6 equivalents, because the Beatbot Products do not practice all elements of those
7 claims.

8 38. Beatbot also does not indirectly infringe the '207 Patent for at least the
9 reasons stated above and because there is no direct infringement of the '207 Patent,
10 either literally or under the doctrine of equivalents.

11 39. As set forth above, an actual controversy exists between Beatbot and
12 Zodiac with respect to alleged infringement of the '207 Patent, and this controversy
13 is likely to continue. Accordingly, Beatbot desires a judicial determination and
14 declaration of the respective rights and duties of the parties with respect to the '207
15 Patent.

16 40. A judicial declaration is necessary and appropriate so that Beatbot may
17 ascertain its rights regarding the claims of the '207 Patent.

18 **PRAYER FOR RELIEF**

19 WHEREFORE, Beatbot respectfully prays for entry of judgment in its favor
20 and against Zodiac as follows:

21 A. For judgment that Beatbot has not infringed and does not infringe at
22 least the identified claims of the Patents-in-Suit, directly or indirectly, literally or
23 under the doctrine of equivalents, by the making, using, selling, offering to sell,
24 and/or importing of the Beatbot Products;

25 B. For a preliminary and permanent injunction precluding Zodiac, its
26 officers, directors, employees, agents, and all other persons acting in concert or
27 participation with them from suing for infringement or otherwise asserting
28 infringement of the Patents-in-Suit against Beatbot;

1 C. For costs and reasonable attorneys' fees incurred in connection with
2 this and related actions;

3 D. For a finding that this case is exceptional; and

4 E. Awarding any other remedy or relief to which Beatbot may be entitled
5 and which is deemed appropriate by the Court.

6 **DEMAND FOR JURY TRIAL**

7 Pursuant to Rule 38(b) of the Federal Rules of Civil Procedure, Beatbot
8 hereby demands a jury trial on all issues so triable.
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1 DATED: July 31, 2025

2 **PERKINS COIE LLP**

3 By: Kyle R. Canavera
4 Kyle R. Canavera, Bar No. 314664
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7 WYuan@perkinscoie.com

8 Attorneys for Plaintiffs
9 *Beatbot Technology (USA) Co. Ltd.,*
10 *Deepwater Innovation Technology*
11 *(Hong Kong) Limited, and Xingmai*
12 *Innovation Technology (Suzhou) Co.,*
13 *Ltd.*
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CIVIL COVER SHEET

The JS 44 civil cover sheet and the information contained herein neither replace nor supplement the filing and service of pleadings or other papers as required by law, except as provided by local rules of court. This form, approved by the Judicial Conference of the United States in September 1974, is required for the use of the Clerk of Court for the purpose of initiating the civil docket sheet. (SEE INSTRUCTIONS ON NEXT PAGE OF THIS FORM.)

I. (a) PLAINTIFFS

BEATBOT TECHNOLOGY (USA) CO. LTD., et al.

(b) County of Residence of First Listed Plaintiff Fort Bend County
(EXCEPT IN U.S. PLAINTIFF CASES)

(c) Attorneys (Firm Name, Address, and Telephone Number)

Perkins Coie LLP
11452 El Camino Real, Suite 300
San Diego, CA 92130-2080: (858) 720-5700

DEFENDANTS

ZODIAC POOL SYSTEMS LLC

County of Residence of First Listed Defendant San Diego County
(IN U.S. PLAINTIFF CASES ONLY)NOTE: IN LAND CONDEMNATION CASES, USE THE LOCATION OF
THE TRACT OF LAND INVOLVED.

Attorneys (If Known)

'25CV1946 GPC JLB

II. BASIS OF JURISDICTION (Place an "X" in One Box Only)

- ☐ 1 U.S. Government Plaintiff
- ☒ 3 Federal Question
(U.S. Government Not a Party)
- ☐ 2 U.S. Government Defendant
- ☐ 4 Diversity
(Indicate Citizenship of Parties in Item III)

III. CITIZENSHIP OF PRINCIPAL PARTIES (Place an "X" in One Box for Plaintiff and One Box for Defendant)

- | | PTF | DEF | | PTF | DEF |
|---|----------------------------|----------------------------|---|----------------------------|----------------------------|
| Citizen of This State | ☐ 1 | ☐ 1 | Incorporated or Principal Place of Business In This State | ☐ 4 | ☐ 4 |
| Citizen of Another State | ☐ 2 | ☐ 2 | Incorporated and Principal Place of Business In Another State | ☐ 5 | ☐ 5 |
| Citizen or Subject of a Foreign Country | ☐ 3 | ☐ 3 | Foreign Nation | ☐ 6 | ☐ 6 |

IV. NATURE OF SUIT (Place an "X" in One Box Only)

Click here for: [Nature of Suit Code Descriptions.](#)

CONTRACT	TORTS	FORFEITURE/PENALTY	BANKRUPTCY	OTHER STATUTES
☐ 110 Insurance	PERSONAL INJURY	☐ 625 Drug Related Seizure of Property 21 USC 881	☐ 422 Appeal 28 USC 158	☐ 375 False Claims Act
☐ 120 Marine	☐ 310 Airplane	☐ 690 Other	☐ 423 Withdrawal 28 USC 157	☐ 376 Qui Tam (31 USC 3729(a))
☐ 130 Miller Act	☐ 315 Airplane Product Liability		INTELLECTUAL PROPERTY RIGHTS	☐ 400 State Reapportionment
☐ 140 Negotiable Instrument	☐ 320 Assault, Libel & Slander		☐ 820 Copyrights	☐ 410 Antitrust
☐ 150 Recovery of Overpayment & Enforcement of Judgment	☐ 330 Federal Employers' Liability		☒ 830 Patent	☐ 430 Banks and Banking
☐ 151 Medicare Act	☐ 340 Marine		☐ 835 Patent - Abbreviated New Drug Application	☐ 450 Commerce
☐ 152 Recovery of Defaulted Student Loans (Excludes Veterans)	☐ 345 Marine Product Liability		☐ 840 Trademark	☐ 460 Deportation
☐ 153 Recovery of Overpayment of Veteran's Benefits	PERSONAL PROPERTY	LABOR	☐ 880 Defend Trade Secrets Act of 2016	☐ 470 Racketeer Influenced and Corrupt Organizations
☐ 160 Stockholders' Suits	☐ 350 Motor Vehicle	☐ 710 Fair Labor Standards Act	SOCIAL SECURITY	☐ 480 Consumer Credit (15 USC 1681 or 1692)
☐ 190 Other Contract	☐ 355 Motor Vehicle Product Liability	☐ 720 Labor/Management Relations	☐ 861 HIA (1395ff)	☐ 485 Telephone Consumer Protection Act
☐ 195 Contract Product Liability	☐ 360 Other Personal Injury	☐ 740 Railway Labor Act	☐ 862 Black Lung (923)	☐ 490 Cable/Sat TV
☐ 196 Franchise	☐ 362 Personal Injury - Medical Malpractice	☐ 751 Family and Medical Leave Act	☐ 863 DIWC/DIWW (405(g))	☐ 850 Securities/Commodities/Exchange
		☐ 790 Other Labor Litigation	☐ 864 SSID Title XVI	☐ 890 Other Statutory Actions
REAL PROPERTY	CIVIL RIGHTS	☐ 791 Employee Retirement Income Security Act	☐ 865 RSI (405(g))	☐ 891 Agricultural Acts
☐ 210 Land Condemnation	☐ 440 Other Civil Rights		FEDERAL TAX SUITS	☐ 893 Environmental Matters
☐ 220 Foreclosure	☐ 441 Voting	IMMIGRATION	☐ 870 Taxes (U.S. Plaintiff or Defendant)	☐ 895 Freedom of Information Act
☐ 230 Rent Lease & Ejectment	☐ 442 Employment	☐ 462 Naturalization Application	☐ 871 IRS—Third Party 26 USC 7609	☐ 896 Arbitration
☐ 240 Torts to Land	☐ 443 Housing/Accommodations	☐ 465 Other Immigration Actions		☐ 899 Administrative Procedure Act/Review or Appeal of Agency Decision
☐ 245 Tort Product Liability	☐ 445 Amer. w/Disabilities - Employment			☐ 950 Constitutionality of State Statutes
☐ 290 All Other Real Property	☐ 446 Amer. w/Disabilities - Other			
	☐ 448 Education			
	PRISONER PETITIONS			
	Habeas Corpus:			
	☐ 463 Alien Detainee			
	☐ 510 Motions to Vacate Sentence			
	☐ 530 General			
	☐ 535 Death Penalty			
	Other:			
	☐ 540 Mandamus & Other			
	☐ 550 Civil Rights			
	☐ 555 Prison Condition			
	☐ 560 Civil Detainee - Conditions of Confinement			

V. ORIGIN (Place an "X" in One Box Only)

- ☒ 1 Original Proceeding
- ☐ 2 Removed from State Court
- ☐ 3 Remanded from Appellate Court
- ☐ 4 Reinstated or Reopened
- ☐ 5 Transferred from Another District (specify)
- ☐ 6 Multidistrict Litigation - Transfer
- ☐ 8 Multidistrict Litigation - Direct File

VI. CAUSE OF ACTION

Cite the U.S. Civil Statute under which you are filing (Do not cite jurisdictional statutes unless diversity):
35 U.S.C. §§ 1 et seq and 28 U.S.C. §§ 2201-2202

Brief description of cause:

Seeking a declaratory judgment that Beatbot does not infringe U.S. Patent Nos. 11,003,191, 11,262,766 and 11,880,207

VII. REQUESTED IN COMPLAINT:

☐ CHECK IF THIS IS A CLASS ACTION UNDER RULE 23, F.R.Cv.P.

DEMAND \$

CHECK YES only if demanded in complaint:

JURY DEMAND: ☒ Yes ☐ No

VIII. RELATED CASE(S) IF ANY

(See instructions):

JUDGE

DOCKET NUMBER

DATE

Jul 31, 2025

SIGNATURE OF ATTORNEY OF RECORD

/s/ Kyle R. Canavera

FOR OFFICE USE ONLY

RECEIPT # _____ AMOUNT _____ APPLYING IFP _____ JUDGE _____ MAG. JUDGE _____

INSTRUCTIONS FOR ATTORNEYS COMPLETING CIVIL COVER SHEET FORM JS 44

Authority For Civil Cover Sheet

The JS 44 civil cover sheet and the information contained herein neither replaces nor supplements the filings and service of pleading or other papers as required by law, except as provided by local rules of court. This form, approved by the Judicial Conference of the United States in September 1974, is required for the use of the Clerk of Court for the purpose of initiating the civil docket sheet. Consequently, a civil cover sheet is submitted to the Clerk of Court for each civil complaint filed. The attorney filing a case should complete the form as follows:

- I.(a) Plaintiffs-Defendants.** Enter names (last, first, middle initial) of plaintiff and defendant. If the plaintiff or defendant is a government agency, use only the full name or standard abbreviations. If the plaintiff or defendant is an official within a government agency, identify first the agency and then the official, giving both name and title.
 - (b) County of Residence.** For each civil case filed, except U.S. plaintiff cases, enter the name of the county where the first listed plaintiff resides at the time of filing. In U.S. plaintiff cases, enter the name of the county in which the first listed defendant resides at the time of filing. (NOTE: In land condemnation cases, the county of residence of the "defendant" is the location of the tract of land involved.)
 - (c) Attorneys.** Enter the firm name, address, telephone number, and attorney of record. If there are several attorneys, list them on an attachment, noting in this section "(see attachment)".
- II. Jurisdiction.** The basis of jurisdiction is set forth under Rule 8(a), F.R.Cv.P., which requires that jurisdictions be shown in pleadings. Place an "X" in one of the boxes. If there is more than one basis of jurisdiction, precedence is given in the order shown below.
- United States plaintiff. (1) Jurisdiction based on 28 U.S.C. 1345 and 1348. Suits by agencies and officers of the United States are included here. United States defendant. (2) When the plaintiff is suing the United States, its officers or agencies, place an "X" in this box.
- Federal question. (3) This refers to suits under 28 U.S.C. 1331, where jurisdiction arises under the Constitution of the United States, an amendment to the Constitution, an act of Congress or a treaty of the United States. In cases where the U.S. is a party, the U.S. plaintiff or defendant code takes precedence, and box 1 or 2 should be marked.
- Diversity of citizenship. (4) This refers to suits under 28 U.S.C. 1332, where parties are citizens of different states. When Box 4 is checked, the citizenship of the different parties must be checked. (See Section III below; **NOTE: federal question actions take precedence over diversity cases.**)
- III. Residence (citizenship) of Principal Parties.** This section of the JS 44 is to be completed if diversity of citizenship was indicated above. Mark this section for each principal party.
- IV. Nature of Suit.** Place an "X" in the appropriate box. If there are multiple nature of suit codes associated with the case, pick the nature of suit code that is most applicable. Click here for: [Nature of Suit Code Descriptions](#).
- V. Origin.** Place an "X" in one of the seven boxes.
- Original Proceedings. (1) Cases which originate in the United States district courts.
- Removed from State Court. (2) Proceedings initiated in state courts may be removed to the district courts under Title 28 U.S.C., Section 1441.
- Remanded from Appellate Court. (3) Check this box for cases remanded to the district court for further action. Use the date of remand as the filing date.
- Reinstated or Reopened. (4) Check this box for cases reinstated or reopened in the district court. Use the reopening date as the filing date.
- Transferred from Another District. (5) For cases transferred under Title 28 U.S.C. Section 1404(a). Do not use this for within district transfers or multidistrict litigation transfers.
- Multidistrict Litigation – Transfer. (6) Check this box when a multidistrict case is transferred into the district under authority of Title 28 U.S.C. Section 1407.
- Multidistrict Litigation – Direct File. (8) Check this box when a multidistrict case is filed in the same district as the Master MDL docket.
- PLEASE NOTE THAT THERE IS NOT AN ORIGIN CODE 7.** Origin Code 7 was used for historical records and is no longer relevant due to changes in statute.
- VI. Cause of Action.** Report the civil statute directly related to the cause of action and give a brief description of the cause. **Do not cite jurisdictional statutes unless diversity.** Example: U.S. Civil Statute: 47 USC 553 Brief Description: Unauthorized reception of cable service.
- VII. Requested in Complaint.** Class Action. Place an "X" in this box if you are filing a class action under Rule 23, F.R.Cv.P.
- Demand. In this space enter the actual dollar amount being demanded or indicate other demand, such as a preliminary injunction.
- Jury Demand. Check the appropriate box to indicate whether or not a jury is being demanded.
- VIII. Related Cases.** This section of the JS 44 is used to reference related cases, if any. If there are related cases, insert the docket numbers and the corresponding judge names for such cases.

Date and Attorney Signature. Date and sign the civil cover sheet.

EXHIBIT 1

(12) **United States Patent**
Durvasula et al.(10) **Patent No.:** **US 11,003,191 B2**(45) **Date of Patent:** ***May 11, 2021**(54) **POOL CLEANING SYSTEM AND METHOD TO AUTOMATICALLY CLEAN SURFACES OF A POOL USING IMAGES FROM A CAMERA**(58) **Field of Classification Search**CPC .. G05D 1/0246; G05D 1/0016; G05D 1/0033;
G05D 1/0038; G05D 2201/0203;
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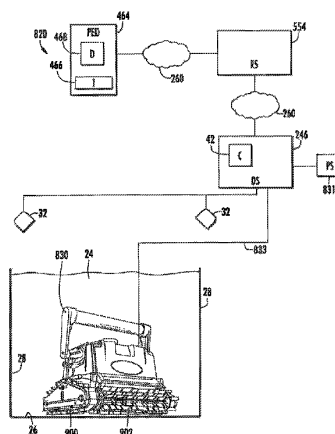
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(74) *Attorney, Agent, or Firm* — Kilpatrick Townsend &
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(Continued)(51) **Int. Cl.**
G05D 1/02 (2020.01)
H04N 7/18 (2006.01)
(Continued)(52) **U.S. Cl.**
CPC **G05D 1/0246** (2013.01); **E04H 4/1654**
(2013.01); **G05D 1/0016** (2013.01);
(Continued)(57) **ABSTRACT**A pool cleaning system for cleaning debris from a sub-
merged surface of a swimming pool includes a self-pro-
pelled pool cleaner having rotatably-mounted supports for
supporting and guiding the cleaner on the pool surface; an
electric motor for enabling the rotation of the rotatably-
mounted supports on the pool surface; at least one camera
to capture imagery of the pool surface; a controller, in elec-
tronic communication with the at least one camera, to
determine a cleanliness characteristic of the pool surface on
which the cleaner has passed based on the camera imagery
and generate a control signal to direct movement of the
cleaner based on the cleanliness characteristic of the pool
surface, and a portable electronic device configured to
present a graphic on a display, the graphic depicting the

(Continued)



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submerged surface of the pool and those portions of the surface that remain uncleaned as the cleaner traverses the pool surface.

3 Claims, 4 Drawing Sheets

Related U.S. Application Data

continuation of application No. 15/973,983, filed on May 8, 2018, now Pat. No. 10,338,599, which is a continuation of application No. 15/207,065, filed on Jul. 11, 2016, now Pat. No. 9,995,051, which is a continuation of application No. 13/545,918, filed on Jul. 10, 2012, now Pat. No. 9,388,595.

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(58) **Field of Classification Search**

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USPC 348/114
See application file for complete search history.

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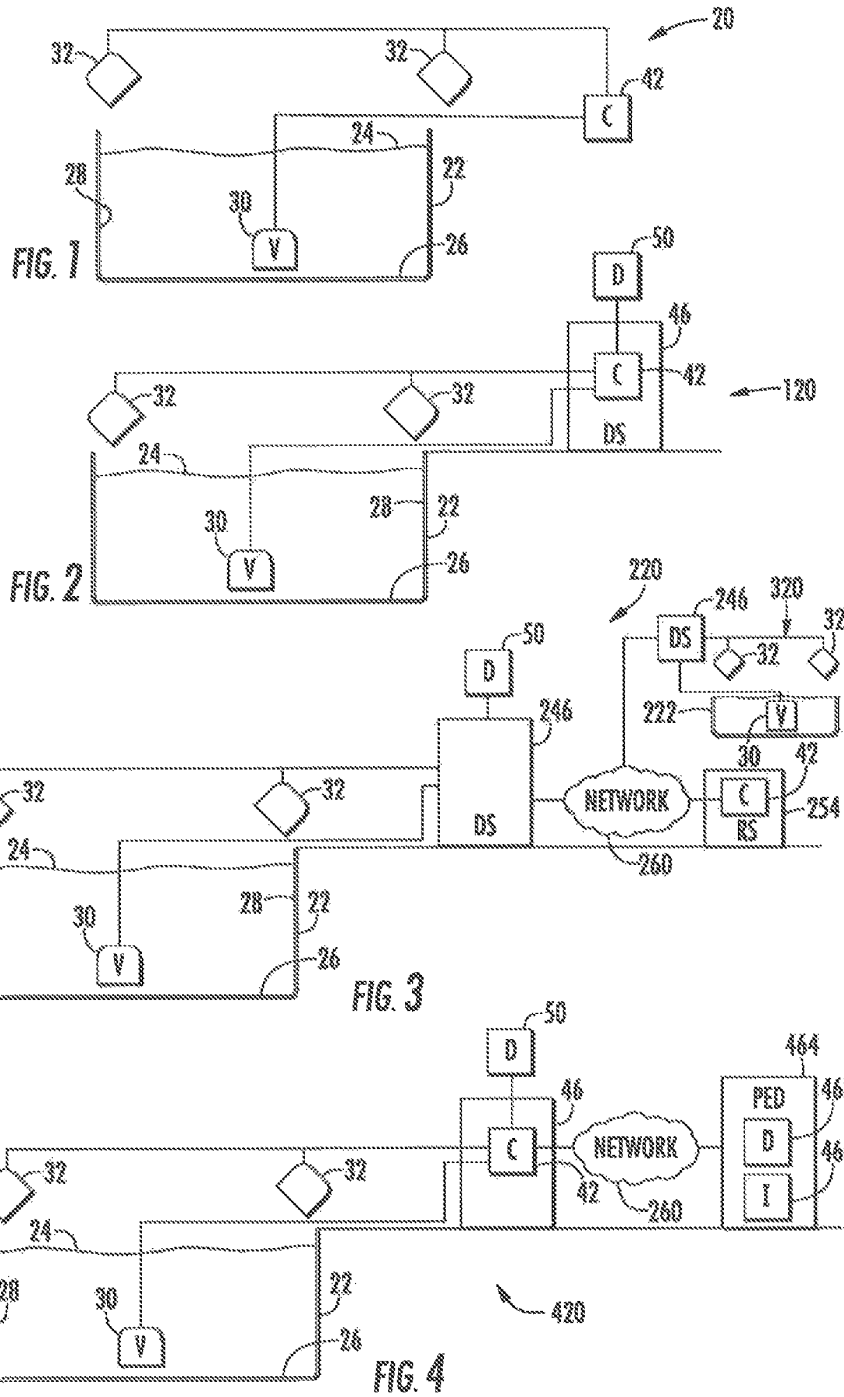
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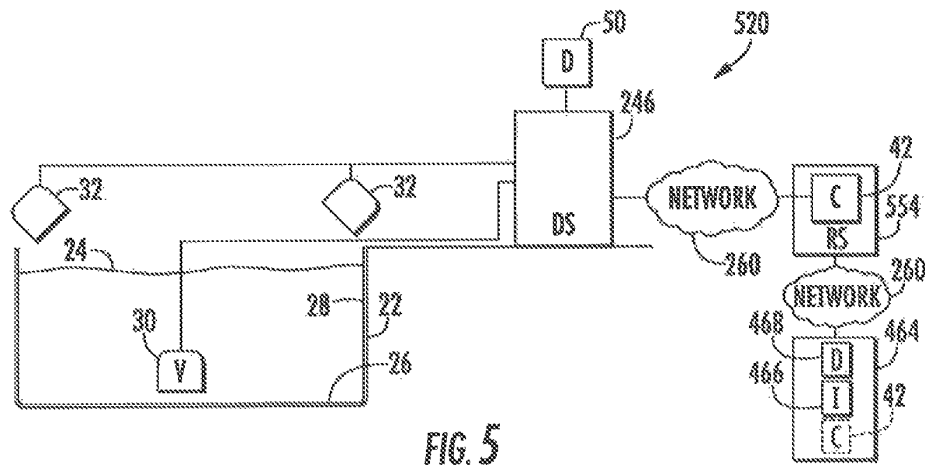


FIG. 5

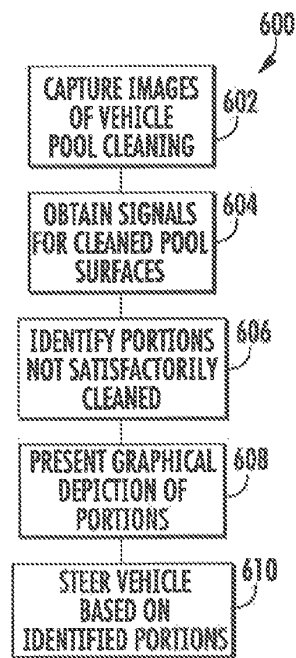


FIG. 6

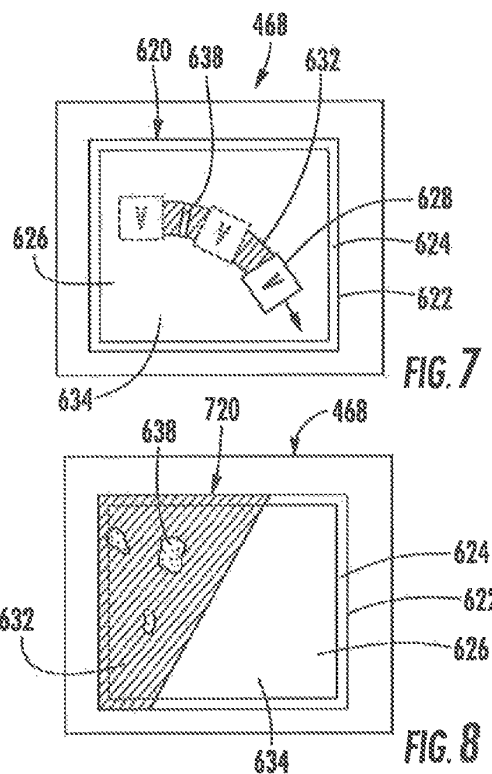


FIG. 7

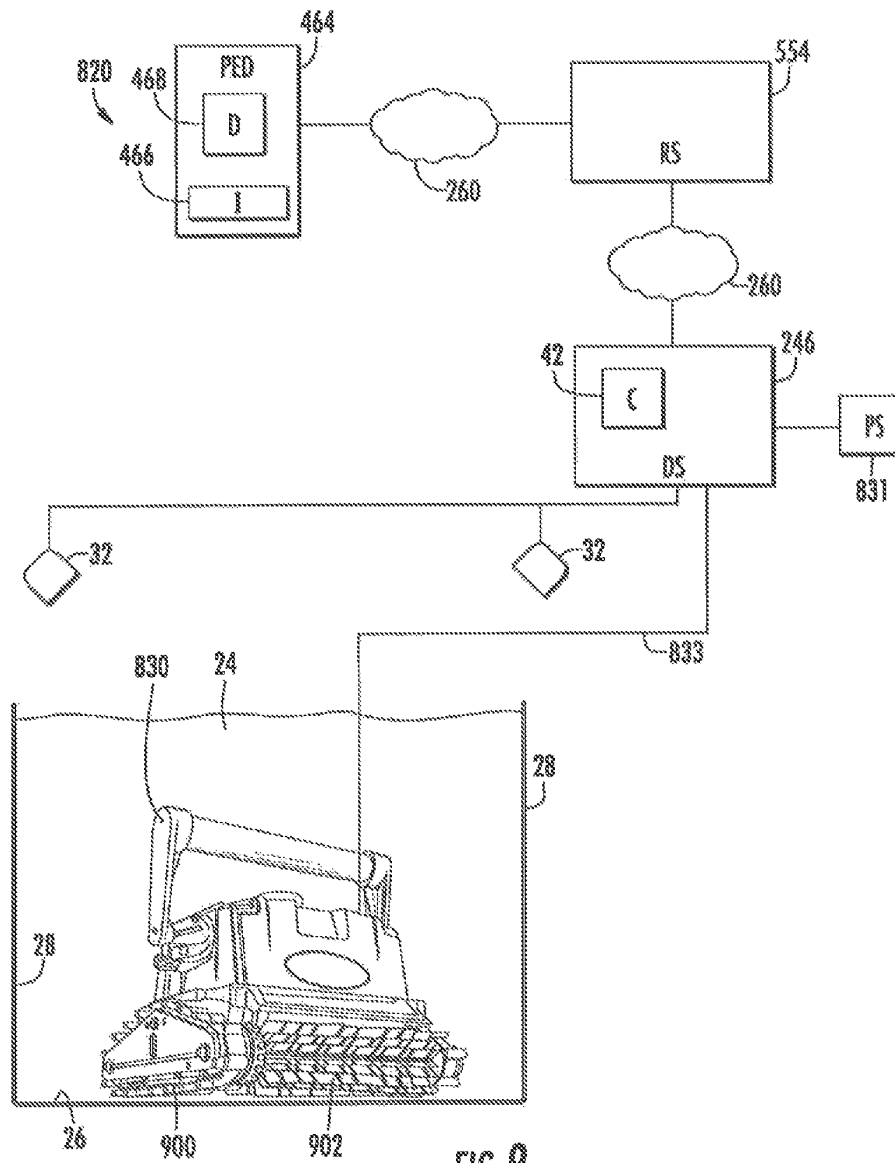
FIG. 8

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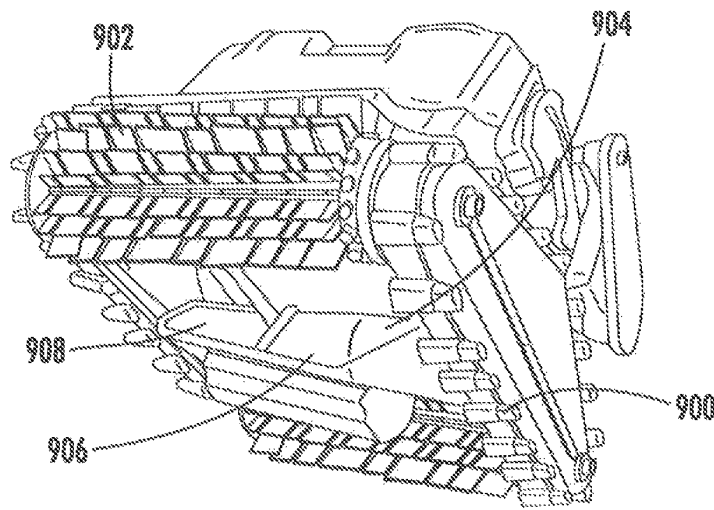


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**POOL CLEANING SYSTEM AND METHOD
TO AUTOMATICALLY CLEAN SURFACES
OF A POOL USING IMAGES FROM A
CAMERA**

**CROSS-REFERENCE TO RELATED
APPLICATION**

This application is a continuation of U.S. patent application Ser. No. 16/416,840, filed May 20, 2019 (now allowed), which is a continuation of U.S. patent application Ser. No. 15/973,983, filed May 8, 2018 (now U.S. Pat. No. 10,338,599), which is a continuation of U.S. patent application Ser. No. 15/207,065, filed Jul. 11, 2016 (now U.S. Pat. No. 9,995,051), which is a continuation of U.S. patent application Ser. No. 13/545,918, filed Jul. 10, 2012 (now U.S. Pat. No. 9,388,595), the contents of all of which are incorporated herein by reference in their entireties.

BACKGROUND

Manually cleaning the floor and sides of a swimming pool may be a tedious and time-consuming task. As a result, automated robotic pool cleaners have been developed. However, controlling and monitoring such automated robotic pool cleaners to insure that all portions of the pool surfaces are satisfactorily cleaned remains a challenge.

SUMMARY OF THE INVENTION

The disadvantages heretofore associated with the prior art are overcome by the present invention of a pool cleaning system for cleaning debris from a submerged surface of a swimming pool comprising: a self-propelled pool cleaner having rotatably-mounted supports for supporting and guiding the cleaner on the pool surface; a filter configured to retain the debris collected from the submerged surface of the swimming pool; an electric motor for enabling the rotation of the rotatably-mounted supports on the pool surface; at least one camera to capture imagery of the pool surface; a controller, in electronic communication with the at least one camera, to determine a cleanliness characteristic of the pool surface on which the cleaner has passed based on the camera imagery and generate a control signal to direct movement of the cleaner based on the cleanliness characteristic of the pool surface; and a portable electronic device is configured to present a graphic on a display, the graphic depicting the submerged surface of the pool and those portions of the surface that remain uncleaned as the cleaner traverses the pool surface.

In one aspect, the at least one camera is carried by the cleaner. In another aspect, the controller is carried by the cleaner. In still another aspect, the electric motor is mechanically connected to at least one of the rotatably-mounted supports.

In yet another aspect, the controller is operable to execute one or more cleaning programs for cleaning the submerged surfaces of the pool. In one aspect, the control signal causes the cleaner to drive in a direction to clean a portion of the pool surface based on the cleanliness characteristic of the pool surface. Alternatively, the control signal causes the cleaner to steer in a direction to clean a portion of the pool surface based on the cleanliness characteristic of the pool surface. In another aspect, the control signal causes the cleaner to drive in a direction to re-clean a portion of the pool surface over which the cleaner has passed. Alternatively,

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tively, the control signal causes the cleaner to steer in a direction to re-clean a portion of the pool surface over which the cleaner has passed.

In one aspect, the captured imagery from the at least one camera is digitally processed by the controller to determine the cleanliness characteristic of the pool surface. Alternatively, the captured imagery from the at least one camera is digitally processed by a remote processor to determine the cleanliness characteristic of the pool surface.

In another aspect, the system further comprises a dry station located remotely from the cleaner and in communication with the cleaner, wherein the dry station includes the controller. Alternatively, the system further comprises a dry station located remotely from the cleaner and in communication with the cleaner, wherein the controller is located remotely from the cleaner and the dry station. In still another aspect, the controller controls electric power provided to the electric motor.

In one aspect, the control signal causes the cleaner to move in a direction of a portion of the pool surface to be cleaned based solely upon signals received from the camera. In another aspect, the control signal causes the cleaner to drive in a direction to clean a portion of the pool surface based on the cleanliness characteristic of the pool surface. Alternatively, the control signal causes the cleaner to steer in a direction to clean a portion of the pool surface based on the cleanliness characteristic of the pool surface. In yet another aspect, the control signal causes the cleaner to drive in a direction to re-clean a portion of the pool surface over which the cleaner has passed. Alternatively, the control signal causes the cleaner to steer in a direction to re-clean a portion of the pool surface over which the cleaner has passed.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a schematic illustration of an example pool cleaning system.

FIG. 2 is a schematic illustration of an implementation of the pool cleaning system of FIG. 1.

FIG. 3 is a schematic illustration of an implementation of the pool cleaning system of FIG. 1.

FIG. 4 is a schematic illustration of an implementation of the pool cleaning system of FIG. 1.

FIG. 5 is a schematic illustration of an implementation of the pool cleaning system of FIG. 1.

FIG. 6 is a flow diagram of an example method that may be carried out with the pool cleaning system of FIG. 2-5.

FIG. 7 is a plan view of an example display with an example graphical depiction.

FIG. 8 is a plan view of another example display with an example graphical depiction.

FIG. 9 is a schematic illustration of an implementation of the pool cleaning system of FIG. 1 with an example pool cleaning vehicle.

FIG. 10 is a bottom perspective view of the example pool cleaning vehicle of the system of FIG. 9.

**DETAILED DESCRIPTION OF THE EXAMPLE
EMBODIMENTS**

FIG. 1 schematically illustrates an example pool cleaning system 20. As schematically shown by FIG. 1, pool cleaning system 20 is adapted to clean submerged surfaces of a pool 22 containing a liquid 24. In particular, pool cleaning system 20 is adapted to clean at least a bottom or floor surface 26 of the pool 22 and possibly to additionally clean surfaces 28 of pool 22. As will be described hereafter, pool cleaning

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system facilitates the control and monitoring of a robotic pool cleaner to better assure that all portions of pool 22 are satisfactorily cleaned.

Pool cleaning system 20 comprises vehicle 30, cameras 32 and controller 42. Vehicle 30 comprises an automated powered device configured to travel adjacent to submerged or water containing surfaces of pool 20 (such as floor 26 and/or side surfaces 28) while cleaning such surfaces. In one implementation, vehicle 30 may include vacuum or suction devices, a liquid circulation system and a filter to draw debris, such as bacterial growth or plant growth, from such pool surfaces, wherein the drawn liquid containing such residue or foreign matter is filtered to collect the debris. In other implementations, vehicle 30 may not collect such debris, wherein vehicle 30 merely loosens such debris on the pool surfaces such that the loosened or separated debris may be subsequently removed using the existing liquid filtering system of pool 22.

To assist in the loosening of debris, in one implementation, vehicle 30 may additionally include a chemical dispenser to closely apply pool cleaning chemicals to the pool surfaces as the vehicle 30 traverses such surfaces. In one implementation, vehicle 30 may additionally or alternatively include one or more scrubbing members, such as active (driven) or passive (undriven or idling) brushes, to assist in the removal of residue or foreign matter from such pool surfaces. In yet another implementation, vehicle 30 may additionally or alternatively include liquid jets to assist in the loosening of debris.

To move along the submerged surfaces of pool 22, vehicle 30 includes one or more propulsion mechanisms. In one implementation, vehicle 30 is propelled along the submerged pool surfaces using wheels, rollers, tracks or other surface contacting members powered by a motor and the like. Such wheels, rollers or tracks may themselves include the scrubbing members used to clean the surfaces. In one implementation vehicle 30 may also alternatively be propelled by means of the vacuum or liquid jets. The vacuum or liquid jets used for such propulsion nozzle facilitate loosening of debris for collection by vehicle 30. In other implementations, vehicle 30 may include other propulsion mechanisms.

Cameras 32 comprise devices configured to capture video or time lapse images of pool 22. In the example illustrated, cameras 32 are mounted on structures external to pool 22. In other words, cameras 32 are not submerged. In other implementations, cameras 32 may alternatively be mounted to vehicle 30. In the example illustrated, cameras 32 capture movement of vehicle 30 while vehicle 30 is submerged within pool 22. In other implementations, cameras 32 merely capture images of submerged surfaces 26, 28 of pool 22.

In the example illustrated, cameras 32 comprise cameras serving as part of a home or pool security system, wherein such cameras detect the presence of a person at pool 22 satisfying a predefined characteristic and wherein an alert is output upon the person's detected presence. For example, in one implementation, cameras 32 are utilized as part of a security system that detects when a person below a predefined age, such as a child, is present at pool 22 without a detected presence of a recognized adult. In another implementation, cameras 32 may detect the presence of an unauthorized person or intruder at pool 22. Identification of the person may be achieved by an off-site human or computerized monitoring system, wherein signals from cameras 32 are transmitted across a wide area network or may be

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achieved with software of controller 42 which includes facial recognition or other identification programming.

Because pool cleaning system 20 utilizes pre-existing cameras 32 provided as part of a security system or shares the use of cameras 32 with such a home or pool security system, pool cleaning system 20 is easier to set up, less complex and less expensive. In other implementations, pool cleaning system 20 may utilize dedicated cameras 22 independent of any cameras associated with a home, facility or pool security system. In such an alternative system, cameras 32 may be more precisely focused upon pool 22 and surfaces 26, 28 while also including appropriate lenses or modifications to account for glare, refraction and the like to better facilitate the capture of surfaces and vehicle 30 which are submerged.

Controller 42 comprises one or more processing units in communication with vehicle 30 and cameras 32. For purposes of this application, the term "processing unit" shall mean a presently developed or future developed processing unit that executes sequences of instructions contained in a memory. Execution of the sequences of instructions causes the processing unit to perform steps such as generating control signals. The instructions may be loaded in a random access memory (RAM) for execution by the processing unit from a read only memory (ROM), a mass storage device, or some other persistent storage. In other embodiments, hard wired circuitry may be used in place of or in combination with software instructions to implement the functions described. For example, controller 42 may be embodied as part of one or more application-specific integrated circuits (ASICs). Unless otherwise specifically noted, the controller is not limited to any specific combination of hardware circuitry and software, nor to any particular source for the instructions executed by the processing unit.

In one implementation, controller 42 communicates with vehicle 30 and cameras 32 entirely across a wired connection. In another implementation, controller 42 communicates with vehicle 30 and cameras 32 across a wireless connection, such as across a local area network (LAN) or a wide area network (WAN) such as the Internet. One of limitation, controller 42 may communicate with vehicle 30 and cameras 32 using a combination of both wired and wireless communication connections.

Controller 42 is configured to generate control signals for steering vehicle 30 based upon signals received from cameras 32. In one implementation, controller 42 provides the sole steering directions for vehicle 30 using signals from cameras 32. Because vehicle 30 is precisely steered under the control of controller 42, rather than traveling in a random manner, entire summer surfaces of pool 22 may be more quickly and efficiently covered and cleaned. Because controller 42 provides the only steering instructions for vehicle 30 and utilizes signals from cameras 32, complex steering algorithms or codes in either vehicle 30 or controller 42 may be omitted to reduce complexity and cost of system 20.

In another implementation, vehicle 30 may cover or travel across surfaces of pool 22 in either a random fashion or according to an automated pool coverage algorithm or pool coverage pattern stored in a memory associated with vehicle 30 or controller 42. In such an implementation, controller 42 utilizes signals from cameras 32 to verify that all of the surfaces of pool 22 have been cleaned, that no spots have been missed. Upon identifying a missed spot, controller 42 utilizes signals from camera 32 to steer vehicle 32 over such missed portions of surfaces 26, 28. According to one example, controller 42 not only uses signals from camera 32 to determine whether any portions of surfaces 26, 28 have

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been missed entirely, but to also determine whether any portions of surfaces **26,28** have been cleaned, but not to a satisfactory degree or extent. In such circumstances, controller **42** uses signals from cameras **32** to steer vehicle **34** such areas to re-clean such portions until such portions have been satisfactorily cleaned such that the portions have a cleanliness characteristic satisfying a predefined threshold.

FIG. 2 schematically illustrates pool cleaning system **120**, the particular example of pool cleaning system **20** described above. Pool cleaning system **120** is similar to pool cleaning system **20** except that pool cleaning system **120** additionally comprises dry station **46** and display **50**. Those remaining components of pool cleaning system **120** which correspond to components of pool cleaning system **20** are numbered similarly.

Dry station **46** comprises a station in communication with vehicle **30** and cameras **32** outside of pool **22**. Dry station **46** incorporates controller **42**. In one implementation, dry station **46** communicates with vehicle **30** in a wired fashion. In such an implementation, dry station **46** further provides electrical power to vehicle **30** in a wired fashion. Dry station **46** communicates with cameras **32** and either a wired or wireless fashion.

Display **50** comprises a device to present a graphical images and text on a display screen. In one implementation, display **58** may be incorporated as part of dry station **46**. In another implementation, display **50** may be provided on a portable electronic device, a computer, a television and the like. Display **50** is utilized by pool cleaning system **120** to present information regarding the cleaning of pool **22** to facilitate control of vehicle **30** by controller **42**. In one implementation, display **50** is utilized by pool cleaning system **120** and a controller **42** to present a graphical depiction of those portions of surfaces **26, 28** of pool **22** have not been satisfactorily cleaned so as to satisfy a predefined cleanliness characteristic threshold. Such portions may comprise portions that have been completely missed by vehicle **30** as well as those portions that have been covered by vehicle **30** but have not been satisfactorily cleaned with the given number of passes of vehicle **30** or the existing cleaning settings of vehicle **30**. The graphical depiction presented on display **50** enables a person view the quality of the prior cleaning session and to input commands causing controller **42** to generate control signals using signals from camera **32** to steer vehicle **30** back to such identified portions where such portions may be cleaned at the same or elevated cleaning aggressiveness settings.

Another implementation, display **50** may be further utilized by controller **42** to depict the progress of vehicle **30** in cleaning pool **22**. Such a display **50** allows a person to visually determine how much of the pool has been currently cleaned and to estimate the remaining time before the pool cleaning task is completed. In certain circumstances, using display **50**, a person may adjust a setting of vehicle **30** to accelerate a rate at which surfaces **26, 28** of pool **22** are cleaned to meet an earlier desired completion time for such pool cleaning.

FIG. 3 schematically illustrates pool cleaning system **220**, another example implementation of pool cleaning system **20**. Pool cleaning system **220** is similar to pool cleaning system **20** except that pool cleaning system **220** additionally comprises dry station **246**, display **50**, and remote server **254**. Those remaining components of pool cleaning system **220** which correspond to components of pool cleaning system **20** or pool cleaning system **120** are numbered similarly.

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Dry station **246** is similar to dry station **46**, described above, except that dry station **246** serves as a local interface for communication with controller **42** across a network **260**. In one implementation, network **260** may comprise a local area network. In another implementation, network **260** may comprise a wide area network, such as the Internet. For example, in one implementation, dry station **246** may incorporate a modem. In one implementation, dry station **246** may communicate across a local area network to controller **42**. In another implementation, dry station **246** may communicate through a router, across a local area network, to a local modem which communicates across a network **260**. The example illustrated, dry station **246** further provides part of vehicle **30** across a wired cable or wired connection. Display **50** is described above with respect to system **120**.

Remote server **254** comprises a server remote from dry station **246** which is in communication with dry station **246** across network **260**. Remote server **254** includes controller **42**. During operation, signals from cameras **32** are transmitted across dry station **246** across network **260** to controller **42** of remote server **254**. Based upon such signals from cameras **32**, controller **42** generates control signals which are transmitted back across network **260** and through dry station **246** to vehicle **30** to steer vehicle **30**.

As shown by FIG. 3, remote server **254** and network **260** may be shared as part of other pool cleaning systems **320**, wherein controller **42** generates control signals for steering the pool cleaning vehicle **30** of system **320** based upon signals from cameras **32** transmitted across dry station **246** of system **320**. In such an implementation, the cost and complexity of pool cleaning system **220** is reduced since controller **42** is remotely provided at remote server **254** which services multiple pool cleaning systems **220,320**. Upgrades to controller **42** and its software are also more easily achieved for all pool cleaning systems to **20, 320** and their pools **22, 222** being serviced. In one implementation, the supervised cleaning, inspection and possible re-cleaning facilitated by the use of cameras **32** may be provided as part of a subscription to users of vehicle **30**. In such an implementation, a pool **22** having security cameras **32** may be upgraded with appropriate software or an appropriate software module added to dry station **246** to make a network connection with controller **42** which directs the security cameras **32** to capture vehicle **30** utilizes such signals for steering vehicle **30**.

FIG. 4 schematically illustrates pool cleaning system **420**, another particular implementation of pool cleaning system **20**. Pool cleaning system **420** is similar to pool cleaning system **120** except that pool cleaning system **420** additionally comprises a portable electronic device **464**. Those remaining components of pool cleaning system **420** which correspond to components of pool cleaning system **120** are numbered similarly.

Portable electronic device **464** comprises a portable handheld electronic device in communication with controller **42** and/or dry station **46** across network **260**. Examples of such a portable electronic device (PED) **300** include, but are not limited to, a smart phone, a personal data assistant (PDA), laptop, notebook computer, tablet computer (e.g. IPAD) and MP3 player (e.g., IPOD TOUCH). In the example illustrated, PED **464** comprises input **466** and display **468**.

Input **466** serves as a user interface for PED **464** by which inputs are made to PED **464**. Input **466** facilitates entry of inputs or commands by a person to cause controller **42** to generate control signals varying the control of vehicle **30**. In one implementation, input **466** comprise a keyboard in other implementations, input **466** may comprise a touchpad, a

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stylus, a microphone with associated speech recognition software or programming, a touch screen, buttons, switches and the like. In some implementations, input 466 may comprise a touch screen incorporated as part of display 468.

Display 468 comprises a user interface by which graphical or textual data is presented to a user. Display 468 may present the same or similar information as presented at dry station 246 by display 50 as described above. In one implementation, display 468 comprises a liquid crystal display. In other implementations, display 468 may comprise other types of display technology such as a light emitting diode display, an organic light emitting diode display (OLED), an electronic ink (e-ink) display or other types of display technology in present use or developed in the future. Although system 420 is illustrated as including controller 422 is part of dry station 46, in some implementations, controller 42 may alternatively be located as part of PED 464.

PED 464 enables a person located remote from pool 22 to monitor the progress of the cleaning of pool 22 by vehicle 30 of system 420. PED 464 provides a person with a graphical presentation (described above with respect to display 50) indicating those portions of surfaces 26, 28 of pool 22 that have been completed as well as those portions 26, 20 and that remain to be cleaned. The person may also be provided with a graphical indication of what portions need to be re-cleaned to meet predetermined cleanliness thresholds. In the example illustrated, input 466 enables a person to enter commands or selections which are transmitted across network 260 to controller 42 to adjust operation of vehicle 30. For example, the path or route of vehicle 30 may be changed, the aggressiveness of the cleaning chemicals or mechanical cleaning devices may be adjusted, the speed at which vehicle 30 traverses surfaces 26, 28 may be adjusted. In response to such adjustment signals from PED 464, controller 42 may utilize signals from cameras 32 to adjust the steering of vehicle 30.

FIG. 5 schematically illustrates pool cleaning system 520, another example implementation of pool cleaning system 20. Pool cleaning system 520 is similar to pool cleaning system 420 except that pool cleaning system 520 additionally comprises a remote server 554. Those remaining components of pool cleaning system 520 which correspond to components of pool cleaning system 420 are numbered similarly.

Remote server 554 is similar to remote server 254 described above with respect to system 220. Remote server 554 comprises a server remote from dry station 246 which is in communication with dry station 246 across network 260. Remote server 254 includes controller 42. During operation, signals from cameras 32 are transmitted across dry station 246 across network 260 to controller 42 of remote server 254. Based upon such signals from cameras 32, controller 42 generates control signals which are transmitted back across network 260 and through dry station 246 to vehicle 30 to steer vehicle 30. Controller 42 further relays either the raw signals from camera 32 or image signals generated based upon signals from cameras 32 to PED 464, wherein such images (described above) are presented on display 468. As noted above, PED may further receive commands through input 466, wherein such commands are transmitted to controller 42 which generates control signals that are ultimately transmitted to vehicle 30 for steering vehicle 30.

As with remote server 254, remote server 554 and network 260 may be shared as part of other pool cleaning systems 320 (shown in FIG. 3), wherein controller 42

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generates control signals for steering the pool cleaning vehicle 30 of system 320 based upon signals from cameras 32 transmitted across dry station 246 of system 320. In such implementations, controller 42 of remote server 554 may interact with other PEDs 464. In such an implementation, the cost and complexity of pool cleaning system 220 is reduced since controller 42 is remotely provided at remote server 254 which services multiple pool cleaning systems 220, 320. Upgrades to controller 42 and its software are also more easily achieved for all pool cleaning systems to 20, 320 and their pools 22, 222 being serviced. In one implementation, the supervised cleaning, inspection and possible re-cleaning facilitated by the use of cameras 32 may be provided as part of a subscription to users of vehicle 30. In such an implementation, a pool 22 having security cameras 32 may be upgraded with appropriate software or an appropriate software module added to dry station 246 to make a network connection with controller 42 which directs the security cameras 32 to capture vehicle 30 utilizes such signals for steering vehicle 30. As indicated by broken lines, in other implementations, the controller 42 for generating control signals steering vehicle 30 based upon signals from cameras 32 may alternatively be relocated in PED 464.

FIG. 6 is a flow diagram illustrating an example method 600 that may be carried out by any of systems 120-520. As indicated by step 602, cameras 32 capture images of pool cleaning by vehicle 30. As indicated by step 604, controller 42 obtain such signals from cameras 32 for the surfaces of pool 22 that have been cleaned. As indicated by step 606, controller 42 uses information gathered from the signals from cameras 32 to identify those portions of surfaces 26, 28 not satisfactorily cleaned—not satisfying a predefined cleanliness characteristic or measurement threshold. One example of a cleanliness characteristic measurement a threshold may be how well the color of a surface matches a predetermined desirable color for the pool surface (such as original color of the tile or surface). A surface that has been missed entirely by vehicle 30 during a pool cleaning session may be automatically deemed to not satisfy a predetermined cleanliness characteristic.

As indicated by step 608, based upon such determinations, controller 42 generates control signals resulting in the presentation of a graphical depiction of those portions of pool 22 that has not been satisfactorily cleaned. Such graphical representations or depictions may be presented on display 50 or display 468. FIGS. 7 and 8 illustrate examples of graphical depictions that may be presented.

FIG. 7 illustrates display 468 presenting graphical depiction 620. Graphical depiction 620 comprises a first graphic 622 having a first portion 624 representing sides or walls 28 of pool 22 and a second portion 626 representing the floor 26 of pool 22. Graphical depiction 620 further comprises a moving icon 628 representing the current positioning of vehicle 30. In one implementation, the path of vehicle 30 may additionally be depicted by icon 628 shown in broken lines. As shown by FIG. 7, those portions 632 of surfaces 26, 28 of pool 22 (shown in FIG. 1) over which of vehicle 30 has moved are identified by graphical depiction 620 either by color, markings or other various distinctive attributes. Likewise, those portions 634 of surfaces 26, 28 of pool 22 that have not been covered by vehicle 30 are identified by a distinct color col marking or distinctive attribute of depiction 620. As a result, a person may view the current position of vehicle 30, the extent to which pool 22 has been cleaned or covered by vehicle 30 and the extent of pool 22 that remains to be cleaned. In the example illustrated, depiction 620 further identifies those portions 638 of surfaces 26, 28

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that have been cleaned, but which have not been cleaned to a satisfactory degree or extent. In one implementation, portions 638 may be identified by colors, brightness, markings or other visually distinctive attributes that are visually distinct from both portions 632 and portions 634. In other implementations, portions 638 may have the same characteristic of portions 634. In yet other implementations, different portions 638 may have different visual attributes depending upon a degree to which such clean portions have failed to satisfy the predefined cleanliness characteristic threshold. In some implementations, different port 638 may have different visual attributes depending upon different cleaning strategies that may be recommended for the different portions 638. For example, controller 42 may determine and recommend a first cleaning strategy (a first chemical solution jetted at a first rate and scrubbed at a first rate) with respect to a first portion 638 and may recommend a second different cleaning strategy (a second chemical solution jetted at a second rate is about a second rate) with respect to a second portion 638, wherein the different cleaning strategies are represented by different visual attributes presented in depiction 620.

FIG. 8 illustrates display 468 presenting a graphical depiction 720. Graphical depiction 720 comprises a first graphic 622 having a first portion 624 representing sides or walls 28 of pool 22 and a second portion 626 representing the floor 26 of pool 22 (shown in FIG. 1). Graphical depiction 720 is similar to graphical depiction 620 except that graphical depiction 720 omits icon 628 presenting vehicle 30. Like depiction 620, depiction 720 graphically depicts those portions 632 of surfaces 26, 28 over which vehicle 30 has traveled while in a cleaning mode. Depiction 720 also visually depicts those portions 634 that have not been covered by vehicle 30 in the cleaning mode and those portions 638 over which vehicle 30 has traveled while in the cleaning mode, but which have not been cleaned to a satisfactory degree. As illustrated in FIG. 8, different portions 638 may be visibly distinguished from one another through color, text or markings indicating either differences in the cleanliness of such portions 638 or indicating different recommended cleaning strategies or approaches that may be selected by a person using input 466 when vehicle 30 is steered back to such portions 638 for re-cleaning using signals from camera 32.

As indicated by step 610 of FIG. 6, controller 42 generates control signals steering vehicle 30 to re-clean portions of pool 22, such as portions 638. Such steering may be facilitated by using signals from cameras 32. As noted above, in some implementations, a person may be allowed choose a cleaning approach for a particular portion 638 using input 466. The selection may be facilitated by visual inspection of the different visual attributes for the particular portion 638 provided by depiction 720 (or depiction 620). In some implementations, input 466 may additionally be utilized by a person to prioritize an order in which portions 638 are re-cleaned.

FIG. 9 illustrates pool cleaning system 820, an example implementation of pool cleaning system 20. Pool cleaning system 820 is similar to pool cleaning system 520 except the pool cleaning system 820 located controller 42 in dry station 246 and includes pool cleaning vehicle 830, a specific example of vehicle 30. As shown by FIG. 9, in addition to transmitting control signals generated by controller 42 to vehicle 830, dry station 246 further transmits power from power source 831 through a power line or power cable 833 to vehicle 830. In the example illustrated, data communication and communication of control signals, also occurs

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across wired connections within or alongside the same line 833. In the example illustrated, remote server 554 serves as a communication link by which upgrades to controller 42 may be implemented across a wide number of pool cleaning systems and by which information from controller 42 is conveyed to one or more portable electronic devices 464 across network 260.

Vehicle 830 comprises a robotic or automated pool cleaning device. Vehicle 830 comprises a self-contained onboard filtration system with drive and pump motors. Vehicle 830 utilizes an internal microprocessor guided drive motor to systematically clean surfaces of pool 22. As shown by FIGS. 9 and 10, vehicle 830 utilizes a toothed track drive 900 provide traction and propulsion for vehicle 30. Vehicle 830 comprises rotating brushes 902 to loosen waterline buildup and breakdown large debris while power washing jets 904 flush out dirt from pores, seams in corners where brushes 902 may not be able to reach. The loosened dirt and debris is vacuumed through off-center vacuum ports 906 which passes the vacuumed debris through internally house filter bag. In the example illustrated, vehicle 830 further comprises rollers 908 which inhibit vehicle 830 from becoming impeded or stuck on raised drains or pop-up heads. Although illustrated as being employed with system 820, vehicle 830 may also be utilized with any of systems 20, 120, 220, 320 and 420. In other implementations, other robotic or automated pool cleaning vehicles may be utilized.

Although the present disclosure has been described with reference to example embodiments, workers skilled in the art will recognize that changes may be made in form and detail without departing from the spirit and scope of the claimed subject matter. For example, although different example embodiments may have been described as including one or more features providing one or more benefits, it is contemplated that the described features may be interchanged with one another or alternatively be combined with one another in the described example embodiments or in other alternative embodiments. Because the technology of the present disclosure is relatively complex, not all changes in the technology are foreseeable. The present disclosure described with reference to the example embodiments and set forth in the following claims is manifestly intended to be as broad as possible. For example, unless specifically otherwise noted, the claims reciting a single particular element also encompass a plurality of such particular elements.

What is claimed is:

1. A self-propelled pool cleaner for cleaning debris from a submerged surface of a swimming pool, comprising:
 - a. a vehicle body;
 - b. means for moving the vehicle body within the swimming pool;
 - c. a filter configured to retain debris collected from the submerged surface;
 - d. at least one camera positioned on or in the body for capturing an image of at least a first portion of the submerged surface; and
 - e. a controller (i) positioned on or in the body, (ii) in electronic communication with the at least one camera, and (iii) configured to generate, in response to the captured image, at least one control signal to cause movement of the body within the swimming pool to, or away from, the first portion of the submerged surface.
2. A system for cleaning debris from a submerged surface of a swimming pool, comprising:

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- a. a self-propelled pool cleaner comprising:
 - i. a vehicle body;
 - ii. means for moving the vehicle body within the swimming pool;
 - iii. at least one camera positioned on or in the body for capturing an image of at least a first portion of the submerged surface; and
 - iv. a controller (i) positioned on or in the body, (ii) in electronic communication with the at least one camera, and (iii) configured to generate, in response to the captured image, at least one control signal to cause movement of the body within the swimming pool to, or away from, the first portion of the submerged surface; and
 - b. a filter configured to retain debris collected from the submerged surface by the self-propelled pool cleaner.
3. A system for cleaning debris from a submerged surface of a swimming pool, comprising:

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- a. a self-propelled pool cleaner comprising:
 - i. a vehicle body;
 - ii. means for moving the vehicle body within the swimming pool;
 - iii. a filter configured to retain debris collected from the submerged surface; and
 - iv. at least one camera positioned on or in the body for capturing an image of at least a first portion of the submerged surface; and
- b. a controller (i) in electronic communication with the at least one camera and (ii) configured to generate, in response to the captured image, at least one control signal to cause movement of the body within the swimming pool to, or away from, the first portion of the submerged surface.

* * * * *

EXHIBIT 2

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(12) **United States Patent**
Durvasula et al.

(10) **Patent No.:** **US 11,262,766 B2**
(45) **Date of Patent:** ***Mar. 1, 2022**

(54) **POOL CLEANING SYSTEM AND METHOD TO AUTOMATICALLY CLEAN SURFACES OF A POOL USING IMAGES FROM A CAMERA**

(58) **Field of Classification Search**
CPC .. G05D 1/0246; G05D 1/0016; G05D 1/0033;
G05D 1/0038; G05D 2201/0203;
(Continued)

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(73) Assignee: **ZODIAC POOL SYSTEMS LLC**,
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(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 0 days.

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This patent is subject to a terminal disclaimer.

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Primary Examiner — Allen C Wong

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(74) *Attorney, Agent, or Firm* — Kilpatrick Townsend & Stockton LLP

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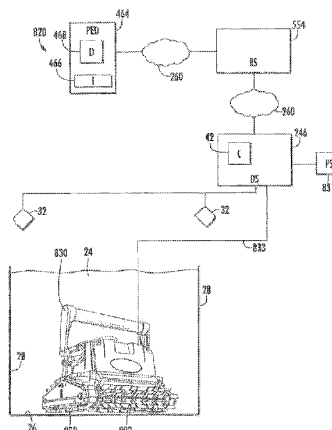
(63) Continuation of application No. 16/919,750, filed on Jul. 2, 2020, now Pat. No. 11,003,191, which is a
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H04N 7/18 (2006.01)
(Continued)

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CPC **G05D 1/0246** (2013.01); **E04H 4/1654** (2013.01); **G05D 1/0016** (2013.01);
(Continued)

(57) **ABSTRACT**

A pool cleaning system for cleaning debris from a submerged surface of a swimming pool includes a self-propelled pool cleaner having rotatably-mounted supports for supporting and guiding the cleaner on the pool surface; an electric motor for enabling the rotation of the rotatably-mounted supports on the pool surface; at least one camera to capture imagery of the pool surface; a controller, in electronic communication with the at least one camera, to determine a cleanliness characteristic of the pool surface on which the cleaner has passed based on the camera imagery and generate a control signal to direct movement of the cleaner based on the cleanliness characteristic of the pool surface, and a portable electronic device configured to present a graphic on a display, the graphic depicting the
(Continued)



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submerged surface of the pool and those portions of the surface that remain uncleaned as the cleaner traverses the pool surface.

5 Claims, 4 Drawing Sheets

Related U.S. Application Data

continuation of application No. 16/416,840, filed on May 20, 2019, now Pat. No. 10,739,785, which is a continuation of application No. 15/973,983, filed on May 8, 2018, now Pat. No. 10,338,599, which is a continuation of application No. 15/207,065, filed on Jul. 11, 2016, now Pat. No. 9,995,051, which is a continuation of application No. 13/545,918, filed on Jul. 10, 2012, now Pat. No. 9,388,595.

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CPC **G05D 1/0033** (2013.01); **G05D 1/0038** (2013.01); **H04N 5/23203** (2013.01); **H04N 7/18** (2013.01); **G05D 2201/0203** (2013.01); **G06T 7/001** (2013.01); **G06T 7/90** (2017.01); **G06T 2207/10024** (2013.01); **H04N 2005/2255** (2013.01)
- (58) **Field of Classification Search**
CPC E04H 4/1654; H04N 5/23203; H04N 7/18; H04N 2005/2255; G06T 7/90; G06T 7/001; G06T 2207/10024
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See application file for complete search history.

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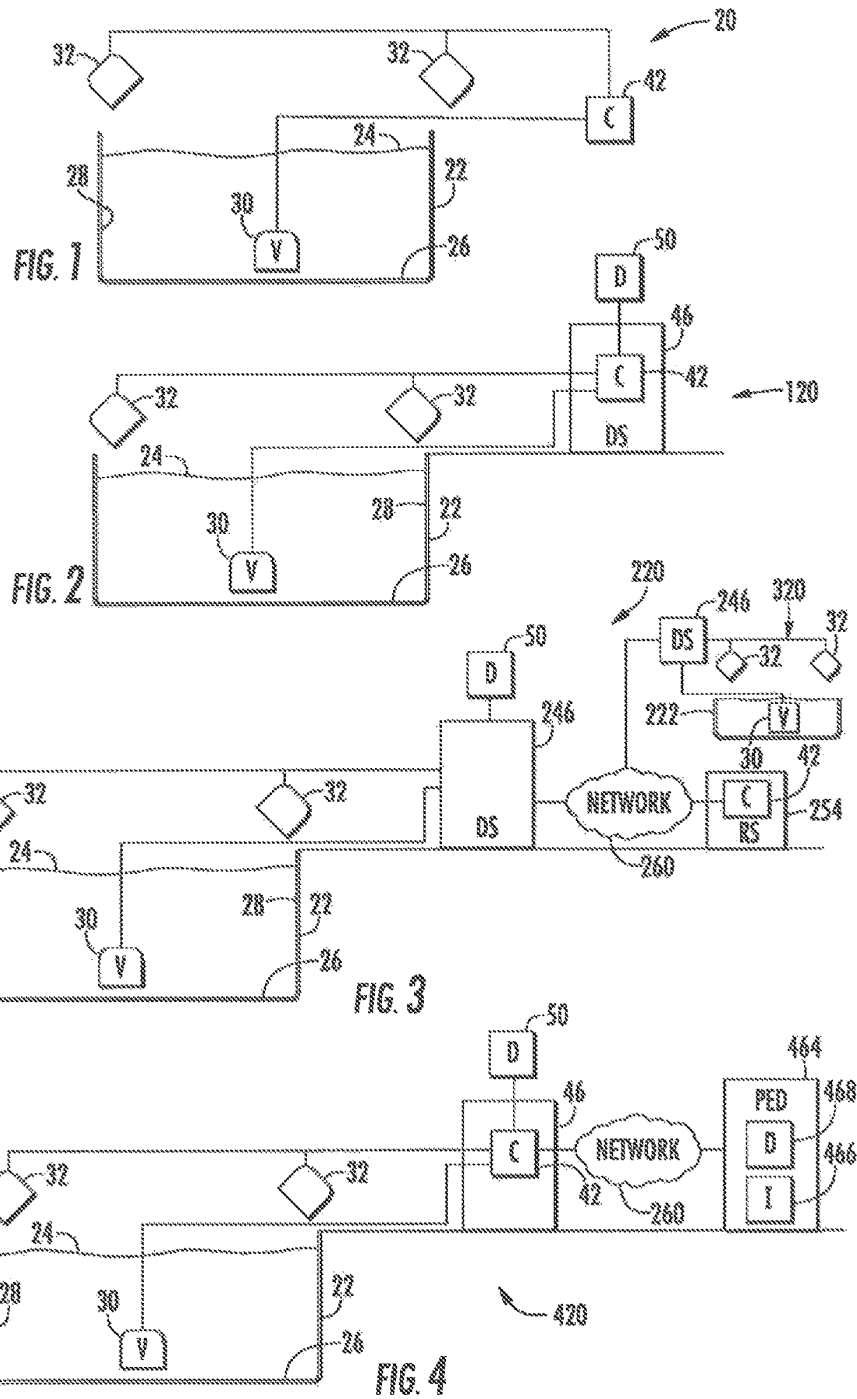
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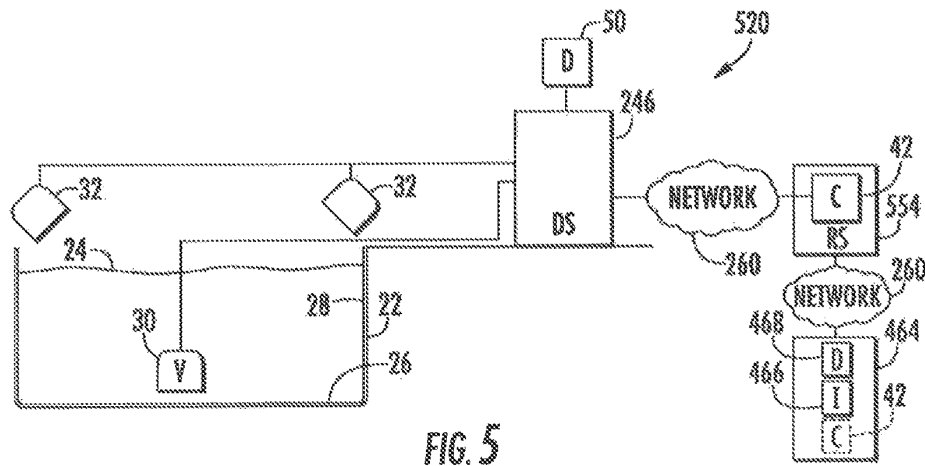


FIG. 5

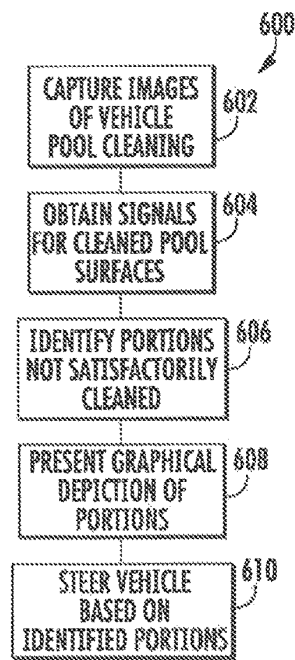


FIG. 6

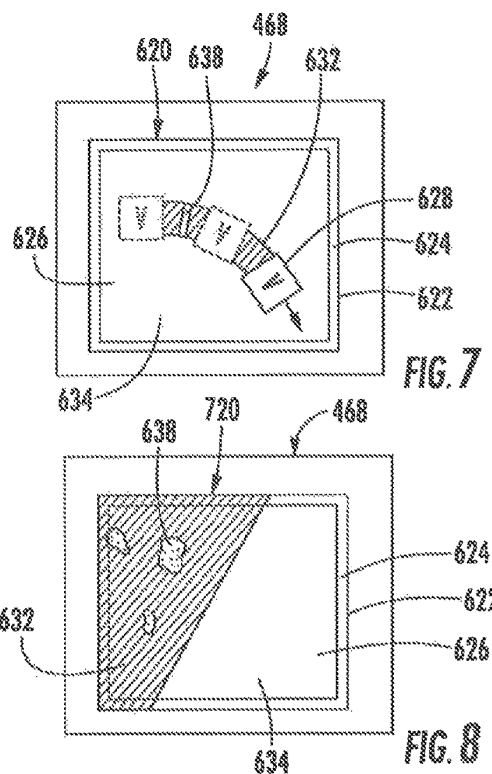


FIG. 7

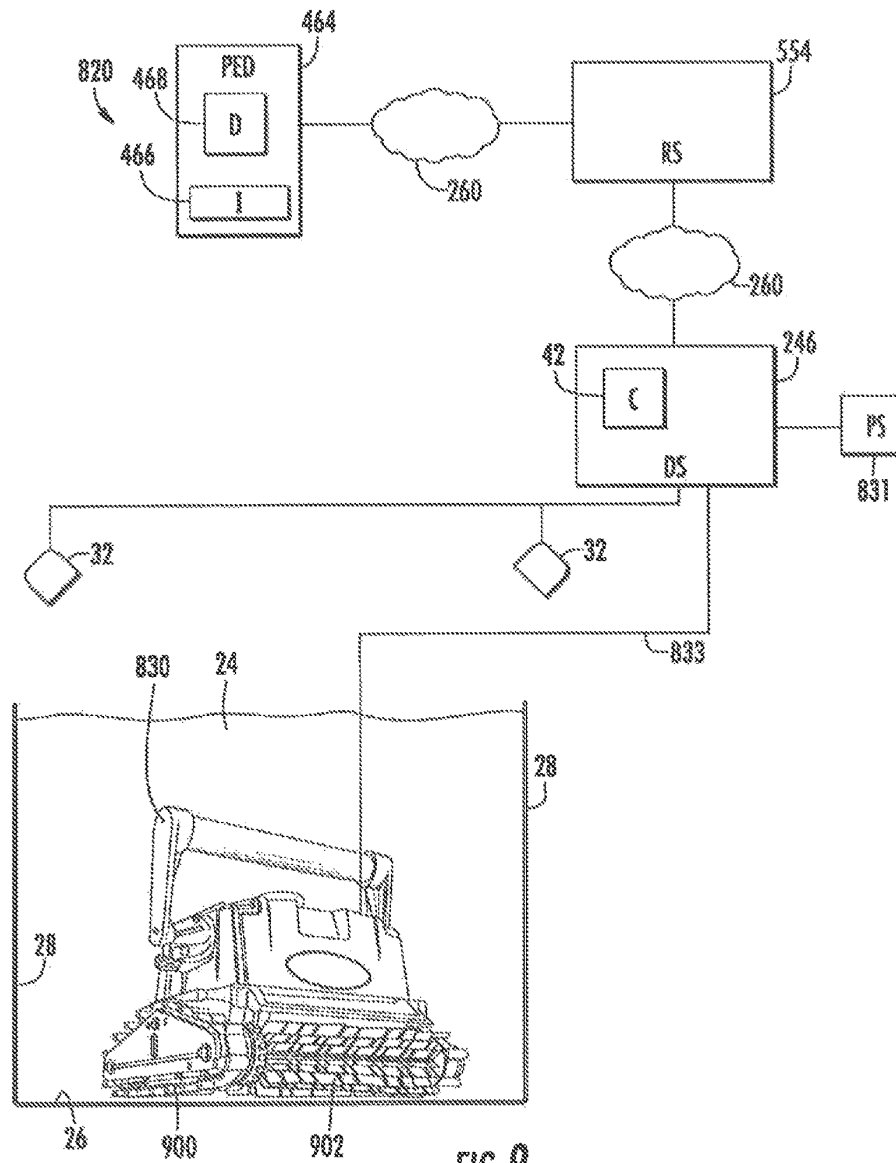
FIG. 8

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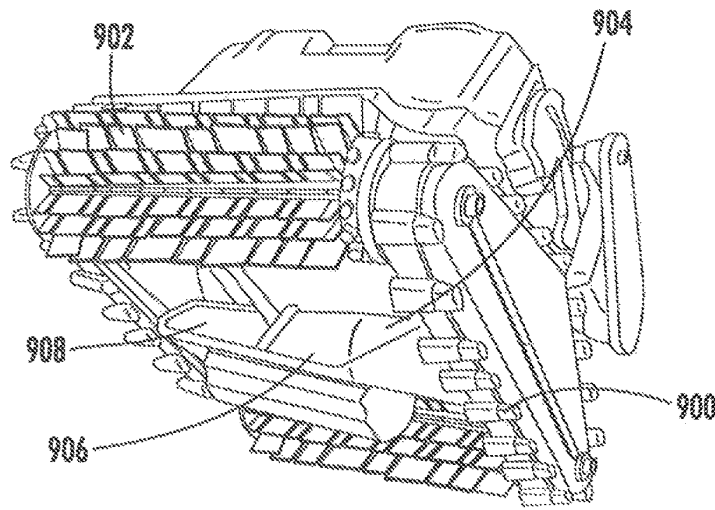


FIG. 10

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**POOL CLEANING SYSTEM AND METHOD
TO AUTOMATICALLY CLEAN SURFACES
OF A POOL USING IMAGES FROM A
CAMERA**

**CROSS-REFERENCE TO RELATED
APPLICATION**

This application is a continuation of U.S. patent application Ser. No. 16/919,750, filed Jul. 2, 2020, which is a continuation of U.S. patent application Ser. No. 16/416,840, filed May 20, 2019 (now U.S. Pat. No. 10,739,785), which is a continuation of U.S. patent application Ser. No. 15/973,983, filed May 8, 2018 (now U.S. Pat. No. 10,338,599), which is a continuation of U.S. patent application Ser. No. 15/207,065, filed Jul. 11, 2016 (now U.S. Pat. No. 9,995,051), which is a continuation of U.S. patent application Ser. No. 13/545,918, filed Jul. 10, 2012 (now U.S. Pat. No. 9,388,595), the contents of all of which are incorporated herein by reference in their entireties.

BACKGROUND

Manually cleaning the floor and sides of a swimming pool may be a tedious and time-consuming task. As a result, automated robotic pool cleaners have been developed. However, controlling and monitoring such automated robotic pool cleaners to insure that all portions of the pool surfaces are satisfactorily cleaned remains a challenge.

SUMMARY OF THE INVENTION

The disadvantages heretofore associated with the prior art are overcome by the present invention of a pool cleaning system for cleaning debris from a submerged surface of a swimming pool comprising: a self-propelled pool cleaner having rotatably-mounted supports for supporting and guiding the cleaner on the pool surface; a filter configured to retain the debris collected from the submerged surface of the swimming pool; an electric motor for enabling the rotation of the rotatably-mounted supports on the pool surface; at least one camera to capture imagery of the pool surface; a controller, in electronic communication with the at least one camera, to determine a cleanliness characteristic of the pool surface on which the cleaner has passed based on the camera imagery and generate a control signal to direct movement of the cleaner based on the cleanliness characteristic of the pool surface; and a portable electronic device is configured to present a graphic on a display, the graphic depicting the submerged surface of the pool and those portions of the surface that remain uncleaned as the cleaner traverses the pool surface.

In one aspect, the at least one camera is carried by the cleaner. In another aspect, the controller is carried by the cleaner. In still another aspect, the electric motor is mechanically connected to at least one of the rotatably-mounted supports.

In yet another aspect, the controller is operable to execute one or more cleaning programs for cleaning the submerged surfaces of the pool. In one aspect, the control signal causes the cleaner to drive in a direction to clean a portion of the pool surface based on the cleanliness characteristic of the pool surface. Alternatively, the control signal causes the cleaner to steer in a direction to clean a portion of the pool surface based on the cleanliness characteristic of the pool surface. In another aspect, the control signal causes the cleaner to drive in a direction to re-clean a portion of the

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pool surface over which the cleaner has passed. Alternatively, the control signal causes the cleaner to steer in a direction to re-clean a portion of the pool surface over which the cleaner has passed.

In one aspect, the captured imagery from the at least one camera is digitally processed by the controller to determine the cleanliness characteristic of the pool surface. Alternatively, the captured imagery from the at least one camera is digitally processed by a remote processor to determine the cleanliness characteristic of the pool surface.

In another aspect, the system further comprises a dry station located remotely from the cleaner and in communication with the cleaner, wherein the dry station includes the controller. Alternatively, the system further comprises a dry station located remotely from the cleaner and in communication with the cleaner, wherein the controller is located remotely from the cleaner and the dry station. In still another aspect, the controller controls electric power provided to the electric motor.

In one aspect, the control signal causes the cleaner to move in a direction of a portion of the pool surface to be cleaned based solely upon signals received from the camera. In another aspect, the control signal causes the cleaner to drive in a direction to clean a portion of the pool surface based on the cleanliness characteristic of the pool surface. Alternatively, the control signal causes the cleaner to steer in a direction to clean a portion of the pool surface based on the cleanliness characteristic of the pool surface. In yet another aspect, the control signal causes the cleaner to drive in a direction to re-clean a portion of the pool surface over which the cleaner has passed. Alternatively, the control signal causes the cleaner to steer in a direction to re-clean a portion of the pool surface over which the cleaner has passed.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a schematic illustration of an example pool cleaning system.

FIG. 2 is a schematic illustration of an implementation of the pool cleaning system of FIG. 1.

FIG. 3 is a schematic illustration of an implementation of the pool cleaning system of FIG. 1.

FIG. 4 is a schematic illustration of an implementation of the pool cleaning system of FIG. 1.

FIG. 5 is a schematic illustration of an implementation of the pool cleaning system of FIG. 1.

FIG. 6 is a flow diagram of an example method that may be carried out with the pool cleaning system of FIG. 2-5.

FIG. 7 is a plan view of an example display with an example graphical depiction.

FIG. 8 is a plan view of another example display with an example graphical depiction.

FIG. 9 is a schematic illustration of an implementation of the pool cleaning system of FIG. 1 with an example pool cleaning vehicle.

FIG. 10 is a bottom perspective view of the example pool cleaning vehicle of the system of FIG. 9.

**DETAILED DESCRIPTION OF THE EXAMPLE
EMBODIMENTS**

FIG. 1 schematically illustrates an example pool cleaning system 20. As schematically shown by FIG. 1, pool cleaning system 20 is adapted to clean submerged surfaces of a pool 22 containing a liquid 24. In particular, pool cleaning system 20 is adapted to clean at least a bottom or floor surface 26 of the pool 22 and possibly to additionally clean surfaces 28

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of pool 22. As will be described hereafter, pool cleaning system facilitates the control and monitoring of a robotic pool cleaner to better assure that all portions of pool 22 are satisfactorily cleaned.

Pool cleaning system 20 comprises vehicle 30, cameras 32 and controller 42. Vehicle 30 comprises an automated powered device configured to travel adjacent to submerged or water containing surfaces of pool 20 (such as floor 26 and/or side surfaces 28) while cleaning such surfaces. In one implementation, vehicle 30 may include vacuum or suction devices, a liquid circulation system and a filter to draw debris, such as bacterial growth or plant growth, from such pool surfaces, wherein the drawn liquid containing such residue or foreign matter is filtered to collect the debris. In other implementations, vehicle 30 may not collect such debris, wherein vehicle 30 merely loosens such debris on the pool surfaces such that the loosened or separated debris may be subsequently removed using the existing liquid filtering system of pool 22.

To assist in the loosening of debris, in one implementation, vehicle 30 may additionally include a chemical dispenser to closely apply pool cleaning chemicals to the pool surfaces as the vehicle 30 traverses such surfaces. In one implementation, vehicle 30 may additionally or alternatively include one or more scrubbing members, such as active (driven) or passive (undriven or idling) brushes, to assist in the removal of residue or foreign matter from such pool surfaces. In yet another implementation, vehicle 30 may additionally or alternatively include liquid jets to assist in the loosening of debris.

To move along the submerged surfaces of pool 22, vehicle 30 includes one or more propulsion mechanisms. In one implementation, vehicle 30 is propelled along the submerged pool surfaces using wheels, rollers, tracks or other surface contacting members powered by a motor and the like. Such wheels, rollers or tracks may themselves include the scrubbing members used to clean the surfaces. In one implementation vehicle 30 may also alternatively be propelled by means of the vacuum or liquid jets. The vacuum or liquid jets used for such propulsion nozzle facilitate loosening of debris for collection by vehicle 30. In other implementations, vehicle 30 may include other propulsion mechanisms.

Cameras 32 comprise devices configured to capture video or time lapse images of pool 22. In the example illustrated, cameras 32 are mounted on structures external to pool 22. In other words, cameras 32 are not submerged. In other implementations, cameras 32 may alternatively be mounted to vehicle 30. In the example illustrated, cameras 32 capture movement of vehicle 30 while vehicle 30 is submerged within pool 22. In other implementations, cameras 32 merely capture images of submerged surfaces 26, 28 of pool 22.

In the example illustrated, cameras 32 comprise cameras serving as part of a home or pool security system, wherein such cameras detect the presence of a person at pool 22 satisfying a predefined characteristic and wherein an alert is output upon the person's detected presence. For example, in one implementation, cameras 32 are utilized as part of a security system that detects when a person below a predefined age, such as a child, is present at pool 22 without a detected presence of a recognized adult. In another implementation, cameras 32 may detect the presence of an unauthorized person or intruder at pool 22. Identification of the person may be achieved by an off-site human or computerized monitoring system, wherein signals from cameras 32 are transmitted across a wide area network or may be

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achieved with software of controller 42 which includes facial recognition or other identification programming.

Because pool cleaning system 20 utilizes pre-existing cameras 32 provided as part of a security system or shares the use of cameras 32 with such a home or pool security system, pool cleaning system 20 is easier to set up, less complex and less expensive. In other implementations, pool cleaning system 20 may utilize dedicated cameras 22 independent of any cameras associated with a home, facility or pool security system. In such an alternative system, cameras 32 may be more precisely focused upon pool 22 and surfaces 26, 28 while also including appropriate lenses or modifications to account for glare, refraction and the like to better facilitate the capture of surfaces and vehicle 30 which are submerged.

Controller 42 comprises one or more processing units in communication with vehicle 30 and cameras 32. For purposes of this application, the term "processing unit" shall mean a presently developed or future developed processing unit that executes sequences of instructions contained in a memory. Execution of the sequences of instructions causes the processing unit to perform steps such as generating control signals. The instructions may be loaded in a random access memory (RAM) for execution by the processing unit from a read only memory (ROM), a mass storage device, or some other persistent storage. In other embodiments, hard wired circuitry may be used in place of or in combination with software instructions to implement the functions described. For example, controller 42 may be embodied as part of one or more application-specific integrated circuits (ASICs). Unless otherwise specifically noted, the controller is not limited to any specific combination of hardware circuitry and software, nor to any particular source for the instructions executed by the processing unit.

In one implementation, controller 42 communicates with vehicle 30 and cameras 32 entirely across a wired connection. In another implementation, controller 42 communicates with vehicle 30 and cameras 32 across a wireless connection, such as cross a local area network (LAN) or a wide area network (WAN) such as the Internet. One of limitation, controller 42 may communicate with vehicle 30 and cameras 32 using a combination of both wired and wireless communication connections.

Controller 42 is configured to generate control signals for steering vehicle 30 based upon signals received from cameras 32. In one implementation, controller 42 provides the sole steering directions for vehicle 30 using signals from cameras 32. Because vehicle 30 is precisely steered under the control of controller 42, rather than traveling in a random manner, entire summer surfaces of pool 22 may be more quickly and efficiently covered and cleaned. Because controller 42 provides the only steering instructions for vehicle 30 and utilizes signals from cameras 32, complex steering algorithms or codes in either vehicle 30 or controller 42 may be omitted to reduce complexity and cost of system 20.

In another implementation, vehicle 30 may cover or travel across surfaces of pool 22 in either a random fashion or according to an automated pool coverage algorithm or pool coverage pattern stored in a memory associated with vehicle 30 or controller 42. In such an implementation, controller 42 utilizes signals from cameras 32 to verify that all of the surfaces of pool 22 have been cleaned, that no spots have been missed. Upon identifying a missed spot, controller 42 utilizes signals from camera 32 to steer vehicle 32 over such missed portions of surfaces 26, 28. According to one example, controller 42 not only uses signals from camera 32 to determine whether any portions of surfaces 26, 28 have

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been missed entirely, but to also determine whether any portions of surfaces **26**, **28** have been cleaned, but not to a satisfactory degree or extent. In such circumstances, controller **42** uses signals from cameras **32** to steer vehicle **34** such areas to re-clean such portions until such portions have been satisfactorily cleaned such that the portions have a cleanliness characteristic satisfying a predefined threshold.

FIG. 2 schematically illustrates pool cleaning system **120**, the particular example of pool cleaning system **20** described above. Pool cleaning system **120** is similar to pool cleaning system **20** except that pool cleaning system **120** additionally comprises dry station **46** and display **50**. Those remaining components of pool cleaning system **120** which correspond to components of pool cleaning system **20** are numbered similarly.

Dry station **46** comprises a station in communication with vehicle **30** and cameras **32** outside of pool **22**. Dry station **46** incorporates controller **42**. In one implementation, dry station **46** communicates with vehicle **30** in a wired fashion. In such an implementation, dry station **46** further provides electrical power to vehicle **30** in a wired fashion. Dry station **46** communicates with cameras **32** and either a wired or wireless fashion.

Display **50** comprises a device to present a graphical images and text on a display screen. In one implementation, display **58** may be incorporated as part of dry station **46**. In another implementation, display **50** may be provided on a portable electronic device, a computer, a television and the like. Display **50** is utilized by pool cleaning system **120** to present information regarding the cleaning of pool **22** to facilitate control of vehicle **30** by controller **42**. In one implementation, display **50** is utilized by pool cleaning system **120** and a controller **42** to present a graphical depiction of those portions of surfaces **26**, **28** of pool **22** have not been satisfactorily cleaned so as to satisfy a predefined cleanliness characteristic threshold. Such portions may comprise portions that have been completely missed by vehicle **30** as well as those portions that have been covered by vehicle **30** but have not been satisfactorily cleaned with the given number of passes of vehicle **30** or the existing cleaning settings of vehicle **30**. The graphical depiction presented on display **50** enables a person view the quality of the prior cleaning session and to input commands causing controller **42** to generate control signals using signals from camera **32** to steer vehicle **30** back to such identified portions where such portions may be cleaned at the same or elevated cleaning aggressiveness settings.

Another implementation, display **50** may be further utilized by controller **42** to depict the progress of vehicle **30** in cleaning pool **22**. Such a display **50** allows a person to visually determine how much of the pool has been currently cleaned and to estimate the remaining time before the pool cleaning task is completed. In certain circumstances, using display **50**, a person may adjust a setting of vehicle **30** to accelerate a rate at which surfaces **26**, **28** of pool **22** are cleaned to meet an earlier desired completion time for such pool cleaning.

FIG. 3 schematically illustrates pool cleaning system **220**, another example implementation of pool cleaning system **20**. Pool cleaning system **220** is similar to pool cleaning system **20** except that pool cleaning system **220** additionally comprises dry station **246**, display **50**, and remote server **254**. Those remaining components of pool cleaning system **220** which correspond to components of pool cleaning system **20** or pool cleaning system **120** are numbered similarly.

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Dry station **246** is similar to dry station **46**, described above, except that dry station **246** serves as a local interface for communication with controller **42** across a network **260**. In one implementation, network **260** may comprise a local area network. In another implementation, network **260** may comprise a wide area network, such as the Internet. For example, in one implementation, dry station **246** may incorporate a modem. In one implementation, dry station **246** may communicate across a local area network to controller **42**. In another implementation, dry station **246** may communicate through a router, across a local area network, to a local modem which communicates across a network **260**. The example illustrated, dry station **246** further provides part of vehicle **30** across a wired cable or wired connection. Display **50** is described above with respect to system **120**.

Remote server **254** comprises a server remote from dry station **246** which is in communication with dry station **246** across network **260**. Remote server **254** includes controller **42**. During operation, signals from cameras **32** are transmitted across dry station **246** across network **260** to controller **42** of remote server **254**. Based upon such signals from cameras **32**, controller **42** generates control signals which are transmitted back across network **260** and through dry station **246** to vehicle **30** to steer vehicle **30**.

As shown by FIG. 3, remote server **254** and network **260** may be shared as part of other pool cleaning systems **320**, wherein controller **42** generates control signals for steering the pool cleaning vehicle **30** of system **320** based upon signals from cameras **32** transmitted across dry station **246** of system **320**. In such an implementation, the cost and complexity of pool cleaning system **220** is reduced since controller **42** is remotely provided at remote server **254** which services multiple pool cleaning systems **220**, **320**. Upgrades to controller **42** and its software are also more easily achieved for all pool cleaning systems to **20**, **320** and their pools **22**, **222** being serviced. In one implementation, the supervised cleaning, inspection and possible re-cleaning facilitated by the use of cameras **32** may be provided as part of a subscription to users of vehicle **30**. In such an implementation, a pool **22** having security cameras **32** may be upgraded with appropriate software or an appropriate software module added to dry station **246** to make a network connection with controller **42** which directs the security cameras **32** to capture vehicle **30** utilizes such signals for steering vehicle **30**.

FIG. 4 schematically illustrates pool cleaning system **420**, another particular implementation of pool cleaning system **20**. Pool cleaning system **420** is similar to pool cleaning system **120** except that pool cleaning system **420** additionally comprises a portable electronic device **464**. Those remaining components of pool cleaning system **420** which correspond to components of pool cleaning system **120** are numbered similarly.

Portable electronic device **464** comprises a portable handheld electronic device in communication with controller **42** and/or dry station **46** across network **260**. Examples of such a portable electronic device (PED) **300** include, but are not limited to, a smart phone, a personal data assistant (PDA), laptop, notebook computer, tablet computer (e.g. IPAD) and MP3 player (e.g., IPOD TOUCH). In the example illustrated, PED **464** comprises input **466** and display **468**.

Input **466** serves as a user interface for PED **464** by which inputs are made to PED **464**. Input **466** facilitates entry of inputs or commands by a person to cause controller **42** to generate control signals varying the control of vehicle **30**. In one implementation, input **466** comprise a keyboard in other implementations, input **466** may comprise a touchpad, a

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stylus, a microphone with associated speech recognition software or programming, a touch screen, buttons, switches and the like. In some implementations, input 466 may comprise a touch screen incorporated as part of display 468.

Display 468 comprises a user interface by which graphical or textual data is presented to a user. Display 468 may present the same or similar information as presented at dry station 246 by display 50 as described above. In one implementation, display 468 comprises a liquid crystal display. In other implementations, display 468 may comprise other types of display technology such as a light emitting diode display, an organic light emitting diode display (OLED), an electronic ink (e-ink) display or other types of display technology in present use or developed in the future. Although system 420 is illustrated as including controller 422 is part of dry station 46, in some implementations, controller 42 may alternatively be located as part of PED 464.

PED 464 enables a person located remote from pool 22 to monitor the progress of the cleaning of pool 22 by vehicle 30 of system 420. PED 464 provides a person with a graphical presentation (described above with respect to display 50) indicating those portions of surfaces 26, 28 of pool 22 that have been completed as well as those portions 26, 20 and that remain to be cleaned. The person may also be provided with a graphical indication of what portions need to be re-cleaned to meet predetermined cleanliness thresholds. In the example illustrated, input 466 enables a person to enter commands or selections which are transmitted across network 260 to controller 42 to adjust operation of vehicle 30. For example, the path or route of vehicle 30 may be changed, the aggressiveness of the cleaning chemicals or mechanical cleaning devices may be adjusted, the speed at which vehicle 30 traverses surfaces 26, 28 may be adjusted. In response to such adjustment signals from PED 464, controller 42 may utilize signals from cameras 32 to adjust the steering of vehicle 30.

FIG. 5 schematically illustrates pool cleaning system 520, another example implementation of pool cleaning system 20. Pool cleaning system 520 is similar to pool cleaning system 420 except that pool cleaning system 520 additionally comprises a remote server 554. Those remaining components of pool cleaning system 520 which correspond to components of pool cleaning system 420 are numbered similarly.

Remote server 554 is similar to remote server 254 described above with respect to system 220. Remote server 554 comprises a server remote from dry station 246 which is in communication with dry station 246 across network 260. Remote server 254 includes controller 42. During operation, signals from cameras 32 are transmitted across dry station 246 across network 260 to controller 42 of remote server 254. Based upon such signals from cameras 32, controller 42 generates control signals which are transmitted back across network 260 and through dry station 246 to vehicle 30 to steer vehicle 30. Controller 42 further relays either the raw signals from camera 32 or image signals generated based upon signals from cameras 32 to PED 464, wherein such images (described above) are presented on display 468. As noted above, PED may further receive commands through input 466, wherein such commands are transmitted to controller 42 which generates control signals that are ultimately transmitted to vehicle 30 for steering vehicle 30.

As with remote server 254, remote server 554 and network 260 may be shared as part of other pool cleaning systems 320 (shown in FIG. 3), wherein controller 42

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generates control signals for steering the pool cleaning vehicle 30 of system 320 based upon signals from cameras 32 transmitted across dry station 246 of system 320. In such implementations, controller 42 of remote server 554 may interact with other PEDs 464. In such an implementation, the cost and complexity of pool cleaning system 220 is reduced since controller 42 is remotely provided at remote server 254 which services multiple pool cleaning systems 220, 320. Upgrades to controller 42 and its software are also more easily achieved for all pool cleaning systems to 20, 320 and their pools 22, 222 being serviced. In one implementation, the supervised cleaning, inspection and possible re-cleaning facilitated by the use of cameras 32 may be provided as part of a subscription to users of vehicle 30. In such an implementation, a pool 22 having security cameras 32 may be upgraded with appropriate software or an appropriate software module added to dry station 246 to make a network connection with controller 42 which directs the security cameras 32 to capture vehicle 30 utilizes such signals for steering vehicle 30. As indicated by broken lines, in other implementations, the controller 42 for generating control signals steering vehicle 30 based upon signals from cameras 32 may alternatively be relocated in PED 464.

FIG. 6 is a flow diagram illustrating an example method 600 that may be carried out by any of systems 120-520. As indicated by step 602, cameras 32 capture images of pool cleaning by vehicle 30. As indicated by step 604, controller 42 obtain such signals from cameras 32 for the surfaces of pool 22 that have been cleaned. As indicated by step 606, controller 42 uses information gathered from the signals from cameras 32 to identify those portions of surfaces 26, 28 not satisfactorily cleaned—not satisfying a predefined cleanliness characteristic or measurement threshold. One example of a cleanliness characteristic measurement a threshold may be how well the color of a surface matches a predetermined desirable color for the pool surface (such as original color of the tile or surface). A surface that has been missed entirely by vehicle 30 during a pool cleaning session may be automatically deemed to not satisfy a predetermined cleanliness characteristic.

As indicated by step 608, based upon such determinations, controller 42 generates control signals resulting in the presentation of a graphical depiction of those portions of pool 22 that has not been satisfactorily cleaned. Such graphical representations or depictions may be presented on display 50 or display 468. FIGS. 7 and 8 illustrate examples of graphical depictions that may be presented.

FIG. 7 illustrates display 468 presenting graphical depiction 620. Graphical depiction 620 comprises a first graphic 622 having a first portion 624 representing sides or walls 28 of pool 22 and a second portion 626 representing the floor 26 of pool 22. Graphical depiction 620 further comprises a moving icon 628 representing the current positioning of vehicle 30. In one implementation, the path of vehicle 30 may additionally be depicted by icon 628 shown in broken lines. As shown by FIG. 7, those portions 632 of surfaces 26, 28 of pool 22 (shown in FIG. 1) over which of vehicle 30 has moved are identified by graphical depiction 620 either by color, markings or other various distinctive attributes. Likewise, those portions 634 of surfaces 26, 28 of pool 22 that have not been covered by vehicle 30 are identified by a distinct color col marking or distinctive attribute of depiction 620. As a result, a person may view the current position of vehicle 30, the extent to which pool 22 has been cleaned or covered by vehicle 30 and the extent of pool 22 that remains to be cleaned. In the example illustrated, depiction 620 further identifies those portions 638 of surfaces 26, 28

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that have been cleaned, but which have not been cleaned to a satisfactory degree or extent. In one implementation, portions 638 may be identified by colors, brightness, markings or other visually distinctive attributes that are visually distinct from both portions 632 and portions 634. In other implementations, portions 638 may have the same characteristic of portions 634 in yet other implementations, different portions 638 may have different visual attributes depending upon a degree to which such clean portions have failed to satisfy the predefined cleanliness characteristic threshold. In some implementations, different port 638 may have different visual attributes depending upon different cleaning strategies that may be recommended for the different portions 638. For example, controller 42 may determine and recommend a first cleaning strategy (a first chemical solution jetted at a first rate and scrubbed at a first rate) with respect to a first portion 638 and may recommend a second different cleaning strategy (a second chemical solution jetted at a second rate is about a second rate) with respect to a second portion 638, wherein the different cleaning strategies are represented by different visual attributes presented in depiction 620.

FIG. 8 illustrates display 468 presenting a graphical depiction 720. Graphical depiction 720 comprises a first graphic 622 having a first portion 624 representing sides or walls 28 of pool 22 and a second portion 626 representing the floor 26 of pool 22 (shown in FIG. 1). Graphical depiction 720 is similar to graphical depiction 620 except that graphical depiction 720 omits icon 628 presenting vehicle 30. Like depiction 620, depiction 720 graphically depicts those portions 632 of surfaces 26, 28 over which vehicle 30 has traveled while in a cleaning mode. Depiction 720 also visually depicts those portions 634 that have not been covered by vehicle 30 in the cleaning mode and those portions 638 over which vehicle 30 has traveled while in the cleaning mode, but which have not been cleaned to a satisfactory degree. As illustrated in FIG. 8, different portions 638 may be visibly distinguished from one another through color, text or markings indicating either differences in the cleanliness of such portions 638 or indicating different recommended cleaning strategies or approaches that may be selected by a person using input 466 when vehicle 30 is steered back to such portions 638 for re-cleaning using signals from camera 32.

As indicated by step 610 of FIG. 6, controller 42 generates control signals steering vehicle 30 to re-clean portions of pool 22, such as portions 638. Such steering may be facilitated by using signals from cameras 32. As noted above, in some implementations, a person may be allowed choose a cleaning approach for a particular portion 638 using input 466. The selection may be facilitated by visual inspection of the different visual attributes for the particular portion 638 provided by depiction 720 (or depiction 620). In some implementations, input 466 may additionally be utilized by a person to prioritize an order in which portions 638 are re-cleaned.

FIG. 9 illustrates pool cleaning system 820, an example implementation of pool cleaning system 20. Pool cleaning system 820 is similar to pool cleaning system 520 except the pool cleaning system 820 located controller 42 in dry station 246 and includes pool cleaning vehicle 830, a specific example of vehicle 30. As shown by FIG. 9, in addition to transmitting control signals generated by controller 42 to vehicle 830, dry station 246 further transmits power from power source 831 through a power line or power cable 833 to vehicle 830. In the example illustrated, data communication and communication of control signals, also occurs

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across wired connections within or alongside the same line 833 in the example illustrated, remote server 554 serves as a communication link by which upgrades to controller 42 may be implemented across a wide number of pool cleaning systems and by which information from controller 42 is conveyed to one or more portable electronic devices 464 across network 260.

Vehicle 830 comprises a robotic or automated pool cleaning device vehicle 830 comprises a self-contained onboard filtration system with drive and pump motors. Vehicle 830 utilizes an internal microprocessor guided drive motor to systematically clean surfaces of pool 22. As shown by FIGS. 9 and 10, vehicle 830 utilizes a toothed track drive 900 provide traction and propulsion for vehicle 30. Vehicle 830 comprises rotating brushes 902 to loosen waterline buildup and breakdown large debris while power washing jets 904 flush out dirt from pores, seams in corners where brushes 902 may not be able to reach. The loosened dirt and debris is vacuumed through off-center vacuum ports 906 which passes the vacuumed debris through internally house filter bag. In the example illustrated, vehicle 830 further comprises rollers 908 which inhibit vehicle 830 from becoming impeded or stuck on raised drains or pop-up heads. Although illustrated as being employed with system 820, vehicle 830 may also be utilized with any of systems 20, 120, 220, 320 and 420. In other implementations, other robotic or automated pool cleaning vehicles may be utilized.

Although the present disclosure has been described with reference to example embodiments, workers skilled in the art will recognize that changes may be made in form and detail without departing from the spirit and scope of the claimed subject matter. For example, although different example embodiments may have been described as including one or more features providing one or more benefits, it is contemplated that the described features may be interchanged with one another or alternatively be combined with one another in the described example embodiments or in other alternative embodiments. Because the technology of the present disclosure is relatively complex, not all changes in the technology are foreseeable. The present disclosure described with reference to the example embodiments and set forth in the following claims is manifestly intended to be as broad as possible. For example, unless specifically otherwise noted, the claims reciting a single particular element also encompass a plurality of such particular elements.

What is claimed is:

1. A self-propelled pool cleaner for cleaning debris from a submerged surface of a swimming pool, comprising:
 - a. a vehicle body;
 - b. means for moving the vehicle body within the swimming pool;
 - c. a filter configured to retain debris collected from the submerged surface;
 - d. at least one camera mounted directly or indirectly to the body for capturing an image of at least a first portion of the submerged surface; and
 - e. a controller (i) positioned on or in the body, (ii) in electronic communication with the at least one camera, and (iii) configured to generate, in response to the captured image, at least one control signal to cause movement of the body within the swimming pool to, or away from, the first portion of the submerged surface.
2. A self-propelled pool cleaner for cleaning debris from a submerged surface of a swimming pool, comprising:
 - a. a vehicle body;
 - b. means for moving the vehicle body within the swimming pool;

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- c. a filter configured to retain debris collected from the submerged surface;
 - d. at least one camera carried by the body for capturing an image of at least a first portion of the submerged surface; and
 - e. a controller (i) positioned on or in the body, (ii) in electronic communication with the at least one camera, and (iii) configured to generate, in response to the captured image, at least one control signal to cause movement of the body within the swimming pool to, or away from, the first portion of the submerged surface.
3. A self-propelled pool cleaner for cleaning debris from a submerged surface of a swimming pool, comprising:
- a. a vehicle body;
 - b. means for moving the vehicle body within the swimming pool;
 - c. a filter configured to retain debris collected from the submerged surface;
 - d. at least one camera positioned on or in, or carried by, the body for capturing an image of at least a first portion of the submerged surface; and
 - e. a controller (i) positioned on or in the body, (ii) in electronic communication with the at least one camera and a portable electronic device, and (iii) configured to generate, in response to at least one of the captured image or information from the portable electronic device, at least one control signal to cause movement of the body within the swimming pool to, or away from, the first portion of the submerged surface.
4. A self-propelled pool cleaner for cleaning debris from a submerged surface of a swimming pool, comprising:
- a. a vehicle body;

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- b. means for moving the vehicle body within the swimming pool;
 - c. a filter configured to retain debris collected from the submerged surface;
 - d. at least one camera for capturing an image of at least a first portion of the submerged surface; and
 - e. a controller (i) positioned on or in the body, (ii) in electronic communication with the at least one camera, and (iii) configured to generate, in response to the captured image, at least one control signal to cause movement of the body within the swimming pool to, or away from, the first portion of the submerged surface.
5. A self-propelled pool cleaner for cleaning debris from a submerged surface of a swimming pool, comprising:
- a. a vehicle body;
 - b. means for moving the vehicle body within the swimming pool;
 - c. a filter configured to retain debris collected from the submerged surface;
 - d. a chemical dispenser on, in, or carried by the vehicle body;
 - e. at least one camera on, in, or carried by the vehicle body, for capturing an image of at least a first portion of the submerged surface; and
 - f. a controller (i) on, in, or carried by the vehicle body, (ii) in electronic communication with the at least one camera and (iii) configured to generate, in response to the captured image, at least one control signal to cause movement of the body within the swimming pool to, or away from, the first portion of the submerged surface.

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EXHIBIT 3

(12) United States Patent
Durvasula et al.**(10) Patent No.: US 11,880,207 B2****(45) Date of Patent: *Jan. 23, 2024****(54) POOL CLEANING SYSTEM AND METHOD TO AUTOMATICALLY CLEAN SURFACES OF A POOL USING IMAGES FROM A CAMERA****(58) Field of Classification Search**CPC .. G05D 1/0246; G05D 1/0016; G05D 1/0033;
G05D 1/0038; G05D 2201/0203;
(Continued)**(71) Applicant: ZODIAC POOL SYSTEMS LLC,**
Carlsbad, CA (US)**(56) References Cited**

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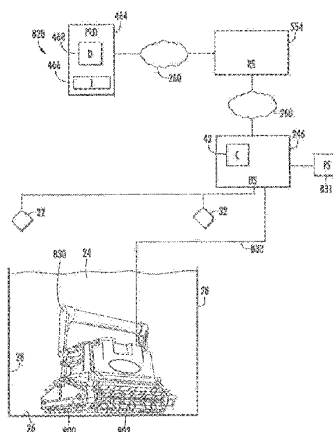
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(74) Attorney, Agent, or Firm — Kilpatrick Townsend &
Stockton LLP**Related U.S. Application Data****(63)** Continuation of application No. 17/143,624, filed on
Jan. 7, 2021, now Pat. No. 11,262,766, which is a
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G05D 1/02 (2020.01)
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CPC **G05D 1/0246** (2013.01); **E04H 4/1654**
(2013.01); **G05D 1/0016** (2013.01);
(Continued)**(57) ABSTRACT**

A pool cleaning system for cleaning debris from a submerged surface of a swimming pool includes a self-propelled pool cleaner having rotatably-mounted supports for supporting and guiding the cleaner on the pool surface; an electric motor for enabling the rotation of the rotatably-mounted supports on the pool surface; at least one camera to capture imagery of the pool surface; a controller, in electronic communication with the at least one camera, to determine a cleanliness characteristic of the pool surface on which the cleaner has passed based on the camera imagery and generate a control signal to direct movement of the cleaner based on the cleanliness characteristic of the pool surface, and a portable electronic device configured to present a graphic on a display, the graphic depicting the

(Continued)



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submerged surface of the pool and those portions of the surface that remain uncleaned as the cleaner traverses the pool surface.

20 Claims, 4 Drawing Sheets

Related U.S. Application Data

continuation of application No. 16/919,750, filed on Jul. 2, 2020, now Pat. No. 11,003,191, which is a continuation of application No. 16/416,840, filed on May 20, 2019, now Pat. No. 10,739,785, which is a continuation of application No. 15/973,983, filed on May 8, 2018, now Pat. No. 10,338,599, which is a continuation of application No. 15/207,065, filed on Jul. 11, 2016, now Pat. No. 9,995,051, which is a continuation of application No. 13/545,918, filed on Jul. 10, 2012, now Pat. No. 9,388,595.

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 CPC *G05D 1/0033* (2013.01); *G05D 1/0038* (2013.01); *H04N 7/18* (2013.01); *H04N 23/66* (2023.01); *G05D 2201/0203* (2013.01); *G06T 7/001* (2013.01); *G06T 7/90* (2017.01); *G06T 2207/10024* (2013.01); *H04N 23/555* (2023.01)
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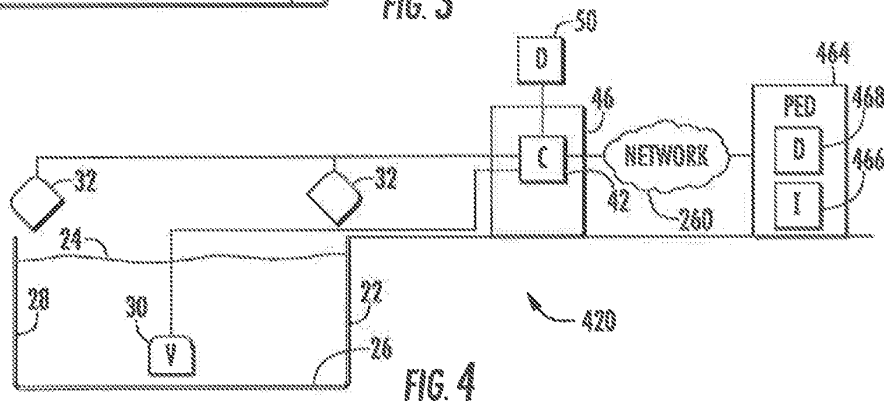
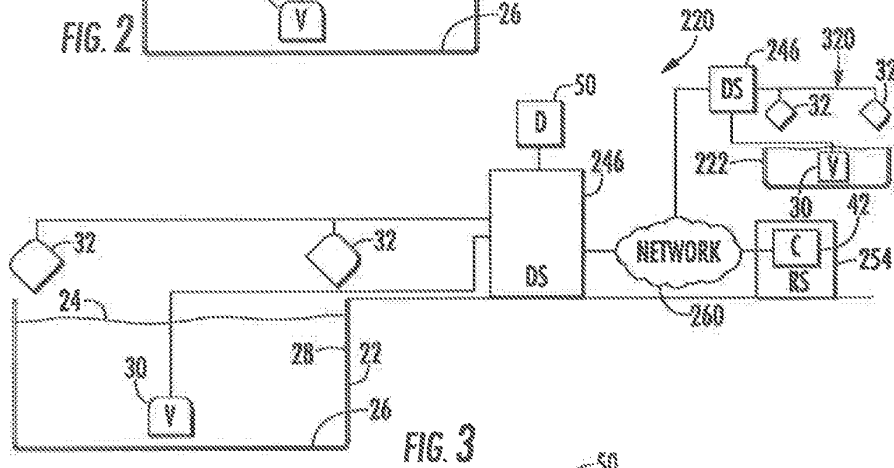
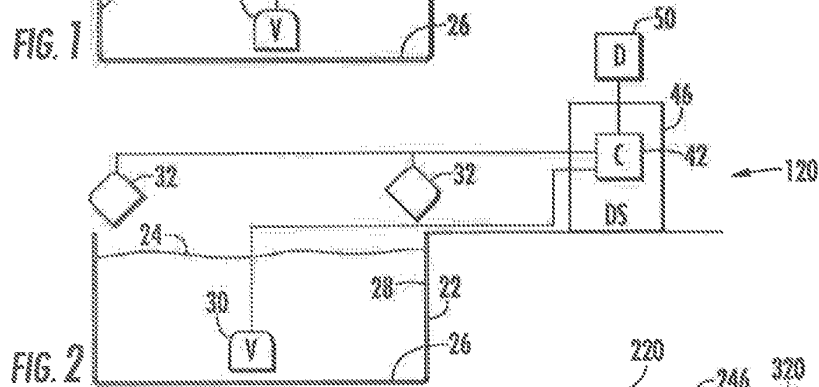
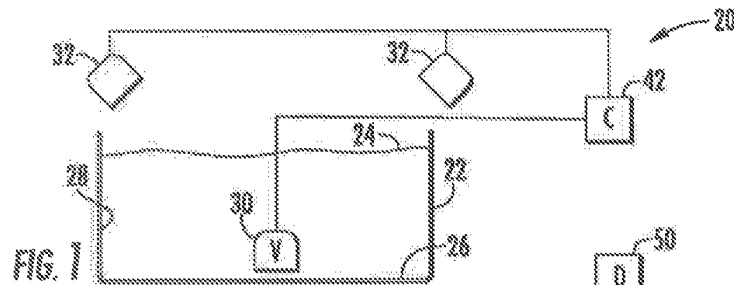
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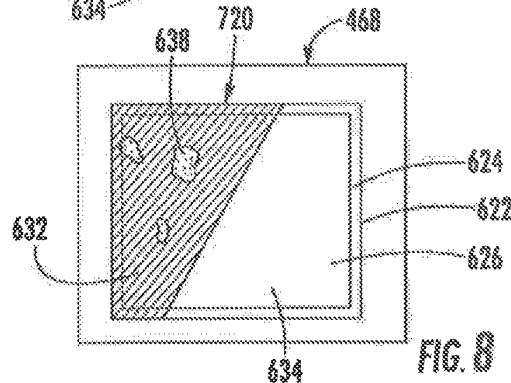
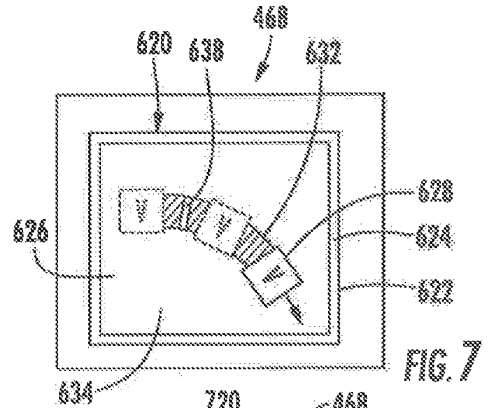
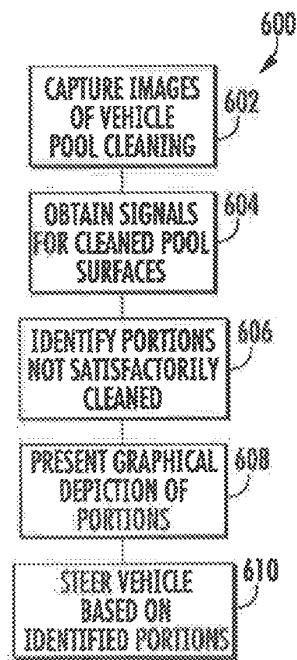
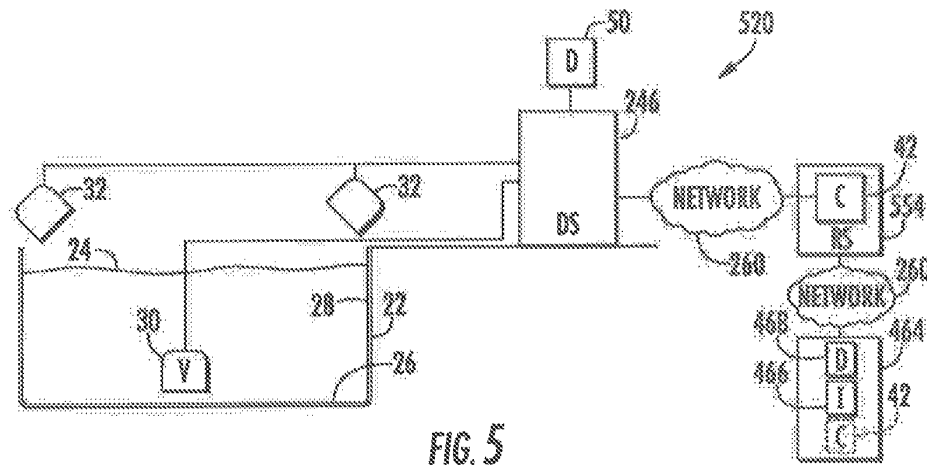


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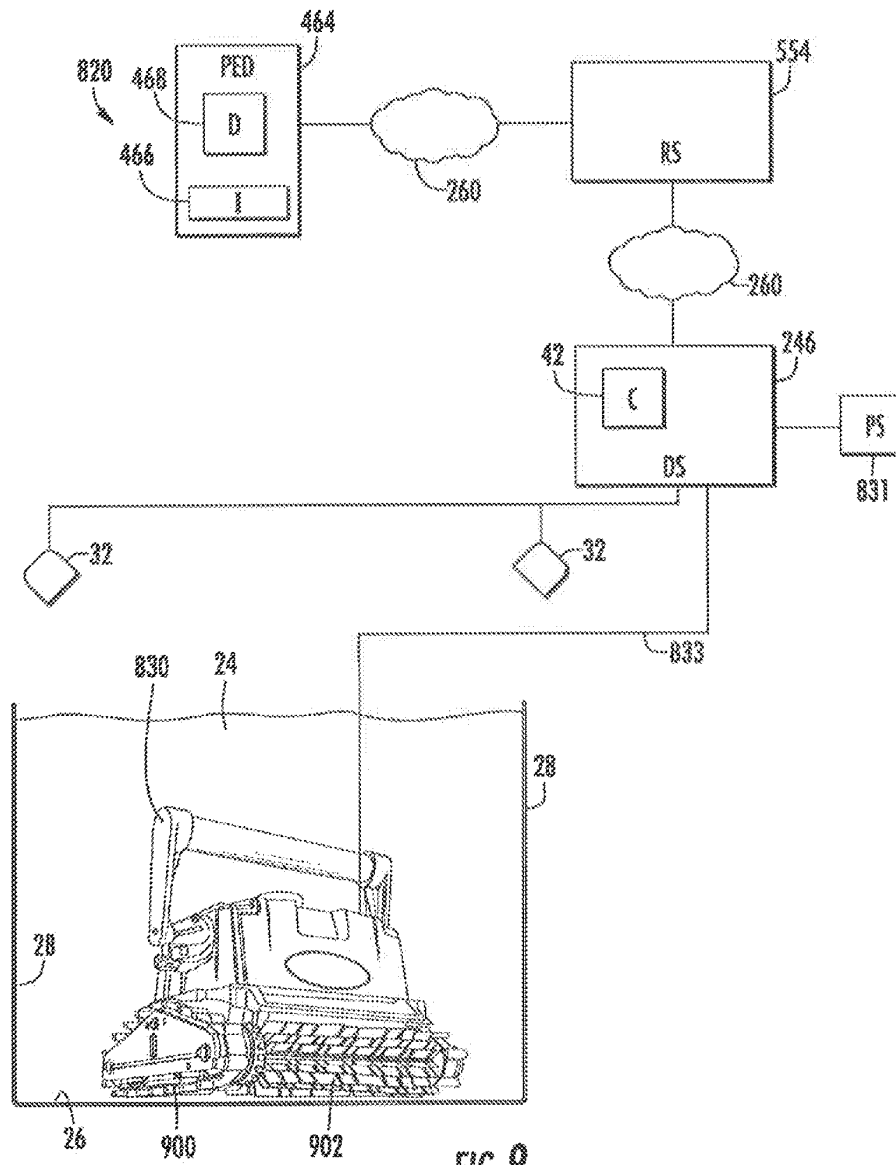


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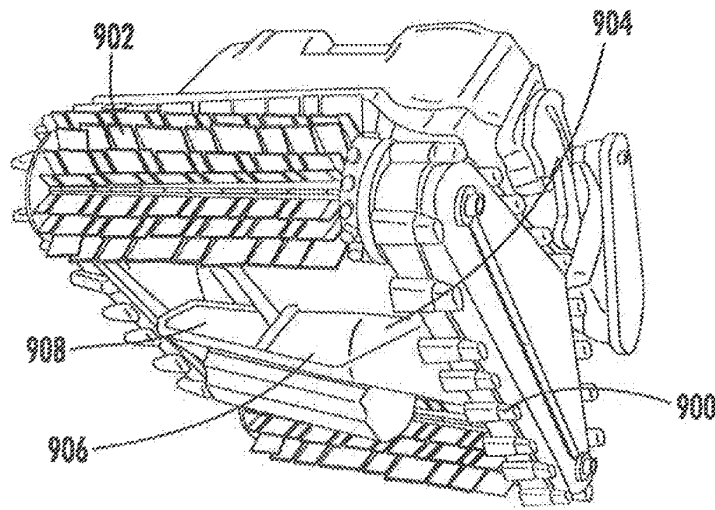


FIG. 10

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**POOL CLEANING SYSTEM AND METHOD
TO AUTOMATICALLY CLEAN SURFACES
OF A POOL USING IMAGES FROM A
CAMERA**

**CROSS-REFERENCE TO RELATED
APPLICATION**

This application is a continuation of allowed U.S. patent application Ser. No. 17/143,624, filed Jan. 7, 2021, which is a continuation of U.S. patent application Ser. No. 16/919,750, filed Jul. 2, 2020 (now U.S. Pat. No. 11,003,191), which is a continuation of U.S. patent application Ser. No. 16/416,840, filed May 20, 2019 (now U.S. Pat. No. 10,739,785), which is a continuation of U.S. patent application Ser. No. 15/973,983, filed May 8, 2018 (now U.S. Pat. No. 10,338,599), which is a continuation of U.S. patent application Ser. No. 15/207,065, filed Jul. 11, 2016 (now U.S. Pat. No. 9,995,051), which is a continuation of U.S. patent application Ser. No. 13/545,918, filed Jul. 10, 2012 (now U.S. Pat. No. 9,388,595), the contents of all of which are incorporated herein by reference in their entireties.

BACKGROUND

Manually cleaning the floor and sides of a swimming pool may be a tedious and time-consuming task. As a result, automated robotic pool cleaners have been developed. However, controlling and monitoring such automated robotic pool cleaners to insure that all portions of the pool surfaces are satisfactorily cleaned remains a challenge.

SUMMARY OF THE INVENTION

The disadvantages heretofore associated with the prior art are overcome by the present invention of a pool cleaning system for cleaning debris from a submerged surface of a swimming pool comprising: a self-propelled pool cleaner having rotatably-mounted supports for supporting and guiding the cleaner on the pool surface; a filter configured to retain the debris collected from the submerged surface of the swimming pool; an electric motor for enabling the rotation of the rotatably-mounted supports on the pool surface; at least one camera to capture imagery of the pool surface; a controller, in electronic communication with the at least one camera, to determine a cleanliness characteristic of the pool surface on which the cleaner has passed based on the camera imagery and generate a control signal to direct movement of the cleaner based on the cleanliness characteristic of the pool surface; and a portable electronic device is configured to present a graphic on a display, the graphic depicting the submerged surface of the pool and those portions of the surface that remain uncleaned as the cleaner traverses the pool surface.

In one aspect, the at least one camera is carried by the cleaner. In another aspect, the controller is carried by the cleaner. In still another aspect, the electric motor is mechanically connected to at least one of the rotatably-mounted supports.

In yet another aspect, the controller is operable to execute one or more cleaning programs for cleaning the submerged surfaces of the pool. In one aspect, the control signal causes the cleaner to drive in a direction to clean a portion of the pool surface based on the cleanliness characteristic of the pool surface. Alternatively, the control signal causes the cleaner to steer in a direction to clean a portion of the pool surface based on the cleanliness characteristic of the pool

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surface. In another aspect, the control signal causes the cleaner to drive in a direction to re-clean a portion of the pool surface over which the cleaner has passed. Alternatively, the control signal causes the cleaner to steer in a direction to re-clean a portion of the pool surface over which the cleaner has passed.

In one aspect, the captured imagery from the at least one camera is digitally processed by the controller to determine the cleanliness characteristic of the pool surface. Alternatively, the captured imagery from the at least one camera is digitally processed by a remote processor to determine the cleanliness characteristic of the pool surface.

In another aspect, the system further comprises a dry station located remotely from the cleaner and in communication with the cleaner, wherein the dry station includes the controller. Alternatively, the system further comprises a dry station located remotely from the cleaner and in communication with the cleaner, wherein the controller is located remotely from the cleaner and the dry station. In still another aspect, the controller controls electric power provided to the electric motor.

In one aspect, the control signal causes the cleaner to move in a direction of a portion of the pool surface to be cleaned based solely upon signals received from the camera.

In another aspect, the control signal causes the cleaner to drive in a direction to clean a portion of the pool surface based on the cleanliness characteristic of the pool surface. Alternatively, the control signal causes the cleaner to steer in a direction to clean a portion of the pool surface based on the cleanliness characteristic of the pool surface. In yet another aspect, the control signal causes the cleaner to drive in a direction to re-clean a portion of the pool surface over which the cleaner has passed. Alternatively, the control signal causes the cleaner to steer in a direction to re-clean a portion of the pool surface over which the cleaner has passed.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a schematic illustration of an example pool cleaning system.

FIG. 2 is a schematic illustration of an implementation of the pool cleaning system of FIG. 1.

FIG. 3 is a schematic illustration of an implementation of the pool cleaning system of FIG. 1.

FIG. 4 is a schematic illustration of an implementation of the pool cleaning system of FIG. 1.

FIG. 5 is a schematic illustration of an implementation of the pool cleaning system of FIG. 1.

FIG. 6 is a flow diagram of an example method that may be carried out with the pool cleaning system of FIG. 2-5.

FIG. 7 is a plan view of an example display with an example graphical depiction.

FIG. 8 is a plan view of another example display with an example graphical depiction.

FIG. 9 is a schematic illustration of an implementation of the pool cleaning system of FIG. 1 with an example pool cleaning vehicle.

FIG. 10 is a bottom perspective view of the example pool cleaning vehicle of the system of FIG. 9.

**DETAILED DESCRIPTION OF THE EXAMPLE
EMBODIMENTS**

FIG. 1 schematically illustrates an example pool cleaning system 20. As schematically shown by FIG. 1, pool cleaning system 20 is adapted to clean submerged surfaces of a pool 22 containing a liquid 24. In particular, pool cleaning system

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20 is adapted to clean at least a bottom or floor surface 26 of the pool 22 and possibly to additionally clean surfaces 28 of pool 22. As will be described hereafter, pool cleaning system facilitates the control and monitoring of a robotic pool cleaner to better assure that all portions of pool 22 are satisfactorily cleaned.

Pool cleaning system 20 comprises vehicle 30, cameras 32 and controller 42. Vehicle 30 comprises an automated powered device configured to travel adjacent to submerged or water containing surfaces of pool 20 (such as floor 26 and/or side surfaces 28) while cleaning such surfaces. In one implementation, vehicle 30 may include vacuum or suction devices, a liquid circulation system and a filter to draw debris, such as bacterial growth or plant growth, from such pool surfaces, wherein the drawn liquid containing such residue or foreign matter is filtered to collect the debris. In other implementations, vehicle 30 may not collect such debris, wherein vehicle 30 merely loosens such debris on the pool surfaces such that the loosened or separated debris may be subsequently removed using the existing liquid filtering system of pool 22.

To assist in the loosening of debris, in one implementation, vehicle 30 may additionally include a chemical dispenser to closely apply pool cleaning chemicals to the pool surfaces as the vehicle 30 traverses such surfaces. In one implementation, vehicle 30 may additionally or alternatively include one or more scrubbing members, such as active (driven) or passive (undriven or idling) brushes, to assist in the removal of residue or foreign matter from such pool surfaces. In yet another implementation, vehicle 30 may additionally or alternatively include liquid jets to assist in the loosening of debris.

To move along the submerged surfaces of pool 22, vehicle 30 includes one or more propulsion mechanisms. In one implementation, vehicle 30 is propelled along the submerged pool surfaces using wheels, rollers, tracks or other surface contacting members powered by a motor and the like. Such wheels, rollers or tracks may themselves include the scrubbing members used to clean the surfaces. In one implementation vehicle 30 may also alternatively be propelled by means of the vacuum or liquid jet. The vacuum or liquid jets used for such propulsion nozzle facilitate loosening of debris for collection by vehicle 30. In other implementations, vehicle 30 may include other propulsion mechanisms.

Cameras 32 comprise devices configured to capture video or time lapse images of pool 22. In the example illustrated, cameras 32 are mounted on structures external to pool 22. In other words, cameras 32 are not submerged. In other implementations, cameras 32 may alternatively be mounted to vehicle 30. In the example illustrated, cameras 32 capture movement of vehicle 30 while vehicle 30 is submerged within pool 22. In other implementations, cameras 32 merely capture images of submerged surfaces 26, 28 of pool 22.

In the example illustrated, cameras 32 comprise cameras serving as part of a home or pool security system, wherein such cameras detect the presence of a person at pool 22 satisfying a predefined characteristic and wherein an alert is output upon the person's detected presence. For example, in one implementation, cameras 32 are utilized as part of a security system that detects when a person below a predefined age, such as a child, is present at pool 22 without a detected presence of a recognized adult. In another implementation, cameras 32 may detect the presence of an unauthorized person or intruder at pool 22. Identification of the person may be achieved by an off-site human or computer-

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ized monitoring system, wherein signals from cameras 32 are transmitted across a wide area network or may be achieved with software of controller 42 which includes facial recognition or other identification programming.

Because pool cleaning system 20 utilizes pre-existing cameras 32 provided as part of a security system or shares the use of cameras 32 with such a home or pool security system, pool cleaning system 20 is easier to set up, less complex and less expensive. In other implementations, pool cleaning system 20 may utilize dedicated cameras 22 independent of any cameras associated with a home, facility or pool security system. In such an alternative system, cameras 32 may be more precisely focused upon pool 22 and surfaces 26, 28 while also including appropriate lenses or modifications to account for glare, refraction and the like to better facilitate the capture of surfaces and vehicle 30 which are submerged.

Controller 42 comprises one or more processing units in communication with vehicle 30 and cameras 32. For purposes of this application, the term "processing unit" shall mean a presently developed or future developed processing unit that executes sequences of instructions contained in a memory. Execution of the sequences of instructions causes the processing unit to perform steps such as generating control signals. The instructions may be loaded in a random access memory (RAM) for execution by the processing unit from a read only memory (ROM), a mass storage device, or some other persistent storage. In other embodiments, hard wired circuitry may be used in place of or in combination with software instructions to implement the functions described. For example, controller 42 may be embodied as part of one or more application-specific integrated circuits (ASICs). Unless otherwise specifically noted, the controller is not limited to any specific combination of hardware circuitry and software, nor to any particular source for the instructions executed by the processing unit.

In one implementation, controller 42 communicates with vehicle 30 and cameras 32 entirely across a wired connection. In another implementation, controller 42 communicates with vehicle 30 and cameras 32 across a wireless connection, such as across a local area network (LAN) or a wide area network (WAN) such as the Internet. One of limitation, controller 42 may communicate with vehicle 30 and cameras 32 using a combination of both wired and wireless communication connections.

Controller 42 is configured to generate control signals for steering vehicle 30 based upon signals received from cameras 32. In one implementation, controller 42 provides the sole steering directions for vehicle 30 using signals from cameras 32. Because vehicle 30 is precisely steered under the control of controller 42, rather than traveling in a random manner, entire summer surfaces of pool 22 may be more quickly and efficiently covered and cleaned. Because controller 42 provides the only steering instructions for vehicle 30 and utilizes signals from cameras 32, complex steering algorithms or codes in either vehicle 30 or controller 42 may be omitted to reduce complexity and cost of system 20.

In another implementation, vehicle 30 may cover or travel across surfaces of pool 22 in either a random fashion or according to an automated pool coverage algorithm or pool coverage pattern stored in a memory associated with vehicle 30 or controller 42. In such an implementation, controller 42 utilizes signals from cameras 32 to verify that all of the surfaces of 22 have been cleaned, that no spots have been missed. Upon identifying a missed spot, controller 42 utilizes signals from camera 32 to steer vehicle 32 over such missed portions of surfaces 26, 28. According to one

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example, controller 42 not only uses signals from camera 32 to determine whether any portions of surfaces 26, 28 have been missed entirely, but to also determine whether any portions of surfaces 26, 28 have been cleaned, but not to a satisfactory degree or extent. In such circumstances, controller 42 uses signals from cameras 32 to steer vehicle 34 such areas to re-clean such portions until such portions have been satisfactorily cleaned such that the portions have a cleanliness characteristic satisfying a predefined threshold.

FIG. 2 schematically illustrates pool cleaning system 120, the particular example of pool cleaning system 20 described above. Pool cleaning system 120 is similar to pool cleaning system 20 except that pool cleaning system 120 additionally comprises dry station 46 and display 50. Those remaining components of pool cleaning system 120 which correspond to components of pool cleaning system 20 are numbered similarly.

Dry station 46 comprises a station in communication with vehicle 30 and cameras 32 outside of pool 22. Dry station 46 incorporates controller 42. In one implementation, dry station 46 communicates with vehicle 30 in a wired fashion. In such an implementation, dry station 46 further provides electrical power to vehicle 30 in a wired fashion. Dry station 46 communicates with cameras 32 and either a wired or wireless fashion.

Display 50 comprises a device to present a graphical images and text on a display screen. In one implementation, display 58 may be incorporated as part of dry station 46. In another implementation, display 50 may be provided on a portable electronic device, a computer, a television and the like. Display 50 is utilized by pool cleaning system 120 to present information regarding the cleaning of pool 22 to facilitate control of vehicle 30 by controller 42. In one implementation, display 50 is utilized by pool cleaning system 120 and a controller 42 to present a graphical depiction of those portions of surfaces 26, 28 of pool 22 have not been satisfactorily cleaned so as to satisfy a predefined cleanliness characteristic threshold. Such portions may comprise portions that have been completely missed by vehicle 30 as well as those portions that have been covered by vehicle 30 but have not been satisfactorily cleaned with the given number of passes of vehicle 30 or the existing cleaning settings of vehicle 30. The graphical depiction presented on display 50 enables a person view the quality of the prior cleaning session and to input commands causing controller 42 to generate control signals using signals from camera 32 to steer vehicle 30 back to such identified portions where such portions may be cleaned at the same or elevated cleaning aggressiveness settings.

Another implementation, display 50 may be further utilized by controller 42 to depict the progress of vehicle 30 in cleaning pool 22. Such a display 50 allows a person to visually determine how much of the pool has been currently cleaned and to estimate the remaining time before the pool cleaning task is completed. In certain circumstances, using display 50, a person may adjust a setting of vehicle 30 to accelerate a rate at which surfaces 26, 20 of pool 22 are cleaned to meet an earlier desired completion time for such pool cleaning.

FIG. 3 schematically illustrates pool cleaning system 220, another example implementation of pool cleaning system 20. Pool cleaning system 220 is similar to pool cleaning system 20 except that pool cleaning system 220 additionally comprises dry station 246, display 50, and remote server 254. Those remaining components of pool cleaning system

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220 which correspond to components of pool cleaning system 20 or pool cleaning system 120 are numbered similarly.

Dry station 246 is similar to dry station 46, described above, except that dry station 246 serves as a local interface for communication with controller 42 across a network 260. In one implementation, network 260 may comprise a local area network. In another implementation, network 260 may comprise a wide area network, such as the Internet. For example, in one implementation, dry station 246 may incorporate a modem. In one implementation, dry station 246 may communicate across a local area network to controller 42. In another implementation, dry station 246 may communicate through a router, across a local area network, to a local modem which communicates across a network 260. The example illustrated, dry station 246 further provides part of vehicle 30 across a wired cable or wired connection. Display 50 is described above with respect to system 120.

Remote server 254 comprises a server remote from dry station 246 which is in communication with dry station 246 across network 260. Remote server 254 includes controller 42. During operation, signals from cameras 32 are transmitted across dry station 246 across network 260 to controller 42 of remote server 254. Based upon such signals from cameras 32, controller 42 generates control signals which are transmitted back across network 260 and through dry station 246 to vehicle 30 to steer vehicle 30.

As shown by FIG. 3, remote server 254 and network 260 may be shared as part of other pool cleaning systems 320, wherein controller 42 generates control signals for steering the pool cleaning vehicle 30 of system 320 based upon signals from cameras 32 transmitted across dry station 246 of system 320. In such an implementation, the cost and complexity of pool cleaning system 220 is reduced since controller 42 is remotely provided at remote server 254 which services multiple pool cleaning systems 220, 320. Upgrades to controller 42 and its software are also more easily achieved for all pool cleaning systems to 20, 320 and their pools 22, 222 being serviced. In one implementation, the supervised cleaning, inspection and possible re-cleaning facilitated by the use of cameras 32 may be provided as part of a subscription to users of vehicle 30. In such an implementation, a pool 22 having security cameras 32 may be upgraded with appropriate software or an appropriate software module added to dry station 246 to make a network connection with controller 42 which directs the security cameras 32 to capture vehicle 30 utilizes such signals for steering vehicle 30.

FIG. 4 schematically illustrates pool cleaning system 420, another particular implementation of pool cleaning system 20. Pool cleaning system 420 is similar to pool cleaning system 120 except that pool cleaning system 420 additionally comprises a portable electronic device 464. Those remaining components of pool cleaning system 420 which correspond to components of pool cleaning system 120 are numbered similarly.

Portable electronic device 464 comprises a portable handheld electronic device in communication with controller 42 and/or dry station 46 across network 260. Examples of such a portable electronic device (PED) 300 include, but are not limited to, a smart phone, a personal data assistant (PDA), laptop, notebook computer, tablet computer (e.g. IPAD) and MP3 player (e.g., IPOD TOUCH). In the example illustrated, PED 464 comprises input 466 and display 468.

Input 466 serves as a user interface for PED 464 by which inputs are made to PED 464. Input 466 facilitates entry of inputs or commands by a person to cause controller 42 to

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generate control signals varying the control of vehicle 30. In one implementation, input 466 comprise a keyboard. In other implementations, input 466 may comprise a touchpad, a stylus, a microphone with associated speech recognition software or programming, a touch screen, buttons, switches and the like. In some implementations, input 466 may comprise a touch screen incorporated as part of display 468.

Display 468 comprises a user interface by which graphical or textual data is presented to a user. Display 468 may present the same or similar information as presented at dry station 246 by display 50 as described above. In one implementation, display 468 comprises a liquid crystal display. In other implementations, display 468 may comprise other types of display technology such as a light emitting diode display, an organic light emitting diode display (OLED), an electronic ink (e-ink) display or other types of display technology in present use or developed in the future. Although system 420 is illustrated as including controller 422 is part of dry station 46, in some implementations, controller 42 may alternatively be located as part of PED 464.

PED 464 enables a person located remote from pool 22 to monitor the progress of the cleaning of pool 22 by vehicle 30 of system 420. PED 464 provides a person with a graphical presentation (described above with respect to display 50) indicating those portions of surfaces 26, 28 of pool 22 that have been completed as well as those portions 26, 20 and that remain to be cleaned. The person may also be provided with a graphical indication of what portions need to be re-cleaned to meet predetermined cleanliness thresholds. In the example illustrated, input 466 enables a person to enter commands or selections which are transmitted across network 260 to controller 42 to adjust operation of vehicle 30. For example, the path or route of vehicle 30 may be changed, the aggressiveness of the cleaning chemicals or mechanical cleaning devices may be adjusted, the speed at which vehicle 30 traverses surfaces 26, 28 may be adjusted. In response to such adjustment signals from PED 464, controller 42 may utilize signals from cameras 32 to adjust the steering of vehicle 30.

FIG. 5 schematically illustrates pool cleaning system 520, another example implementation of pool cleaning system 20. Pool cleaning system 520 is similar to pool cleaning system 420 except that pool cleaning system 520 additionally comprises a remote server 554. Those remaining components of pool cleaning system 520 which correspond to components of pool cleaning system 420 are numbered similarly.

Remote server 554 is similar to remote server 254 described above with respect to system 220. Remote server 554 comprises a server remote from dry station 246 which is in communication with dry station 246 across network 260. Remote server 254 includes controller 42. During operation, signals from cameras 32 are transmitted across dry station 246 across network 260 to controller 42 of remote server 254. Based upon such signals from cameras 32, controller 42 generates control signals which are transmitted back across network 260 and through dry station 246 to vehicle 30 to steer vehicle 30. Controller 42 further relays either the raw signals from camera 32 or image signals generated based upon signals from cameras 32 to PED 464, wherein such images (described above) are presented on display 468. As noted above, PED may further receive commands through input 466, wherein such commands are transmitted to controller 42 which generates control signals that are ultimately transmitted to vehicle 30 for steering vehicle 30.

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As with remote server 254, remote server 554 and network 260 may be shared as part of other pool cleaning systems 320 (shown in FIG. 3), wherein controller 42 generates control signals for steering the pool cleaning vehicle 30 of system 320 based upon signals from cameras 32 transmitted across dry station 246 of system 320. In such implementations, controller 42 of remote server 554 may interact with other PEDs 464. In such an implementation, the cost and complexity of pool cleaning system 220 is reduced since controller 42 is remotely provided at remote server 254 which services multiple pool cleaning systems 220, 320. Upgrades to controller 42 and its software are also more easily achieved for all pool cleaning systems to 20, 320 and their pools 22, 222 being serviced. In one implementation, the supervised cleaning, inspection and possible re-cleaning facilitated by the use of cameras 32 may be provided as part of a subscription to users of vehicle 30. In such an implementation, a pool 22 having security cameras 32 may be upgraded with appropriate software or an appropriate software module added to dry station 246 to make a network connection with controller 42 which directs the security cameras 32 to capture vehicle 30 utilizes such signals for steering vehicle 30. As indicated by broken lines, in other implementations, the controller 42 for generating control signals steering vehicle 30 based upon signals from cameras 32 may alternatively be relocated in PED 464.

FIG. 6 is a flow diagram illustrating an example method 600 that may be carried out by any of systems 120-520. As indicated by step 602, cameras 32 capture images of pool cleaning by vehicle 30. As indicated by step 604, controller 42 obtain such signals from cameras 32 for the surfaces of pool 22 that have been cleaned. As indicated by step 606, controller 42 uses information gathered from the signals from cameras 32 to identify those portions of surfaces 26, 28 not satisfactorily cleaned not satisfying a predefined cleanliness characteristic or measurement threshold. One example of a cleanliness characteristic measurement a threshold may be how well the color of a surface matches a predetermined desirable color for the pool surface (such as original color of the tile or surface). A surface that has been missed entirely by vehicle 30 during a pool cleaning session may be automatically deemed to not satisfy a predetermined cleanliness characteristic.

As indicated by step 608, based upon such determinations, controller 42 generates control signals resulting in the presentation of a graphical depiction of those portions of pool 22 that has not been satisfactorily cleaned. Such graphical representations or depictions may be presented on display 50 or display 468. FIGS. 7 and 8 illustrate examples of graphical depictions that may be presented.

FIG. 7 illustrates display 468 presenting graphical depiction 620. Graphical depiction 620 comprises a first graphic 622 having a first portion 624 representing sides or walls 28 of pool 22 and a second portion 626 representing the floor 26 of pool 22. Graphical depiction 620 further comprises a moving icon 628 representing the current positioning of vehicle 30. In one implementation, the path of vehicle 30 may additionally be depicted by icon 628 shown in broken lines. As shown by FIG. 7, those portions 632 of surfaces 26, 28 of pool 22 (shown in FIG. 1) over which of vehicle 30 has moved are identified by graphical depiction 620 either by color, markings or other various distinctive attributes. Likewise, those portions 634 of surfaces 26, 28 of pool 22 that have not been covered by vehicle 30 are identified by a distinct color col marking or distinctive attribute of depiction 620. As a result, a person may view the current position of vehicle 30, the extent to which pool 22 has been cleaned

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or covered by vehicle 30 and the extent of pool 22 that remains to be cleaned. In the example illustrated, depiction 620 further identifies those portions 638 of surfaces 26, 28 that have been cleaned, but which have not been cleaned to a satisfactory degree or extent. In one implementation, portions 638 may be identified by colors, brightness, markings or other visually distinctive attributes that are visually distinct from both portions 632 and portions 634. In other implementations, portions 638 may have the same characteristic of portions 634. In yet other implementations, different portions 638 may have different visual attributes depending upon a degree to which such clean portions have failed to satisfy the predefined cleanliness characteristic threshold. In some implementations, different portions 638 may have different visual attributes depending upon different cleaning strategies that may be recommended for the different portions 638. For example, controller 42 may determine and recommend a first cleaning strategy (a first chemical solution jetted at a first rate and scrubbed at a first rate) with respect to a first portion 638 and may recommend a second different cleaning strategy (a second chemical solution jetted at a second rate is about a second rate) with respect to a second portion 638, wherein the different cleaning strategies are represented by different visual attributes presented in depiction 620.

FIG. 8 illustrates display 468 presenting a graphical depiction 720. Graphical depiction 720 comprises a first graphic 622 having a first portion 624 representing sides or walls 22 of pool 22 and a second portion 626 representing the floor 26 of pool 22 (shown in FIG. 1). Graphical depiction 720 is similar to graphical depiction 620 except that graphical depiction 720 omits icon 628 presenting vehicle 30. Like depiction 620, depiction 720 graphically depicts those portions 632 of surfaces 26, 28 over which vehicle 30 has traveled while in a cleaning mode. Depiction 720 also visually depicts those portions 634 that have not been covered by vehicle 30 in the cleaning mode and those portions 638 over which vehicle 30 has traveled while in the cleaning mode, but which have not been cleaned to a satisfactory degree. As illustrated in FIG. 8, different portions 638 may be visibly distinguished from one another through color, text or markings indicating either differences in the cleanliness of such portions 638 or indicating different recommended cleaning strategies or approaches that may be selected by a person using input 466 when vehicle 30 is steered back to such portions 638 for re-cleaning using signals from camera 32.

As indicated by step 610 of FIG. 6, controller 42 generates control signals steering vehicle 30 to re-clean portions of pool 22, such as portions 638. Such steering may be facilitated by using signals from cameras 32. As noted above, in some implementations, a person may be allowed Choose a cleaning approach for a particular portion 638 using input 466. The selection may be facilitated by visual inspection of the different visual attributes for the particular portion 638 provided by depiction 720 (or depiction 620). In some implementations, input 466 may additionally be utilized by a person to prioritize an order in which portions 638 are re-cleaned.

FIG. 9 illustrates pool cleaning system 820, an example implementation of pool cleaning system 20. Pool cleaning system 820 is similar to pool cleaning system 520 except the pool cleaning system 820 located controller 42 in dry station 246 and includes pool cleaning vehicle 830, a specific example of vehicle 30. As shown by FIG. 9, in addition to transmitting control signals generated by controller 42 to vehicle 830, dry station 246 further transmits power from

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power source 831 through a power line or power cable 833 to vehicle 830. In the example illustrated, data communication and communication of control signals, also occurs across wired connections within or alongside the same line 833. In the example illustrated, remote server 554 serves as a communication link by which upgrades to controller 42 may be implemented across a wide number of pool cleaning systems and by which information from controller 42 is conveyed to one or more portable electronic devices 464 across network 260.

Vehicle 830 comprises a robotic or automated pool cleaning device. Vehicle 830 comprises a self-contained onboard filtration system with drive and pump motors. Vehicle 830 utilizes an internal microprocessor guided drive motor to systematically clean surfaces of pool 22. As shown by FIGS. 9 and 10, vehicle 830 utilizes a toothed track drive 900 provide traction and propulsion for vehicle 30. Vehicle 830 comprises rotating brushes 902 to loosen waterline buildup and breakdown large debris while power washing jets 904 flush out dirt from pores, seems in corners where brushes 902 may not be able to reach. The loosened dirt and debris is vacuumed through off-center vacuum ports 906 which passes the vacuumed debris through internally house filter bag. In the example illustrated, vehicle 830 further comprises rollers 908 which inhibit vehicle 830 from becoming impeded or stuck on raised drains or pop-up heads. Although illustrated as being employed with system 820, vehicle 830 may also be utilized with any of systems 20, 120, 220, 320 and 420. In other implementations, other robotic or automated pool cleaning vehicles may be utilized.

Although the present disclosure has been described with reference to example embodiments, workers skilled in the art will recognize that changes may be made in form and detail without departing from the spirit and scope of the claimed subject matter. For example, although different example embodiments may have been described as including one or more features providing one or in ore benefits, it is contemplated that the described features may be interchanged with one another or alternatively be combined with one another in the described example embodiments or in other alternative embodiments. Because the technology of the present disclosure is relatively complex, not all changes in the technology are foreseeable. The present disclosure described with reference to the example embodiments and set forth in the following claims is manifestly intended to be as broad as possible. For example, unless specifically otherwise noted, the claims reciting a single particular element also encompass a plurality of such particular elements.

What is claimed is:

1. A self-propelled pool cleaning system for cleaning debris from a submerged surface of a swimming pool, comprising:

- a. a vehicle body;
- b. means for moving the vehicle body within the swimming pool;
- c. a filter configured to retain debris collected from the submerged surface;
- d. at least one camera for capturing an image of at least a first object within the swimming pool; and
- e. a controller (i) in electronic communication with the at least one camera and (ii) configured to generate, in response to the captured image, at least one control signal to cause movement of the body within the swimming pool to, or away from, the first object.

2. A pool system comprising:

- at least one piece of equipment for a swimming pool or spa;

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one or more cameras configured to capture video or images of at least a portion of a location including the swimming pool or spa; and
a controller in communication with the at least one piece of equipment and the one or more cameras, the controller configured to receive visual data from the one or more cameras and determine a control action for the at least one piece of equipment based on the received visual data.

3. The pool system of claim 2, wherein the at least one piece of equipment comprises a cleaning device with one or more propulsion mechanisms, the cleaning device configured to travel adjacent to submerged or water-containing surfaces of the swimming pool or spa and to perform a cleaning operation.

4. The pool system of claim 2, wherein the one or more cameras are mounted external to the swimming pool or spa.

5. The pool system of claim 2, wherein the one or more cameras are mounted on the at least one piece of equipment.

6. The pool system of claim 2, wherein the one or more cameras are submergible or submerged within the swimming pool or spa.

7. The pool system of claim 2, wherein the controller is configured to detect a characteristic of the location based on the visual data and control the piece of equipment based on the detected characteristic.

8. The pool system of claim 7, wherein the characteristic comprises a cleanliness of a surface of the swimming pool, and wherein the controller is configured to control the piece of equipment based on the detected cleanliness being outside of a threshold.

9. The pool system of claim 2, wherein the controller is configured to communicate with the at least one piece of equipment and the one or more cameras via a wireless connection.

10. The pool system of claim 2, wherein the controller is further configured to present a graphical depiction on a remote device based on the received visual data as the control action.

11. The pool system of claim 2, wherein the controller is remote from the camera.

12. A method for monitoring a pool system, the method comprising:
receiving images of at least a portion of a location including a swimming pool or spa from one or more cameras;

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determining a target area and detecting a characteristic of the target area based on the images; and
generating a control response based on the detected characteristic of the target area.

13. The method of claim 12, wherein the target area comprises a portion of a surface of the swimming pool or spa, and wherein the characteristic comprises a cleanliness characteristic of the portion of the surface of the swimming pool or spa.

14. The method of claim 12, wherein generating the control response comprises controlling an operation of a piece of equipment of the swimming pool or spa.

15. The method of claim 12, wherein generating the control response comprises generating an alert on a remote device.

16. The method of claim 12, wherein generating the control response comprises wirelessly communicating with a piece of equipment for the swimming pool or spa or a remote device.

17. The method of claim 12, wherein generating the control response comprises prompting a user on a remote device, and wherein the method further comprises receiving a control input from the user on the remote device for controlling a piece of equipment of the swimming pool or spa.

18. The method of claim 17, wherein prompting the user comprises providing recommended cleaning strategies for a cleaning device based on the detected characteristic of the target area.

19. The method of claim 12, wherein generating the control response comprises controlling operation of a cleaning device configured to travel adjacent to submerged or water-containing surfaces of the swimming pool or spa and to perform a cleaning operation, wherein controlling operation of the cleaning device comprises one or more of controlling a path or route of the cleaning device, an aggressiveness of cleaning chemicals deployed, an aggressiveness of mechanical cleaning, or a speed of the cleaning device.

20. The method of claim 19, wherein the characteristic of the target area is a presence of a person at the swimming pool or spa, and wherein generating the control response is based on the detected presence of the person satisfying a predefined characteristic.

* * * * *

EXHIBIT 4



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Re: Beatbot's Infringing Pool Cleaners Containing Camera Technology

To Whom It May Concern:

I represent Zodiac Pool Systems LLC, the owner of enclosed U.S. Patent Nos. 11,880,207; 11,262,766; 11,003,191; 10,739,785; 10,338,599; 9,995,051; 9,388,595; 11,828,082; and 11,519,732, attached as Exs. A–I, respectively.

It has come to our attention that Beatbot Technology (USA) Co., LTD, Xingmai Innovation Technology (Hong Kong) Limited, and their affiliates (collectively, "Beatbot") has been promoting and offering for sale one or more pool cleaners that infringe at least some of the above listed patents, including but not limited to the Beatbot Aquasense 2 Ultra Robotic Pool Cleaner pictured below:



<https://beatbot.com/products/aquasense-2-ultra>.

Beatbot Technology (USA) Co., Ltd.
July 17, 2025
Page 2

As shown in the exemplary claim chart in Exhibit J to this letter, the Beatbot Aquasense 2 Ultra product contains all of the elements of at least claim 1 of U.S. Patent No. 11,880,207, which recites as follows:

1. A self-propelled pool cleaning system for cleaning debris from a submerged surface of a swimming pool, comprising:
 - a. a vehicle body;
 - b. means for moving the vehicle body within the swimming pool;
 - c. a filter configured to retain debris collected from the submerged surface;
 - d. at least one camera for capturing an image of at least a first object within the swimming pool; and
 - e. a controller (i) in electronic communication with the at least one camera and (ii) configured to generate, in response to the captured image, at least one control signal to cause movement of the body within the swimming pool to, or away from, the first object.

Additionally, this product contains all of the elements of at least one claim in each of U.S. Patent Nos. 11,262,766 and 11,003,191, and possibly others.

Therefore, Beatbot's activities with respect to the above-referenced product and any products substantially similar to it in the United States, including but not limited to the manufacture, use, sale, offer for sale, or importation, infringes U.S. Patent Nos. 11,880,207; 11,262,766; and 11,003,191. Beatbot must cease this infringing conduct immediately.

Zodiac would also like to make Beatbot aware of the attached U.S. Patent Nos. 10,739,785; 10,338,599; 9,995,051; 9,388,595; 11,828,082; and 11,519,732, which also relate to pool cleaners and pool cleaning systems that utilize cameras or other sensing technologies. Zodiac reserves the right to assert infringement of any or all of these additional patents should further investigation reveal infringement.

Zodiac does not wish to engage in unneeded litigation. However, if this infringement is not ceased, Zodiac will have no choice but to enforce its intellectual property rights. As such, Zodiac expects written confirmation that Beatbot and any entity related thereto will contact me to discuss this matter immediately, including with respect to agreeing to cease its infringing activities. If Zodiac does not receive such confirmation within ten business days of confirmed delivery to the first of the above addresses, Zodiac will understand Beatbot's position is that it does not intend to address this issue, and Zodiac reserves all rights to take all actions available to it, including but not limited to enforcement of any of the patents mentioned herein.

Best regards,



Steven D. Moore

cc: Christopher S. Leah (cleah@ktslaw.com)

EXHIBIT A

(12) United States Patent
Durvasula et al.**(10) Patent No.: US 11,880,207 B2****(45) Date of Patent: *Jan. 23, 2024****(54) POOL CLEANING SYSTEM AND METHOD TO AUTOMATICALLY CLEAN SURFACES OF A POOL USING IMAGES FROM A CAMERA****(58) Field of Classification Search**CPC .. G05D 1/0246; G05D 1/0016; G05D 1/0033;
G05D 1/0038; G05D 2201/0203;
(Continued)**(71) Applicant: ZODIAC POOL SYSTEMS LLC,**
Carlsbad, CA (US)**(56) References Cited****U.S. PATENT DOCUMENTS****(72) Inventors: Kameshwar Durvasula,** Garfield, NJ
(US); **William Londono Correa,**
Bloomfield, NJ (US)5,205,174 A 4/1993 Silverman et al.
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(Continued)**(73) Assignee: ZODIAC POOL SYSTEMS LLC,**
Carlsbad, CA (US)**FOREIGN PATENT DOCUMENTS****(*) Notice:** Subject to any disclaimer, the term of this
patent is extended or adjusted under 35
U.S.C. 154(b) by 0 days.CN 101139007 3/2008
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This patent is subject to a terminal disclaimer.

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Jun. 8, 2016, 2 pages.**(21) Appl. No.: 17/572,388**

(Continued)

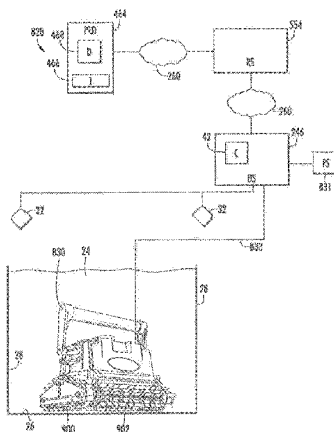
(22) Filed: Jan. 10, 2022*Primary Examiner* — Allen C Wong**(65) Prior Publication Data**

US 2022/0129005 A1 Apr. 28, 2022

(74) Attorney, Agent, or Firm — Kilpatrick Townsend &
Stockton LLP**Related U.S. Application Data****(63)** Continuation of application No. 17/143,624, filed on
Jan. 7, 2021, now Pat. No. 11,262,766, which is a
(Continued)**(51) Int. Cl.**
G05D 1/02 (2020.01)
H04N 7/18 (2006.01)
(Continued)**(52) U.S. Cl.**
CPC **G05D 1/0246** (2013.01); **E04H 4/1654**
(2013.01); **G05D 1/0016** (2013.01);
(Continued)**(57) ABSTRACT**

A pool cleaning system for cleaning debris from a submerged surface of a swimming pool includes a self-propelled pool cleaner having rotatably-mounted supports for supporting and guiding the cleaner on the pool surface; an electric motor for enabling the rotation of the rotatably-mounted supports on the pool surface; at least one camera to capture imagery of the pool surface; a controller, in electronic communication with the at least one camera, to determine a cleanliness characteristic of the pool surface on which the cleaner has passed based on the camera imagery and generate a control signal to direct movement of the cleaner based on the cleanliness characteristic of the pool surface, and a portable electronic device configured to present a graphic on a display, the graphic depicting the

(Continued)



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submerged surface of the pool and those portions of the surface that remain uncleaned as the cleaner traverses the pool surface.

20 Claims, 4 Drawing Sheets

Related U.S. Application Data

continuation of application No. 16/919,750, filed on Jul. 2, 2020, now Pat. No. 11,003,191, which is a continuation of application No. 16/416,840, filed on May 20, 2019, now Pat. No. 10,739,785, which is a continuation of application No. 15/973,983, filed on May 8, 2018, now Pat. No. 10,338,599, which is a continuation of application No. 15/207,065, filed on Jul. 11, 2016, now Pat. No. 9,995,051, which is a continuation of application No. 13/545,918, filed on Jul. 10, 2012, now Pat. No. 9,388,595.

- (51) **Int. Cl.**
H04N 23/66 (2023.01)
E04H 4/16 (2006.01)
G05D 1/00 (2006.01)
H04N 23/50 (2023.01)
G06T 7/90 (2017.01)
G06T 7/00 (2017.01)
- (52) **U.S. Cl.**
 CPC *G05D 1/0033* (2013.01); *G05D 1/0038* (2013.01); *H04N 7/18* (2013.01); *H04N 23/66* (2023.01); *G05D 2201/0203* (2013.01); *G06T 7/001* (2013.01); *G06T 7/90* (2017.01); *G06T 2207/10024* (2013.01); *H04N 23/555* (2023.01)
- (58) **Field of Classification Search**
 CPC H04N 23/66; H04N 23/555; H04N 7/18; E04H 4/1654; G06T 7/90; G06T 7/001; G06T 2207/10024
 USPC 348/114
 See application file for complete search history.

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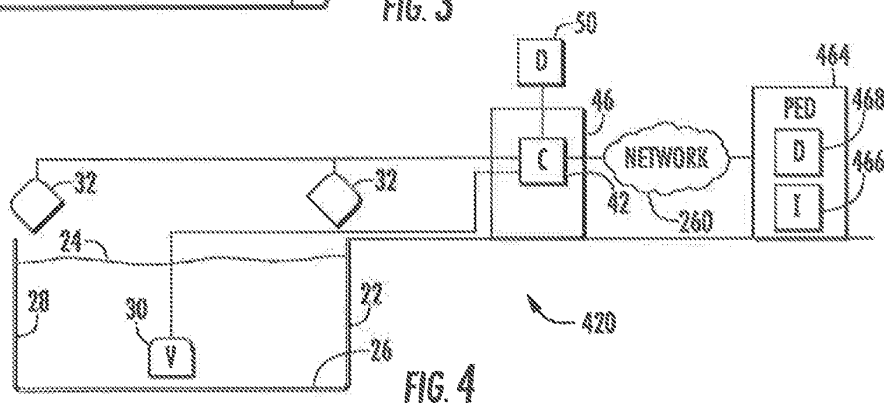
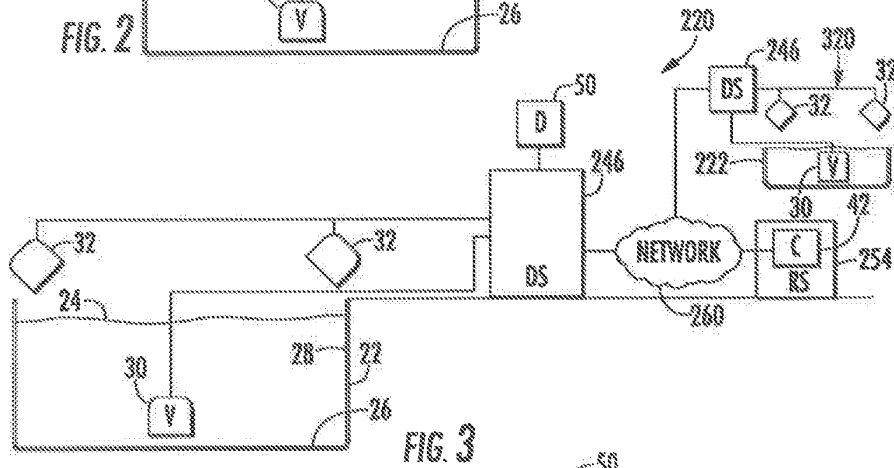
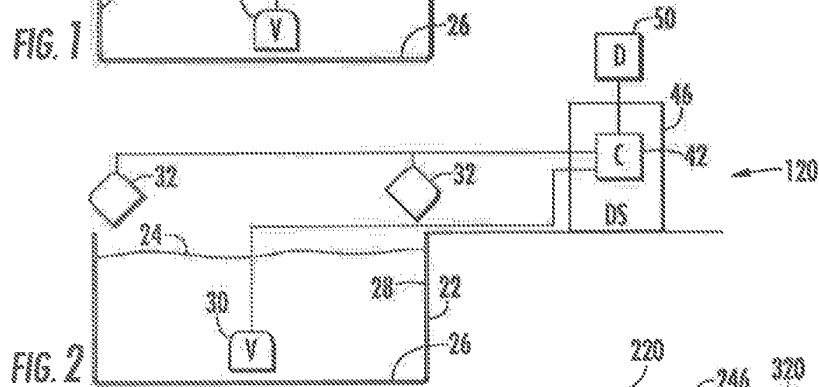
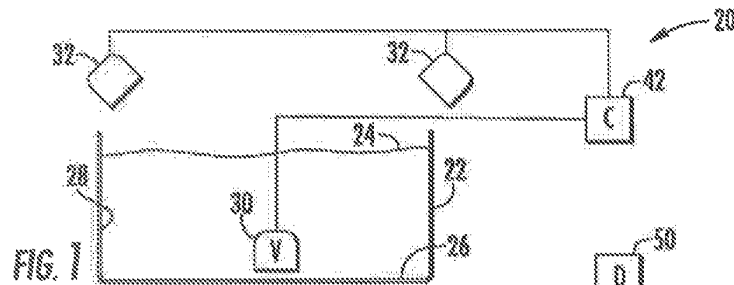
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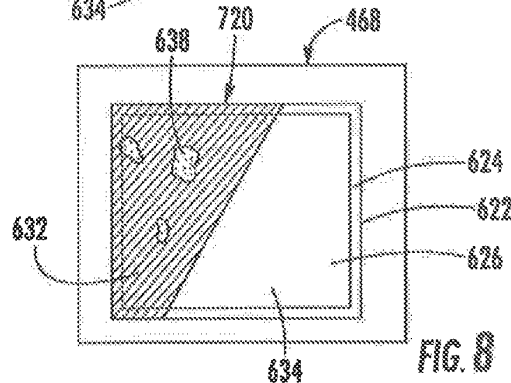
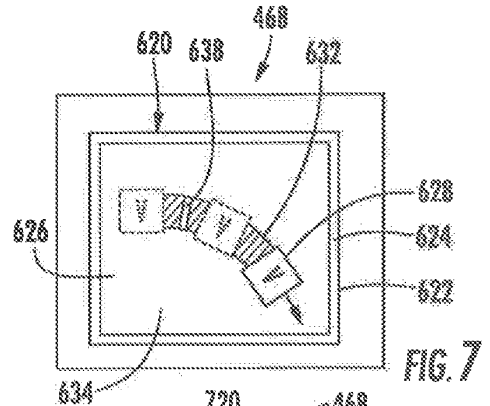
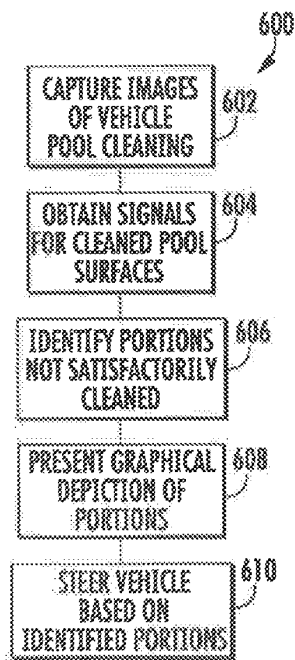
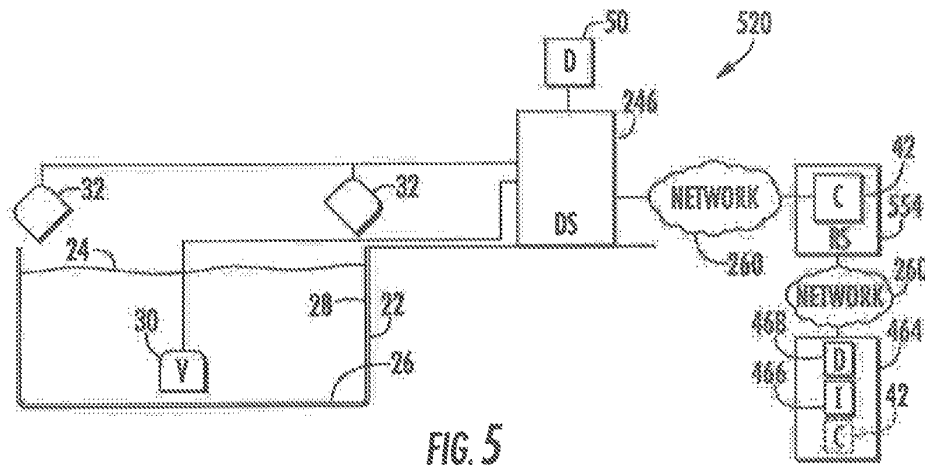


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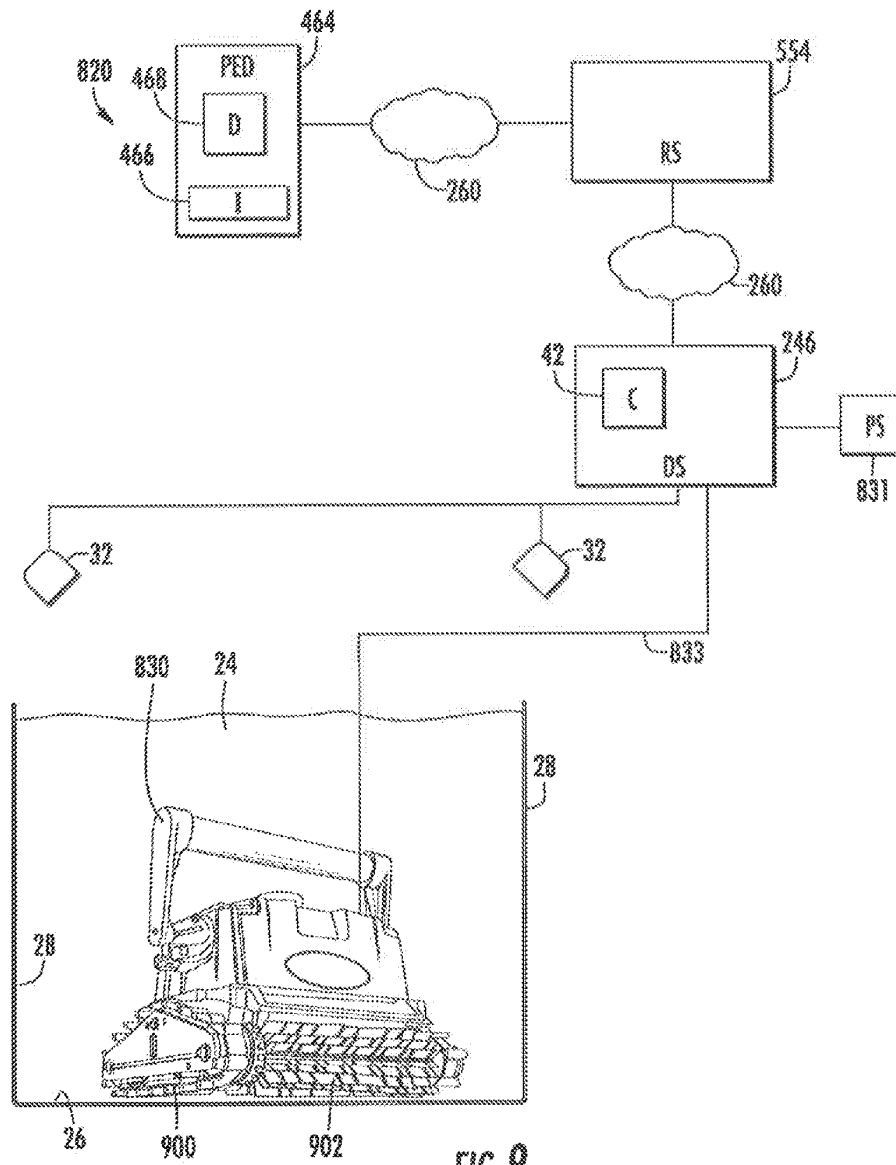


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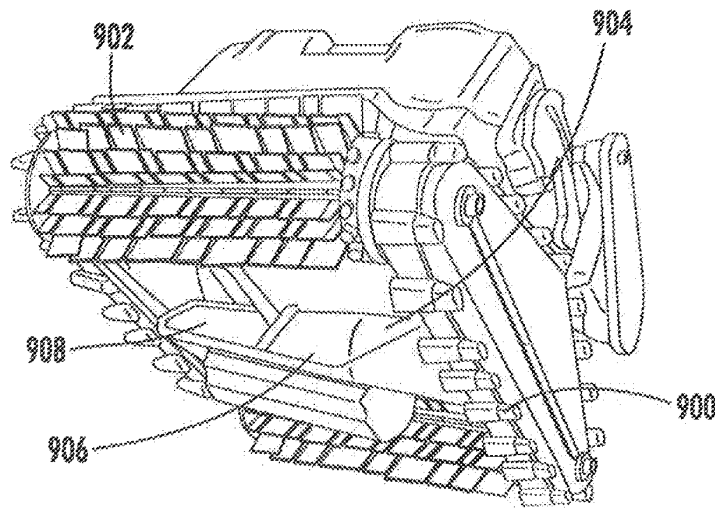


FIG. 10

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**POOL CLEANING SYSTEM AND METHOD
TO AUTOMATICALLY CLEAN SURFACES
OF A POOL USING IMAGES FROM A
CAMERA**

**CROSS-REFERENCE TO RELATED
APPLICATION**

This application is a continuation of allowed U.S. patent application Ser. No. 17/143,624, filed Jan. 7, 2021, which is a continuation of U.S. patent application Ser. No. 16/919,750, filed Jul. 2, 2020 (now U.S. Pat. No. 11,003,191), which is a continuation of U.S. patent application Ser. No. 16/416,840, filed May 20, 2019 (now U.S. Pat. No. 10,739,785), which is a continuation of U.S. patent application Ser. No. 15/973,983, filed May 8, 2018 (now U.S. Pat. No. 10,338,599), which is a continuation of U.S. patent application Ser. No. 15/207,065, filed Jul. 11, 2016 (now U.S. Pat. No. 9,995,051), which is a continuation of U.S. patent application Ser. No. 13/545,918, filed Jul. 10, 2012 (now U.S. Pat. No. 9,388,595), the contents of all of which are incorporated herein by reference in their entireties.

BACKGROUND

Manually cleaning the floor and sides of a swimming pool may be a tedious and time-consuming task. As a result, automated robotic pool cleaners have been developed. However, controlling and monitoring such automated robotic pool cleaners to insure that all portions of the pool surfaces are satisfactorily cleaned remains a challenge.

SUMMARY OF THE INVENTION

The disadvantages heretofore associated with the prior art are overcome by the present invention of a pool cleaning system for cleaning debris from a submerged surface of a swimming pool comprising: a self-propelled pool cleaner having rotatably-mounted supports for supporting and guiding the cleaner on the pool surface; a filter configured to retain the debris collected from the submerged surface of the swimming pool; an electric motor for enabling the rotation of the rotatably-mounted supports on the pool surface; at least one camera to capture imagery of the pool surface; a controller, in electronic communication with the at least one camera, to determine a cleanliness characteristic of the pool surface on which the cleaner has passed based on the camera imagery and generate a control signal to direct movement of the cleaner based on the cleanliness characteristic of the pool surface; and a portable electronic device is configured to present a graphic on a display, the graphic depicting the submerged surface of the pool and those portions of the surface that remain uncleaned as the cleaner traverses the pool surface.

In one aspect, the at least one camera is carried by the cleaner. In another aspect, the controller is carried by the cleaner. In still another aspect, the electric motor is mechanically connected to at least one of the rotatably-mounted supports.

In yet another aspect, the controller is operable to execute one or more cleaning programs for cleaning the submerged surfaces of the pool. In one aspect, the control signal causes the cleaner to drive in a direction to clean a portion of the pool surface based on the cleanliness characteristic of the pool surface. Alternatively, the control signal causes the cleaner to steer in a direction to clean a portion of the pool surface based on the cleanliness characteristic of the pool

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surface. In another aspect, the control signal causes the cleaner to drive in a direction to re-clean a portion of the pool surface over which the cleaner has passed. Alternatively, the control signal causes the cleaner to steer in a direction to re-clean a portion of the pool surface over which the cleaner has passed.

In one aspect, the captured imagery from the at least one camera is digitally processed by the controller to determine the cleanliness characteristic of the pool surface. Alternatively, the captured imagery from the at least one camera is digitally processed by a remote processor to determine the cleanliness characteristic of the pool surface.

In another aspect, the system further comprises a dry station located remotely from the cleaner and in communication with the cleaner, wherein the dry station includes the controller. Alternatively, the system further comprises a dry station located remotely from the cleaner and in communication with the cleaner, wherein the controller is located remotely from the cleaner and the dry station. In still another aspect, the controller controls electric power provided to the electric motor.

In one aspect, the control signal causes the cleaner to move in a direction of a portion of the pool surface to be cleaned based solely upon signals received from the camera.

In another aspect, the control signal causes the cleaner to drive in a direction to clean a portion of the pool surface based on the cleanliness characteristic of the pool surface. Alternatively, the control signal causes the cleaner to steer in a direction to clean a portion of the pool surface based on the cleanliness characteristic of the pool surface. In yet another aspect, the control signal causes the cleaner to drive in a direction to re-clean a portion of the pool surface over which the cleaner has passed. Alternatively, the control signal causes the cleaner to steer in a direction to re-clean a portion of the pool surface over which the cleaner has passed.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a schematic illustration of an example pool cleaning system.

FIG. 2 is a schematic illustration of an implementation of the pool cleaning system of FIG. 1.

FIG. 3 is a schematic illustration of an implementation of the pool cleaning system of FIG. 1.

FIG. 4 is a schematic illustration of an implementation of the pool cleaning system of FIG. 1.

FIG. 5 is a schematic illustration of an implementation of the pool cleaning system of FIG. 1.

FIG. 6 is a flow diagram of an example method that may be carried out with the pool cleaning system of FIG. 2-5.

FIG. 7 is a plan view of an example display with an example graphical depiction.

FIG. 8 is a plan view of another example display with an example graphical depiction.

FIG. 9 is a schematic illustration of an implementation of the pool cleaning system of FIG. 1 with an example pool cleaning vehicle.

FIG. 10 is a bottom perspective view of the example pool cleaning vehicle of the system of FIG. 9.

**DETAILED DESCRIPTION OF THE EXAMPLE
EMBODIMENTS**

FIG. 1 schematically illustrates an example pool cleaning system 20. As schematically shown by FIG. 1, pool cleaning system 20 is adapted to clean submerged surfaces of a pool 22 containing a liquid 24. In particular, pool cleaning system

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20 is adapted to clean at least a bottom or floor surface 26 of the pool 22 and possibly to additionally clean surfaces 28 of pool 22. As will be described hereafter, pool cleaning system facilitates the control and monitoring of a robotic pool cleaner to better assure that all portions of pool 22 are satisfactorily cleaned.

Pool cleaning system 20 comprises vehicle 30, cameras 32 and controller 42. Vehicle 30 comprises an automated powered device configured to travel adjacent to submerged or water containing surfaces of pool 20 (such as floor 26 and/or side surfaces 28) while cleaning such surfaces. In one implementation, vehicle 30 may include vacuum or suction devices, a liquid circulation system and a filter to draw debris, such as bacterial growth or plant growth, from such pool surfaces, wherein the drawn liquid containing such residue or foreign matter is filtered to collect the debris. In other implementations, vehicle 30 may not collect such debris, wherein vehicle 30 merely loosens such debris on the pool surfaces such that the loosened or separated debris may be subsequently removed using the existing liquid filtering system of pool 22.

To assist in the loosening of debris, in one implementation, vehicle 30 may additionally include a chemical dispenser to closely apply pool cleaning chemicals to the pool surfaces as the vehicle 30 traverses such surfaces. In one implementation, vehicle 30 may additionally or alternatively include one or more scrubbing members, such as active (driven) or passive (undriven or idling) brushes, to assist in the removal of residue or foreign matter from such pool surfaces. In yet another implementation, vehicle 30 may additionally or alternatively include liquid jets to assist in the loosening of debris.

To move along the submerged surfaces of pool 22, vehicle 30 includes one or more propulsion mechanisms. In one implementation, vehicle 30 is propelled along the submerged pool surfaces using wheels, rollers, tracks or other surface contacting members powered by a motor and the like. Such wheels, rollers or tracks may themselves include the scrubbing members used to clean the surfaces. In one implementation vehicle 30 may also alternatively be propelled by means of the vacuum or liquid jet. The vacuum or liquid jets used for such propulsion nozzle facilitate loosening of debris for collection by vehicle 30. In other implementations, vehicle 30 may include other propulsion mechanisms.

Cameras 32 comprise devices configured to capture video or time lapse images of pool 22. In the example illustrated, cameras 32 are mounted on structures external to pool 22. In other words, cameras 32 are not submerged. In other implementations, cameras 32 may alternatively be mounted to vehicle 30. In the example illustrated, cameras 32 capture movement of vehicle 30 while vehicle 30 is submerged within pool 22. In other implementations, cameras 32 merely capture images of submerged surfaces 26, 28 of pool 22.

In the example illustrated, cameras 32 comprise cameras serving as part of a home or pool security system, wherein such cameras detect the presence of a person at pool 22 satisfying a predefined characteristic and wherein an alert is output upon the person's detected presence. For example, in one implementation, cameras 32 are utilized as part of a security system that detects when a person below a predefined age, such as a child, is present at pool 22 without a detected presence of a recognized adult. In another implementation, cameras 32 may detect the presence of an unauthorized person or intruder at pool 22. Identification of the person may be achieved by an off-site human or computer-

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ized monitoring system, wherein signals from cameras 32 are transmitted across a wide area network or may be achieved with software of controller 42 which includes facial recognition or other identification programming.

Because pool cleaning system 20 utilizes pre-existing cameras 32 provided as part of a security system or shares the use of cameras 32 with such a home or pool security system, pool cleaning system 20 is easier to set up, less complex and less expensive. In other implementations, pool cleaning system 20 may utilize dedicated cameras 22 independent of any cameras associated with a home, facility or pool security system. In such an alternative system, cameras 32 may be more precisely focused upon pool 22 and surfaces 26, 28 while also including appropriate lenses or modifications to account for glare, refraction and the like to better facilitate the capture of surfaces and vehicle 30 which are submerged.

Controller 42 comprises one or more processing units in communication with vehicle 30 and cameras 32. For purposes of this application, the term "processing unit" shall mean a presently developed or future developed processing unit that executes sequences of instructions contained in a memory. Execution of the sequences of instructions causes the processing unit to perform steps such as generating control signals. The instructions may be loaded in a random access memory (RAM) for execution by the processing unit from a read only memory (ROM), a mass storage device, or some other persistent storage. In other embodiments, hard wired circuitry may be used in place of or in combination with software instructions to implement the functions described. For example, controller 42 may be embodied as part of one or more application-specific integrated circuits (ASICs). Unless otherwise specifically noted, the controller is not limited to any specific combination of hardware circuitry and software, nor to any particular source for the instructions executed by the processing unit.

In one implementation, controller 42 communicates with vehicle 30 and cameras 32 entirely across a wired connection. In another implementation, controller 42 communicates with vehicle 30 and cameras 32 across a wireless connection, such as across a local area network (LAN) or a wide area network (WAN) such as the Internet. One of limitation, controller 42 may communicate with vehicle 30 and cameras 32 using a combination of both wired and wireless communication connections.

Controller 42 is configured to generate control signals for steering vehicle 30 based upon signals received from cameras 32. In one implementation, controller 42 provides the sole steering directions for vehicle 30 using signals from cameras 32. Because vehicle 30 is precisely steered under the control of controller 42, rather than traveling in a random manner, entire summer surfaces of pool 22 may be more quickly and efficiently covered and cleaned. Because controller 42 provides the only steering instructions for vehicle 30 and utilizes signals from cameras 32, complex steering algorithms or codes in either vehicle 30 or controller 42 may be omitted to reduce complexity and cost of system 20.

In another implementation, vehicle 30 may cover or travel across surfaces of pool 22 in either a random fashion or according to an automated pool coverage algorithm or pool coverage pattern stored in a memory associated with vehicle 30 or controller 42. In such an implementation, controller 42 utilizes signals from cameras 32 to verify that all of the surfaces of 22 have been cleaned, that no spots have been missed. Upon identifying a missed spot, controller 42 utilizes signals from camera 32 to steer vehicle 32 over such missed portions of surfaces 26, 28. According to one

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example, controller 42 not only uses signals from camera 32 to determine whether any portions of surfaces 26, 28 have been missed entirely, but to also determine whether any portions of surfaces 26, 28 have been cleaned, but not to a satisfactory degree or extent. In such circumstances, controller 42 uses signals from cameras 32 to steer vehicle 34 such areas to re-clean such portions until such portions have been satisfactorily cleaned such that the portions have a cleanliness characteristic satisfying a predefined threshold.

FIG. 2 schematically illustrates pool cleaning system 120, the particular example of pool cleaning system 20 described above. Pool cleaning system 120 is similar to pool cleaning system 20 except that pool cleaning system 120 additionally comprises dry station 46 and display 50. Those remaining components of pool cleaning system 120 which correspond to components of pool cleaning system 20 are numbered similarly.

Dry station 46 comprises a station in communication with vehicle 30 and cameras 32 outside of pool 22. Dry station 46 incorporates controller 42. In one implementation, dry station 46 communicates with vehicle 30 in a wired fashion. In such an implementation, dry station 46 further provides electrical power to vehicle 30 in a wired fashion. Dry station 46 communicates with cameras 32 and either a wired or wireless fashion.

Display 50 comprises a device to present a graphical images and text on a display screen. In one implementation, display 58 may be incorporated as part of dry station 46. In another implementation, display 50 may be provided on a portable electronic device, a computer, a television and the like. Display 50 is utilized by pool cleaning system 120 to present information regarding the cleaning of pool 22 to facilitate control of vehicle 30 by controller 42. In one implementation, display 50 is utilized by pool cleaning system 120 and a controller 42 to present a graphical depiction of those portions of surfaces 26, 28 of pool 22 have not been satisfactorily cleaned so as to satisfy a predefined cleanliness characteristic threshold. Such portions may comprise portions that have been completely missed by vehicle 30 as well as those portions that have been covered by vehicle 30 but have not been satisfactorily cleaned with the given number of passes of vehicle 30 or the existing cleaning settings of vehicle 30. The graphical depiction presented on display 50 enables a person view the quality of the prior cleaning session and to input commands causing controller 42 to generate control signals using signals from camera 32 to steer vehicle 30 back to such identified portions where such portions may be cleaned at the same or elevated cleaning aggressiveness settings.

Another implementation, display 50 may be further utilized by controller 42 to depict the progress of vehicle 30 in cleaning pool 22. Such a display 50 allows a person to visually determine how much of the pool has been currently cleaned and to estimate the remaining time before the pool cleaning task is completed. In certain circumstances, using display 50, a person may adjust a setting of vehicle 30 to accelerate a rate at which surfaces 26, 20 of pool 22 are cleaned to meet an earlier desired completion time for such pool cleaning.

FIG. 3 schematically illustrates pool cleaning system 220, another example implementation of pool cleaning system 20. Pool cleaning system 220 is similar to pool cleaning system 20 except that pool cleaning system 220 additionally comprises dry station 246, display 50, and remote server 254. Those remaining components of pool cleaning system

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220 which correspond to components of pool cleaning system 20 or pool cleaning system 120 are numbered similarly.

Dry station 246 is similar to dry station 46, described above, except that dry station 246 serves as a local interface for communication with controller 42 across a network 260. In one implementation, network 260 may comprise a local area network. In another implementation, network 260 may comprise a wide area network, such as the Internet. For example, in one implementation, dry station 246 may incorporate a modem. In one implementation, dry station 246 may communicate across a local area network to controller 42. In another implementation, dry station 246 may communicate through a router, across a local area network, to a local modem which communicates across a network 260. The example illustrated, dry station 246 further provides part of vehicle 30 across a wired cable or wired connection. Display 50 is described above with respect to system 120.

Remote server 254 comprises a server remote from dry station 246 which is in communication with dry station 246 across network 260. Remote server 254 includes controller 42. During operation, signals from cameras 32 are transmitted across dry station 246 across network 260 to controller 42 of remote server 254. Based upon such signals from cameras 32, controller 42 generates control signals which are transmitted back across network 260 and through dry station 246 to vehicle 30 to steer vehicle 30.

As shown by FIG. 3, remote server 254 and network 260 may be shared as part of other pool cleaning systems 320, wherein controller 42 generates control signals for steering the pool cleaning vehicle 30 of system 320 based upon signals from cameras 32 transmitted across dry station 246 of system 320. In such an implementation, the cost and complexity of pool cleaning system 220 is reduced since controller 42 is remotely provided at remote server 254 which services multiple pool cleaning systems 220, 320. Upgrades to controller 42 and its software are also more easily achieved for all pool cleaning systems to 20, 320 and their pools 22, 222 being serviced. In one implementation, the supervised cleaning, inspection and possible re-cleaning facilitated by the use of cameras 32 may be provided as part of a subscription to users of vehicle 30. In such an implementation, a pool 22 having security cameras 32 may be upgraded with appropriate software or an appropriate software module added to dry station 246 to make a network connection with controller 42 which directs the security cameras 32 to capture vehicle 30 utilizes such signals for steering vehicle 30.

FIG. 4 schematically illustrates pool cleaning system 420, another particular implementation of pool cleaning system 20. Pool cleaning system 420 is similar to pool cleaning system 120 except that pool cleaning system 420 additionally comprises a portable electronic device 464. Those remaining components of pool cleaning system 420 which correspond to components of pool cleaning system 120 are numbered similarly.

Portable electronic device 464 comprises a portable handheld electronic device in communication with controller 42 and/or dry station 46 across network 260. Examples of such a portable electronic device (PED) 300 include, but are not limited to, a smart phone, a personal data assistant (PDA), laptop, notebook computer, tablet computer (e.g. IPAD) and MP3 player (e.g., IPOD TOUCH). In the example illustrated, PED 464 comprises input 466 and display 468.

Input 466 serves as a user interface for PED 464 by which inputs are made to PED 464. Input 466 facilitates entry of inputs or commands by a person to cause controller 42 to

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generate control signals varying the control of vehicle 30. In one implementation, input 466 comprise a keyboard. In other implementations, input 466 may comprise a touchpad, a stylus, a microphone with associated speech recognition software or programming, a touch screen, buttons, switches and the like. In some implementations, input 466 may comprise a touch screen incorporated as part of display 468.

Display 468 comprises a user interface by which graphical or textual data is presented to a user. Display 468 may present the same or similar information as presented at dry station 246 by display 50 as described above. In one implementation, display 468 comprises a liquid crystal display. In other implementations, display 468 may comprise other types of display technology such as a light emitting diode display, an organic light emitting diode display (OLED), an electronic ink (e-ink) display or other types of display technology in present use or developed in the future. Although system 420 is illustrated as including controller 422 is part of dry station 46, in some implementations, controller 42 may alternatively be located as part of PED 464.

PED 464 enables a person located remote from pool 22 to monitor the progress of the cleaning of pool 22 by vehicle 30 of system 420. PED 464 provides a person with a graphical presentation (described above with respect to display 50) indicating those portions of surfaces 26, 28 of pool 22 that have been completed as well as those portions 26, 20 and that remain to be cleaned. The person may also be provided with a graphical indication of what portions need to be re-cleaned to meet predetermined cleanliness thresholds. In the example illustrated, input 466 enables a person to enter commands or selections which are transmitted across network 260 to controller 42 to adjust operation of vehicle 30. For example, the path or route of vehicle 30 may be changed, the aggressiveness of the cleaning chemicals or mechanical cleaning devices may be adjusted, the speed at which vehicle 30 traverses surfaces 26, 28 may be adjusted. In response to such adjustment signals from PED 464, controller 42 may utilize signals from cameras 32 to adjust the steering of vehicle 30.

FIG. 5 schematically illustrates pool cleaning system 520, another example implementation of pool cleaning system 20. Pool cleaning system 520 is similar to pool cleaning system 420 except that pool cleaning system 520 additionally comprises a remote server 554. Those remaining components of pool cleaning system 520 which correspond to components of pool cleaning system 420 are numbered similarly.

Remote server 554 is similar to remote server 254 described above with respect to system 220. Remote server 554 comprises a server remote from dry station 246 which is in communication with dry station 246 across network 260. Remote server 254 includes controller 42. During operation, signals from cameras 32 are transmitted across dry station 246 across network 260 to controller 42 of remote server 254. Based upon such signals from cameras 32, controller 42 generates control signals which are transmitted back across network 260 and through dry station 246 to vehicle 30 to steer vehicle 30. Controller 42 further relays either the raw signals from camera 32 or image signals generated based upon signals from cameras 32 to PED 464, wherein such images (described above) are presented on display 468. As noted above, PED may further receive commands through input 466, wherein such commands are transmitted to controller 42 which generates control signals that are ultimately transmitted to vehicle 30 for steering vehicle 30.

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As with remote server 254, remote server 554 and network 260 may be shared as part of other pool cleaning systems 320 (shown in FIG. 3), wherein controller 42 generates control signals for steering the pool cleaning vehicle 30 of system 320 based upon signals from cameras 32 transmitted across dry station 246 of system 320. In such implementations, controller 42 of remote server 554 may interact with other PEDs 464. In such an implementation, the cost and complexity of pool cleaning system 220 is reduced since controller 42 is remotely provided at remote server 254 which services multiple pool cleaning systems 220, 320. Upgrades to controller 42 and its software are also more easily achieved for all pool cleaning systems to 20, 320 and their pools 22, 222 being serviced. In one implementation, the supervised cleaning, inspection and possible re-cleaning facilitated by the use of cameras 32 may be provided as part of a subscription to users of vehicle 30. In such an implementation, a pool 22 having security cameras 32 may be upgraded with appropriate software or an appropriate software module added to dry station 246 to make a network connection with controller 42 which directs the security cameras 32 to capture vehicle 30 utilizes such signals for steering vehicle 30. As indicated by broken lines, in other implementations, the controller 42 for generating control signals steering vehicle 30 based upon signals from cameras 32 may alternatively be relocated in PED 464.

FIG. 6 is a flow diagram illustrating an example method 600 that may be carried out by any of systems 120-520. As indicated by step 602, cameras 32 capture images of pool cleaning by vehicle 30. As indicated by step 604, controller 42 obtain such signals from cameras 32 for the surfaces of pool 22 that have been cleaned. As indicated by step 606, controller 42 uses information gathered from the signals from cameras 32 to identify those portions of surfaces 26, 28 not satisfactorily cleaned not satisfying a predefined cleanliness characteristic or measurement threshold. One example of a cleanliness characteristic measurement a threshold may be how well the color of a surface matches a predetermined desirable color for the pool surface (such as original color of the tile or surface). A surface that has been missed entirely by vehicle 30 during a pool cleaning session may be automatically deemed to not satisfy a predetermined cleanliness characteristic.

As indicated by step 608, based upon such determinations, controller 42 generates control signals resulting in the presentation of a graphical depiction of those portions of pool 22 that has not been satisfactorily cleaned. Such graphical representations or depictions may be presented on display 50 or display 468. FIGS. 7 and 8 illustrate examples of graphical depictions that may be presented.

FIG. 7 illustrates display 468 presenting graphical depiction 620. Graphical depiction 620 comprises a first graphic 622 having a first portion 624 representing sides or walls 28 of pool 22 and a second portion 626 representing the floor 26 of pool 22. Graphical depiction 620 further comprises a moving icon 628 representing the current positioning of vehicle 30. In one implementation, the path of vehicle 30 may additionally be depicted by icon 628 shown in broken lines. As shown by FIG. 7, those portions 632 of surfaces 26, 28 of pool 22 (shown in FIG. 1) over which of vehicle 30 has moved are identified by graphical depiction 620 either by color, markings or other various distinctive attributes. Likewise, those portions 634 of surfaces 26, 28 of pool 22 that have not been covered by vehicle 30 are identified by a distinct color col marking or distinctive attribute of depiction 620. As a result, a person may view the current position of vehicle 30, the extent to which pool 22 has been cleaned

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or covered by vehicle 30 and the extent of pool 22 that remains to be cleaned. In the example illustrated, depiction 620 further identifies those portions 638 of surfaces 26, 28 that have been cleaned, but which have not been cleaned to a satisfactory degree or extent. In one implementation, portions 638 may be identified by colors, brightness, markings or other visually distinctive attributes that are visually distinct from both portions 632 and portions 634. In other implementations, portions 638 may have the same characteristic of portions 634. In yet other implementations, different portions 638 may have different visual attributes depending upon a degree to which such clean portions have failed to satisfy the predefined cleanliness characteristic threshold. In some implementations, different portions 638 may have different visual attributes depending upon different cleaning strategies that may be recommended for the different portions 638. For example, controller 42 may determine and recommend a first cleaning strategy (a first chemical solution jetted at a first rate and scrubbed at a first rate) with respect to a first portion 638 and may recommend a second different cleaning strategy (a second chemical solution jetted at a second rate is about a second rate) with respect to a second portion 638, wherein the different cleaning strategies are represented by different visual attributes presented in depiction 620.

FIG. 8 illustrates display 468 presenting a graphical depiction 720. Graphical depiction 720 comprises a first graphic 622 having a first portion 624 representing sides or walls 22 of pool 22 and a second portion 626 representing the floor 26 of pool 22 (shown in FIG. 1). Graphical depiction 720 is similar to graphical depiction 620 except that graphical depiction 720 omits icon 628 presenting vehicle 30. Like depiction 620, depiction 720 graphically depicts those portions 632 of surfaces 26, 28 over which vehicle 30 has traveled while in a cleaning mode. Depiction 720 also visually depicts those portions 634 that have not been covered by vehicle 30 in the cleaning mode and those portions 638 over which vehicle 30 has traveled while in the cleaning mode, but which have not been cleaned to a satisfactory degree. As illustrated in FIG. 8, different portions 638 may be visibly distinguished from one another through color, text or markings indicating either differences in the cleanliness of such portions 638 or indicating different recommended cleaning strategies or approaches that may be selected by a person using input 466 when vehicle 30 is steered back to such portions 638 for re-cleaning using signals from camera 32.

As indicated by step 610 of FIG. 6, controller 42 generates control signals steering vehicle 30 to re-clean portions of pool 22, such as portions 638. Such steering may be facilitated by using signals from cameras 32. As noted above, in some implementations, a person may be allowed Choose a cleaning approach for a particular portion 638 using input 466. The selection may be facilitated by visual inspection of the different visual attributes for the particular portion 638 provided by depiction 720 (or depiction 620). In some implementations, input 466 may additionally be utilized by a person to prioritize an order in which portions 638 are re-cleaned.

FIG. 9 illustrates pool cleaning system 820, an example implementation of pool cleaning system 20. Pool cleaning system 820 is similar to pool cleaning system 520 except the pool cleaning system 820 located controller 42 in dry station 246 and includes pool cleaning vehicle 830, a specific example of vehicle 30. As shown by FIG. 9, in addition to transmitting control signals generated by controller 42 to vehicle 830, dry station 246 further transmits power from

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power source 831 through a power line or power cable 833 to vehicle 830. In the example illustrated, data communication and communication of control signals, also occurs across wired connections within or alongside the same line 833. In the example illustrated, remote server 554 serves as a communication link by which upgrades to controller 42 may be implemented across a wide number of pool cleaning systems and by which information from controller 42 is conveyed to one or more portable electronic devices 464 across network 260.

Vehicle 830 comprises a robotic or automated pool cleaning device. Vehicle 830 comprises a self-contained onboard filtration system with drive and pump motors. Vehicle 830 utilizes an internal microprocessor guided drive motor to systematically clean surfaces of pool 22. As shown by FIGS. 9 and 10, vehicle 830 utilizes a toothed track drive 900 provide traction and propulsion for vehicle 30. Vehicle 830 comprises rotating brushes 902 to loosen waterline buildup and breakdown large debris while power washing jets 904 flush out dirt from pores, seems in corners where brushes 902 may not be able to reach. The loosened dirt and debris is vacuumed through off-center vacuum ports 906 which passes the vacuumed debris through internally house filter bag. In the example illustrated, vehicle 830 further comprises rollers 908 which inhibit vehicle 830 from becoming impeded or stuck on raised drains or pop-up heads. Although illustrated as being employed with system 820, vehicle 830 may also be utilized with any of systems 20, 120, 220, 320 and 420. In other implementations, other robotic or automated pool cleaning vehicles may be utilized.

Although the present disclosure has been described with reference to example embodiments, workers skilled in the art will recognize that changes may be made in form and detail without departing from the spirit and scope of the claimed subject matter. For example, although different example embodiments may have been described as including one or more features providing one or in ore benefits, it is contemplated that the described features may be interchanged with one another or alternatively be combined with one another in the described example embodiments or in other alternative embodiments. Because the technology of the present disclosure is relatively complex, not all changes in the technology are foreseeable. The present disclosure described with reference to the example embodiments and set forth in the following claims is manifestly intended to be as broad as possible. For example, unless specifically otherwise noted, the claims reciting a single particular element also encompass a plurality of such particular elements.

What is claimed is:

1. A self-propelled pool cleaning system for cleaning debris from a submerged surface of a swimming pool, comprising:

- a. a vehicle body;
- b. means for moving the vehicle body within the swimming pool;
- c. a filter configured to retain debris collected from the submerged surface;
- d. at least one camera for capturing an image of at least a first object within the swimming pool; and
- e. a controller (i) in electronic communication with the at least one camera and (ii) configured to generate, in response to the captured image, at least one control signal to cause movement of the body within the swimming pool to, or away from, the first object.

2. A pool system comprising:

- at least one piece of equipment for a swimming pool or spa;

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one or more cameras configured to capture video or images of at least a portion of a location including the swimming pool or spa; and
a controller in communication with the at least one piece of equipment and the one or more cameras, the controller configured to receive visual data from the one or more cameras and determine a control action for the at least one piece of equipment based on the received visual data.

3. The pool system of claim 2, wherein the at least one piece of equipment comprises a cleaning device with one or more propulsion mechanisms, the cleaning device configured to travel adjacent to submerged or water-containing surfaces of the swimming pool or spa and to perform a cleaning operation.

4. The pool system of claim 2, wherein the one or more cameras are mounted external to the swimming pool or spa.

5. The pool system of claim 2, wherein the one or more cameras are mounted on the at least one piece of equipment.

6. The pool system of claim 2, wherein the one or more cameras are submersible or submerged within the swimming pool or spa.

7. The pool system of claim 2, wherein the controller is configured to detect a characteristic of the location based on the visual data and control the piece of equipment based on the detected characteristic.

8. The pool system of claim 7, wherein the characteristic comprises a cleanliness of a surface of the swimming pool, and wherein the controller is configured to control the piece of equipment based on the detected cleanliness being outside of a threshold.

9. The pool system of claim 2, wherein the controller is configured to communicate with the at least one piece of equipment and the one or more cameras via a wireless connection.

10. The pool system of claim 2, wherein the controller is further configured to present a graphical depiction on a remote device based on the received visual data as the control action.

11. The pool system of claim 2, wherein the controller is remote from the camera.

12. A method for monitoring a pool system, the method comprising:
receiving images of at least a portion of a location including a swimming pool or spa from one or more cameras;

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determining a target area and detecting a characteristic of the target area based on the images; and
generating a control response based on the detected characteristic of the target area.

13. The method of claim 12, wherein the target area comprises a portion of a surface of the swimming pool or spa, and wherein the characteristic comprises a cleanliness characteristic of the portion of the surface of the swimming pool or spa.

14. The method of claim 12, wherein generating the control response comprises controlling an operation of a piece of equipment of the swimming pool or spa.

15. The method of claim 12, wherein generating the control response comprises generating an alert on a remote device.

16. The method of claim 12, wherein generating the control response comprises wirelessly communicating with a piece of equipment for the swimming pool or spa or a remote device.

17. The method of claim 12, wherein generating the control response comprises prompting a user on a remote device, and wherein the method further comprises receiving a control input from the user on the remote device for controlling a piece of equipment of the swimming pool or spa.

18. The method of claim 17, wherein prompting the user comprises providing recommended cleaning strategies for a cleaning device based on the detected characteristic of the target area.

19. The method of claim 12, wherein generating the control response comprises controlling operation of a cleaning device configured to travel adjacent to submerged or water-containing surfaces of the swimming pool or spa and to perform a cleaning operation, wherein controlling operation of the cleaning device comprises one or more of controlling a path or route of the cleaning device, an aggressiveness of cleaning chemicals deployed, an aggressiveness of mechanical cleaning, or a speed of the cleaning device.

20. The method of claim 19, wherein the characteristic of the target area is a presence of a person at the swimming pool or spa, and wherein generating the control response is based on the detected presence of the person satisfying a predefined characteristic.

* * * * *

EXHIBIT B

US011262766B2

(12) **United States Patent**
Durvasula et al.(10) **Patent No.:** **US 11,262,766 B2**(45) **Date of Patent:** ***Mar. 1, 2022**(54) **POOL CLEANING SYSTEM AND METHOD TO AUTOMATICALLY CLEAN SURFACES OF A POOL USING IMAGES FROM A CAMERA**(58) **Field of Classification Search**CPC .. G05D 1/0246; G05D 1/0016; G05D 1/0033;
G05D 1/0038; G05D 2201/0203;
(Continued)(71) Applicant: **ZODIAC POOL SYSTEMS LLC**,
Carlsbad, CA (US)(56) **References Cited**

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(Continued)(73) Assignee: **ZODIAC POOL SYSTEMS LLC**,
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This patent is subject to a terminal disclaimer.

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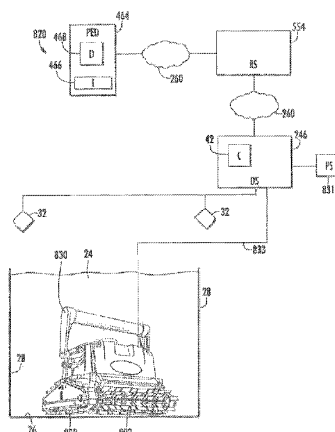
(22) Filed: **Jan. 7, 2021***Primary Examiner* — Allen C Wong(65) **Prior Publication Data**

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(74) *Attorney, Agent, or Firm* — Kilpatrick Townsend &
Stockton LLP**Related U.S. Application Data**(63) Continuation of application No. 16/919,750, filed on
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CPC **G05D 1/0246** (2013.01); **E04H 4/1654**
(2013.01); **G05D 1/0016** (2013.01);
(Continued)(57) **ABSTRACT**

A pool cleaning system for cleaning debris from a submerged surface of a swimming pool includes a self-propelled pool cleaner having rotatably-mounted supports for supporting and guiding the cleaner on the pool surface; an electric motor for enabling the rotation of the rotatably-mounted supports on the pool surface; at least one camera to capture imagery of the pool surface; a controller, in electronic communication with the at least one camera, to determine a cleanliness characteristic of the pool surface on which the cleaner has passed based on the camera imagery and generate a control signal to direct movement of the cleaner based on the cleanliness characteristic of the pool surface, and a portable electronic device configured to present a graphic on a display, the graphic depicting the

(Continued)



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submerged surface of the pool and those portions of the surface that remain uncleaned as the cleaner traverses the pool surface.

5 Claims, 4 Drawing Sheets

Related U.S. Application Data

continuation of application No. 16/416,840, filed on May 20, 2019, now Pat. No. 10,739,785, which is a continuation of application No. 15/973,983, filed on May 8, 2018, now Pat. No. 10,338,599, which is a continuation of application No. 15/207,065, filed on Jul. 11, 2016, now Pat. No. 9,995,051, which is a continuation of application No. 13/545,918, filed on Jul. 10, 2012, now Pat. No. 9,388,595.

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- (52) **U.S. Cl.**
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- (58) **Field of Classification Search**
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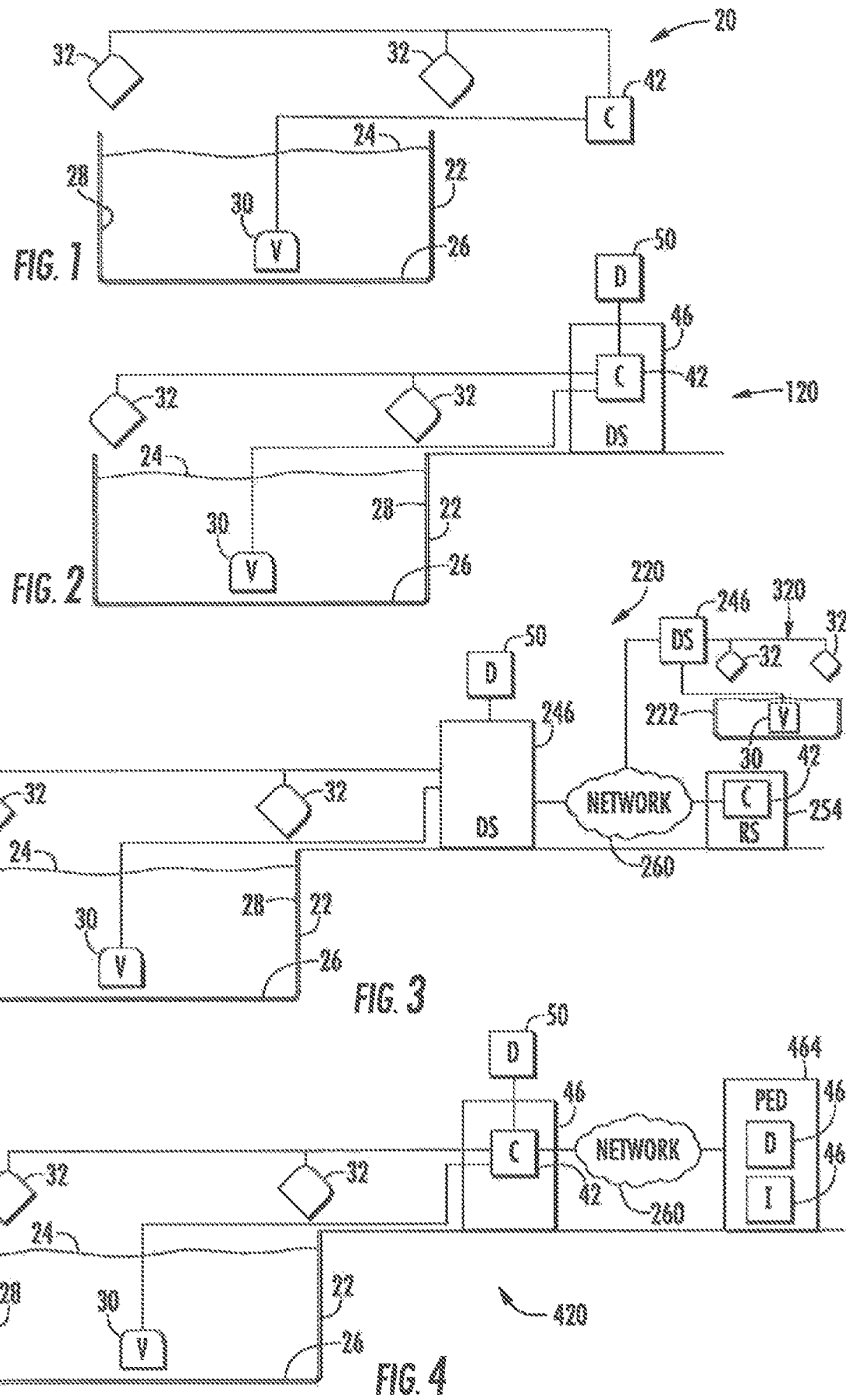
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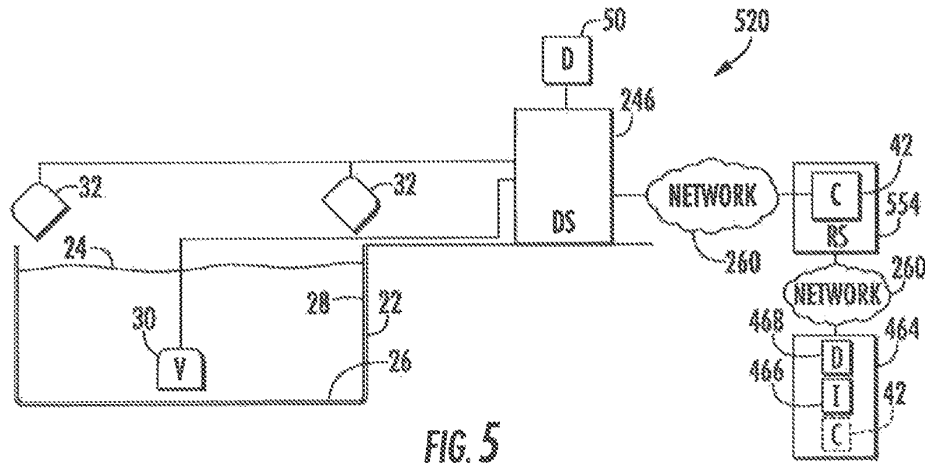


FIG. 5

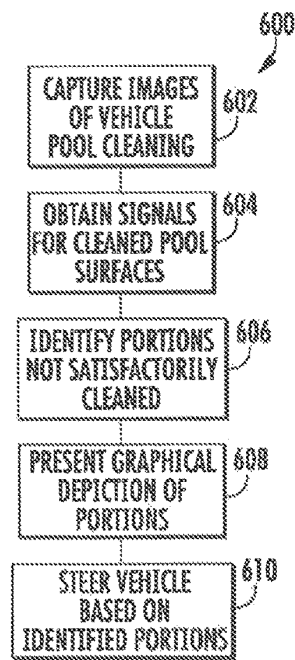


FIG. 6

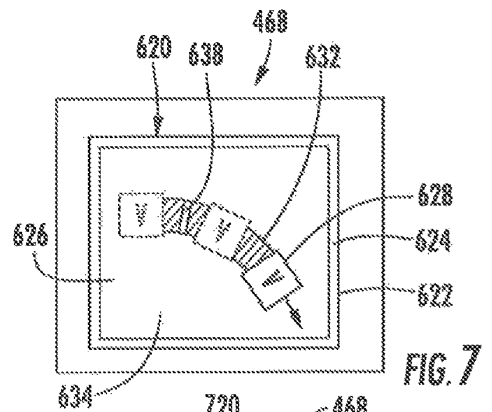


FIG. 7

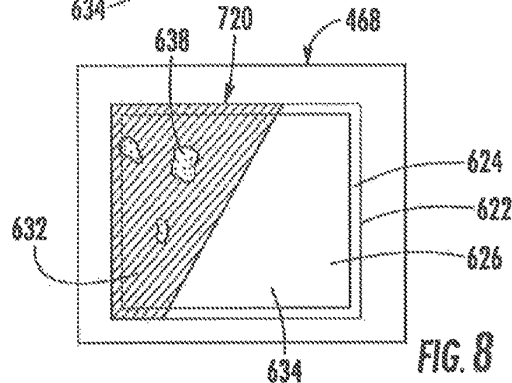


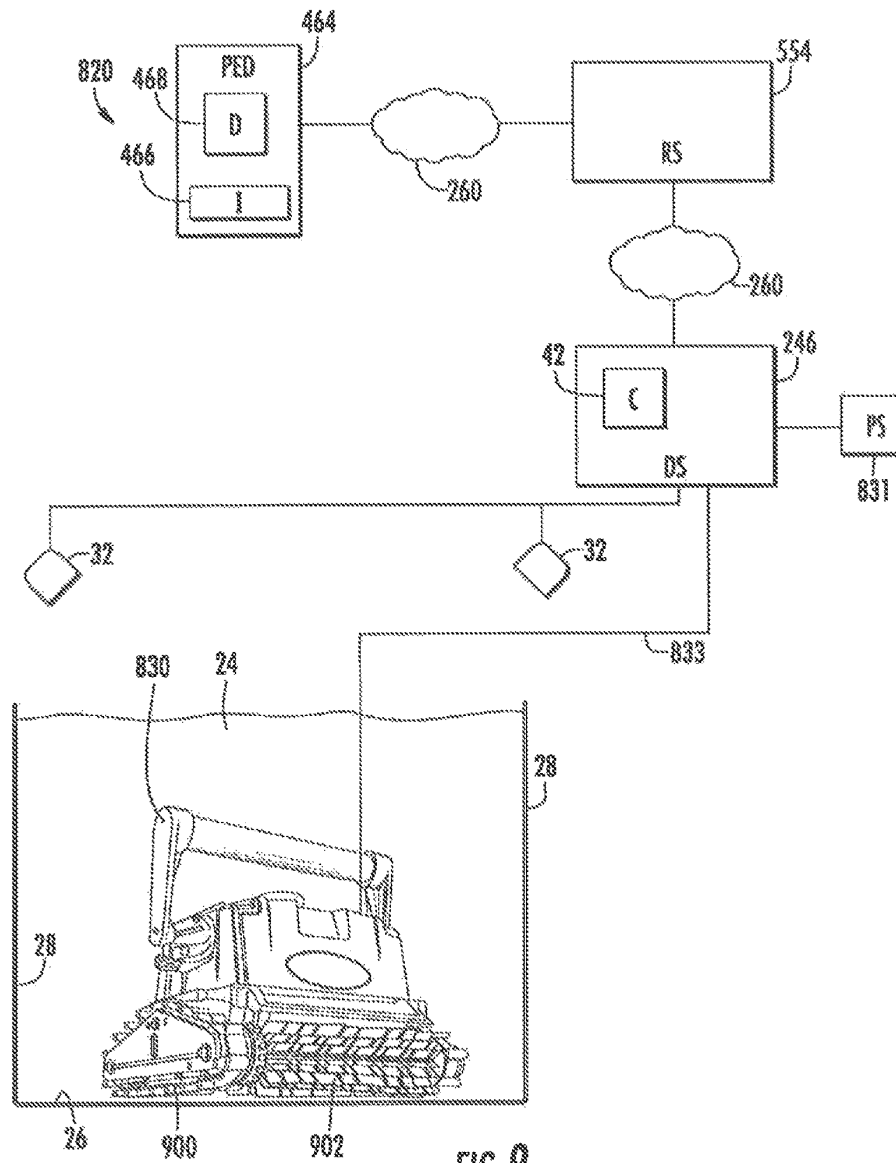
FIG. 8

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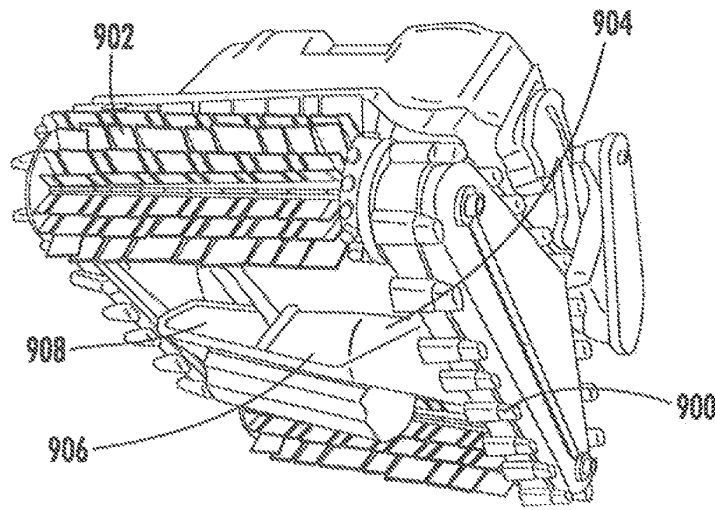


FIG. 10

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**POOL CLEANING SYSTEM AND METHOD
TO AUTOMATICALLY CLEAN SURFACES
OF A POOL USING IMAGES FROM A
CAMERA**

**CROSS-REFERENCE TO RELATED
APPLICATION**

This application is a continuation of U.S. patent application Ser. No. 16/919,750, filed Jul. 2, 2020, which is a continuation of U.S. patent application Ser. No. 16/416,840, filed May 20, 2019 (now U.S. Pat. No. 10,739,785), which is a continuation of U.S. patent application Ser. No. 15/973,983, filed May 8, 2018 (now U.S. Pat. No. 10,338,599), which is a continuation of U.S. patent application Ser. No. 15/207,065, filed Jul. 11, 2016 (now U.S. Pat. No. 9,995,051), which is a continuation of U.S. patent application Ser. No. 13/545,918, filed Jul. 10, 2012 (now U.S. Pat. No. 9,388,595), the contents of all of which are incorporated herein by reference in their entireties.

BACKGROUND

Manually cleaning the floor and sides of a swimming pool may be a tedious and time-consuming task. As a result, automated robotic pool cleaners have been developed. However, controlling and monitoring such automated robotic pool cleaners to insure that all portions of the pool surfaces are satisfactorily cleaned remains a challenge.

SUMMARY OF THE INVENTION

The disadvantages heretofore associated with the prior art are overcome by the present invention of a pool cleaning system for cleaning debris from a submerged surface of a swimming pool comprising: a self-propelled pool cleaner having rotatably-mounted supports for supporting and guiding the cleaner on the pool surface; a filter configured to retain the debris collected from the submerged surface of the swimming pool; an electric motor for enabling the rotation of the rotatably-mounted supports on the pool surface; at least one camera to capture imagery of the pool surface; a controller, in electronic communication with the at least one camera, to determine a cleanliness characteristic of the pool surface on which the cleaner has passed based on the camera imagery and generate a control signal to direct movement of the cleaner based on the cleanliness characteristic of the pool surface; and a portable electronic device is configured to present a graphic on a display, the graphic depicting the submerged surface of the pool and those portions of the surface that remain uncleaned as the cleaner traverses the pool surface.

In one aspect, the at least one camera is carried by the cleaner. In another aspect, the controller is carried by the cleaner. In still another aspect, the electric motor is mechanically connected to at least one of the rotatably-mounted supports.

In yet another aspect, the controller is operable to execute one or more cleaning programs for cleaning the submerged surfaces of the pool. In one aspect, the control signal causes the cleaner to drive in a direction to clean a portion of the pool surface based on the cleanliness characteristic of the pool surface. Alternatively, the control signal causes the cleaner to steer in a direction to clean a portion of the pool surface based on the cleanliness characteristic of the pool surface. In another aspect, the control signal causes the cleaner to drive in a direction to re-clean a portion of the

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pool surface over which the cleaner has passed. Alternatively, the control signal causes the cleaner to steer in a direction to re-clean a portion of the pool surface over which the cleaner has passed.

In one aspect, the captured imagery from the at least one camera is digitally processed by the controller to determine the cleanliness characteristic of the pool surface. Alternatively, the captured imagery from the at least one camera is digitally processed by a remote processor to determine the cleanliness characteristic of the pool surface.

In another aspect, the system further comprises a dry station located remotely from the cleaner and in communication with the cleaner, wherein the dry station includes the controller. Alternatively, the system further comprises a dry station located remotely from the cleaner and in communication with the cleaner, wherein the controller is located remotely from the cleaner and the dry station. In still another aspect, the controller controls electric power provided to the electric motor.

In one aspect, the control signal causes the cleaner to move in a direction of a portion of the pool surface to be cleaned based solely upon signals received from the camera. In another aspect, the control signal causes the cleaner to drive in a direction to clean a portion of the pool surface based on the cleanliness characteristic of the pool surface. Alternatively, the control signal causes the cleaner to steer in a direction to clean a portion of the pool surface based on the cleanliness characteristic of the pool surface. In yet another aspect, the control signal causes the cleaner to drive in a direction to re-clean a portion of the pool surface over which the cleaner has passed. Alternatively, the control signal causes the cleaner to steer in a direction to re-clean a portion of the pool surface over which the cleaner has passed.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a schematic illustration of an example pool cleaning system.

FIG. 2 is a schematic illustration of an implementation of the pool cleaning system of FIG. 1.

FIG. 3 is a schematic illustration of an implementation of the pool cleaning system of FIG. 1.

FIG. 4 is a schematic illustration of an implementation of the pool cleaning system of FIG. 1.

FIG. 5 is a schematic illustration of an implementation of the pool cleaning system of FIG. 1.

FIG. 6 is a flow diagram of an example method that may be carried out with the pool cleaning system of FIG. 2-5.

FIG. 7 is a plan view of an example display with an example graphical depiction.

FIG. 8 is a plan view of another example display with an example graphical depiction.

FIG. 9 is a schematic illustration of an implementation of the pool cleaning system of FIG. 1 with an example pool cleaning vehicle.

FIG. 10 is a bottom perspective view of the example pool cleaning vehicle of the system of FIG. 9.

**DETAILED DESCRIPTION OF THE EXAMPLE
EMBODIMENTS**

FIG. 1 schematically illustrates an example pool cleaning system 20. As schematically shown by FIG. 1, pool cleaning system 20 is adapted to clean submerged surfaces of a pool 22 containing a liquid 24. In particular, pool cleaning system 20 is adapted to clean at least a bottom or floor surface 26 of the pool 22 and possibly to additionally clean surfaces 28

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of pool 22. As will be described hereafter, pool cleaning system facilitates the control and monitoring of a robotic pool cleaner to better assure that all portions of pool 22 are satisfactorily cleaned.

Pool cleaning system 20 comprises vehicle 30, cameras 32 and controller 42. Vehicle 30 comprises an automated powered device configured to travel adjacent to submerged or water containing surfaces of pool 20 (such as floor 26 and/or side surfaces 28) while cleaning such surfaces. In one implementation, vehicle 30 may include vacuum or suction devices, a liquid circulation system and a filter to draw debris, such as bacterial growth or plant growth, from such pool surfaces, wherein the drawn liquid containing such residue or foreign matter is filtered to collect the debris. In other implementations, vehicle 30 may not collect such debris, wherein vehicle 30 merely loosens such debris on the pool surfaces such that the loosened or separated debris may be subsequently removed using the existing liquid filtering system of pool 22.

To assist in the loosening of debris, in one implementation, vehicle 30 may additionally include a chemical dispenser to closely apply pool cleaning chemicals to the pool surfaces as the vehicle 30 traverses such surfaces. In one implementation, vehicle 30 may additionally or alternatively include one or more scrubbing members, such as active (driven) or passive (undriven or idling) brushes, to assist in the removal of residue or foreign matter from such pool surfaces. In yet another implementation, vehicle 30 may additionally or alternatively include liquid jets to assist in the loosening of debris.

To move along the submerged surfaces of pool 22, vehicle 30 includes one or more propulsion mechanisms. In one implementation, vehicle 30 is propelled along the submerged pool surfaces using wheels, rollers, tracks or other surface contacting members powered by a motor and the like. Such wheels, rollers or tracks may themselves include the scrubbing members used to clean the surfaces. In one implementation vehicle 30 may also alternatively be propelled by means of the vacuum or liquid jets. The vacuum or liquid jets used for such propulsion nozzle facilitate loosening of debris for collection by vehicle 30. In other implementations, vehicle 30 may include other propulsion mechanisms.

Cameras 32 comprise devices configured to capture video or time lapse images of pool 22. In the example illustrated, cameras 32 are mounted on structures external to pool 22. In other words, cameras 32 are not submerged. In other implementations, cameras 32 may alternatively be mounted to vehicle 30. In the example illustrated, cameras 32 capture movement of vehicle 30 while vehicle 30 is submerged within pool 22. In other implementations, cameras 32 merely capture images of submerged surfaces 26, 28 of pool 22.

In the example illustrated, cameras 32 comprise cameras serving as part of a home or pool security system, wherein such cameras detect the presence of a person at pool 22 satisfying a predefined characteristic and wherein an alert is output upon the person's detected presence. For example, in one implementation, cameras 32 are utilized as part of a security system that detects when a person below a predefined age, such as a child, is present at pool 22 without a detected presence of a recognized adult. In another implementation, cameras 32 may detect the presence of an unauthorized person or intruder at pool 22. Identification of the person may be achieved by an off-site human or computerized monitoring system, wherein signals from cameras 32 are transmitted across a wide area network or may be

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achieved with software of controller 42 which includes facial recognition or other identification programming.

Because pool cleaning system 20 utilizes pre-existing cameras 32 provided as part of a security system or shares the use of cameras 32 with such a home or pool security system, pool cleaning system 20 is easier to set up, less complex and less expensive. In other implementations, pool cleaning system 20 may utilize dedicated cameras 22 independent of any cameras associated with a home, facility or pool security system. In such an alternative system, cameras 32 may be more precisely focused upon pool 22 and surfaces 26, 28 while also including appropriate lenses or modifications to account for glare, refraction and the like to better facilitate the capture of surfaces and vehicle 30 which are submerged.

Controller 42 comprises one or more processing units in communication with vehicle 30 and cameras 32. For purposes of this application, the term "processing unit" shall mean a presently developed or future developed processing unit that executes sequences of instructions contained in a memory. Execution of the sequences of instructions causes the processing unit to perform steps such as generating control signals. The instructions may be loaded in a random access memory (RAM) for execution by the processing unit from a read only memory (ROM), a mass storage device, or some other persistent storage. In other embodiments, hard wired circuitry may be used in place of or in combination with software instructions to implement the functions described. For example, controller 42 may be embodied as part of one or more application-specific integrated circuits (ASICs). Unless otherwise specifically noted, the controller is not limited to any specific combination of hardware circuitry and software, nor to any particular source for the instructions executed by the processing unit.

In one implementation, controller 42 communicates with vehicle 30 and cameras 32 entirely across a wired connection. In another implementation, controller 42 communicates with vehicle 30 and cameras 32 across a wireless connection, such as across a local area network (LAN) or a wide area network (WAN) such as the Internet. One of limitation, controller 42 may communicate with vehicle 30 and cameras 32 using a combination of both wired and wireless communication connections.

Controller 42 is configured to generate control signals for steering vehicle 30 based upon signals received from cameras 32. In one implementation, controller 42 provides the sole steering directions for vehicle 30 using signals from cameras 32. Because vehicle 30 is precisely steered under the control of controller 42, rather than traveling in a random manner, entire summer surfaces of pool 22 may be more quickly and efficiently covered and cleaned. Because controller 42 provides the only steering instructions for vehicle 30 and utilizes signals from cameras 32, complex steering algorithms or codes in either vehicle 30 or controller 42 may be omitted to reduce complexity and cost of system 20.

In another implementation, vehicle 30 may cover or travel across surfaces of pool 22 in either a random fashion or according to an automated pool coverage algorithm or pool coverage pattern stored in a memory associated with vehicle 30 or controller 42. In such an implementation, controller 42 utilizes signals from cameras 32 to verify that all of the surfaces of pool 22 have been cleaned, that no spots have been missed. Upon identifying a missed spot, controller 42 utilizes signals from camera 32 to steer vehicle 32 over such missed portions of surfaces 26, 28. According to one example, controller 42 not only uses signals from camera 32 to determine whether any portions of surfaces 26, 28 have

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been missed entirely, but to also determine whether any portions of surfaces 26, 28 have been cleaned, but not to a satisfactory degree or extent. In such circumstances, controller 42 uses signals from cameras 32 to steer vehicle 34 such areas to re-clean such portions until such portions have been satisfactorily cleaned such that the portions have a cleanliness characteristic satisfying a predefined threshold.

FIG. 2 schematically illustrates pool cleaning system 120, the particular example of pool cleaning system 20 described above. Pool cleaning system 120 is similar to pool cleaning system 20 except that pool cleaning system 120 additionally comprises dry station 46 and display 50. Those remaining components of pool cleaning system 120 which correspond to components of pool cleaning system 20 are numbered similarly.

Dry station 46 comprises a station in communication with vehicle 30 and cameras 32 outside of pool 22. Dry station 46 incorporates controller 42. In one implementation, dry station 46 communicates with vehicle 30 in a wired fashion. In such an implementation, dry station 46 further provides electrical power to vehicle 30 in a wired fashion. Dry station 46 communicates with cameras 32 and either a wired or wireless fashion.

Display 50 comprises a device to present a graphical images and text on a display screen. In one implementation, display 58 may be incorporated as part of dry station 46. In another implementation, display 50 may be provided on a portable electronic device, a computer, a television and the like. Display 50 is utilized by pool cleaning system 120 to present information regarding the cleaning of pool 22 to facilitate control of vehicle 30 by controller 42. In one implementation, display 50 is utilized by pool cleaning system 120 and a controller 42 to present a graphical depiction of those portions of surfaces 26, 28 of pool 22 have not been satisfactorily cleaned so as to satisfy a predefined cleanliness characteristic threshold. Such portions may comprise portions that have been completely missed by vehicle 30 as well as those portions that have been covered by vehicle 30 but have not been satisfactorily cleaned with the given number of passes of vehicle 30 or the existing cleaning settings of vehicle 30. The graphical depiction presented on display 50 enables a person view the quality of the prior cleaning session and to input commands causing controller 42 to generate control signals using signals from camera 32 to steer vehicle 30 back to such identified portions where such portions may be cleaned at the same or elevated cleaning aggressiveness settings.

Another implementation, display 50 may be further utilized by controller 42 to depict the progress of vehicle 30 in cleaning pool 22. Such a display 50 allows a person to visually determine how much of the pool has been currently cleaned and to estimate the remaining time before the pool cleaning task is completed. In certain circumstances, using display 50, a person may adjust a setting of vehicle 30 to accelerate a rate at which surfaces 26, 20 of pool 22 are cleaned to meet an earlier desired completion time for such pool cleaning.

FIG. 3 schematically illustrates pool cleaning system 220, another example implementation of pool cleaning system 20. Pool cleaning system 220 is similar to pool cleaning system 20 except that pool cleaning system 220 additionally comprises dry station 246, display 50, and remote server 254. Those remaining components of pool cleaning system 220 which correspond to components of pool cleaning system 20 or pool cleaning system 120 are numbered similarly.

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Dry station 246 is similar to dry station 46, described above, except that dry station 246 serves as a local interface for communication with controller 42 across a network 260. In one implementation, network 260 may comprise a local area network. In another implementation, network 260 may comprise a wide area network, such as the Internet. For example, in one implementation, dry station 246 may incorporate a modem. In one implementation, dry station 246 may communicate across a local area network to controller 42. In another implementation, dry station 246 may communicate through a router, across a local area network, to a local modem which communicates across a network 260. The example illustrated, dry station 246 further provides part of vehicle 30 across a wired cable or wired connection. Display 50 is described above with respect to system 120.

Remote server 254 comprises a server remote from dry station 246 which is in communication with dry station 246 across network 260. Remote server 254 includes controller 42. During operation, signals from cameras 32 are transmitted across dry station 246 across network 260 to controller 42 of remote server 254. Based upon such signals from cameras 32, controller 42 generates control signals which are transmitted back across network 260 and through dry station 246 to vehicle 30 to steer vehicle 30.

As shown by FIG. 3, remote server 254 and network 260 may be shared as part of other pool cleaning systems 320, wherein controller 42 generates control signals for steering the pool cleaning vehicle 30 of system 320 based upon signals from cameras 32 transmitted across dry station 246 of system 320. In such an implementation, the cost and complexity of pool cleaning system 220 is reduced since controller 42 is remotely provided at remote server 254 which services multiple pool cleaning systems 220, 320. Upgrades to controller 42 and its software are also more easily achieved for all pool cleaning systems to 20, 320 and their pools 22, 222 being serviced. In one implementation, the supervised cleaning, inspection and possible re-cleaning facilitated by the use of cameras 32 may be provided as part of a subscription to users of vehicle 30. In such an implementation, a pool 22 having security cameras 32 may be upgraded with appropriate software or an appropriate software module added to dry station 246 to make a network connection with controller 42 which directs the security cameras 32 to capture vehicle 30 utilizes such signals for steering vehicle 30.

FIG. 4 schematically illustrates pool cleaning system 420, another particular implementation of pool cleaning system 20. Pool cleaning system 420 is similar to pool cleaning system 120 except that pool cleaning system 420 additionally comprises a portable electronic device 464. Those remaining components of pool cleaning system 420 which correspond to components of pool cleaning system 120 are numbered similarly.

Portable electronic device 464 comprises a portable handheld electronic device in communication with controller 42 and/or dry station 46 across network 260. Examples of such a portable electronic device (PED) 300 include, but are not limited to, a smart phone, a personal data assistant (PDA), laptop, notebook computer, tablet computer (e.g. IPAD) and MP3 player (e.g., IPOD TOUCH). In the example illustrated, PED 464 comprises input 466 and display 468.

Input 466 serves as a user interface for PED 464 by which inputs are made to PED 464. Input 466 facilitates entry of inputs or commands by a person to cause controller 42 to generate control signals varying the control of vehicle 30. In one implementation, input 466 comprise a keyboard in other implementations, input 466 may comprise a touchpad, a

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stylus, a microphone with associated speech recognition software or programming, a touch screen, buttons, switches and the like. In some implementations, input 466 may comprise a touch screen incorporated as part of display 468.

Display 468 comprises a user interface by which graphical or textual data is presented to a user. Display 468 may present the same or similar information as presented at dry station 246 by display 50 as described above. In one implementation, display 468 comprises a liquid crystal display. In other implementations, display 468 may comprise other types of display technology such as a light emitting diode display, an organic light emitting diode display (OLED), an electronic ink (e-ink) display or other types of display technology in present use or developed in the future. Although system 420 is illustrated as including controller 422 is part of dry station 46, in some implementations, controller 42 may alternatively be located as part of PED 464.

PED 464 enables a person located remote from pool 22 to monitor the progress of the cleaning of pool 22 by vehicle 30 of system 420. PED 464 provides a person with a graphical presentation (described above with respect to display 50) indicating those portions of surfaces 26, 28 of pool 22 that have been completed as well as those portions 26, 20 and that remain to be cleaned. The person may also be provided with a graphical indication of what portions need to be re-cleaned to meet predetermined cleanliness thresholds. In the example illustrated, input 466 enables a person to enter commands or selections which are transmitted across network 260 to controller 42 to adjust operation of vehicle 30. For example, the path or route of vehicle 30 may be changed, the aggressiveness of the cleaning chemicals or mechanical cleaning devices may be adjusted, the speed at which vehicle 30 traverses surfaces 26, 28 may be adjusted. In response to such adjustment signals from PED 464, controller 42 may utilize signals from cameras 32 to adjust the steering of vehicle 30.

FIG. 5 schematically illustrates pool cleaning system 520, another example implementation of pool cleaning system 20. Pool cleaning system 520 is similar to pool cleaning system 420 except that pool cleaning system 520 additionally comprises a remote server 554. Those remaining components of pool cleaning system 520 which correspond to components of pool cleaning system 420 are numbered similarly.

Remote server 554 is similar to remote server 254 described above with respect to system 220. Remote server 554 comprises a server remote from dry station 246 which is in communication with dry station 246 across network 260. Remote server 254 includes controller 42. During operation, signals from cameras 32 are transmitted across dry station 246 across network 260 to controller 42 of remote server 254. Based upon such signals from cameras 32, controller 42 generates control signals which are transmitted back across network 260 and through dry station 246 to vehicle 30 to steer vehicle 30. Controller 42 further relays either the raw signals from camera 32 or image signals generated based upon signals from cameras 32 to PED 464, wherein such images (described above) are presented on display 468. As noted above, PED may further receive commands through input 466, wherein such commands are transmitted to controller 42 which generates control signals that are ultimately transmitted to vehicle 30 for steering vehicle 30.

As with remote server 254, remote server 554 and network 260 may be shared as part of other pool cleaning systems 320 (shown in FIG. 3), wherein controller 42

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generates control signals for steering the pool cleaning vehicle 30 of system 320 based upon signals from cameras 32 transmitted across dry station 246 of system 320. In such implementations, controller 42 of remote server 554 may interact with other PEDs 464. In such an implementation, the cost and complexity of pool cleaning system 220 is reduced since controller 42 is remotely provided at remote server 254 which services multiple pool cleaning systems 220, 320. Upgrades to controller 42 and its software are also more easily achieved for all pool cleaning systems to 20, 320 and their pools 22, 222 being serviced. In one implementation, the supervised cleaning, inspection and possible re-cleaning facilitated by the use of cameras 32 may be provided as part of a subscription to users of vehicle 30. In such an implementation, a pool 22 having security cameras 32 may be upgraded with appropriate software or an appropriate software module added to dry station 246 to make a network connection with controller 42 which directs the security cameras 32 to capture vehicle 30 utilizes such signals for steering vehicle 30. As indicated by broken lines, in other implementations, the controller 42 for generating control signals steering vehicle 30 based upon signals from cameras 32 may alternatively be relocated in PED 464.

FIG. 6 is a flow diagram illustrating an example method 600 that may be carried out by any of systems 120-520. As indicated by step 602, cameras 32 capture images of pool cleaning by vehicle 30. As indicated by step 604, controller 42 obtain such signals from cameras 32 for the surfaces of pool 22 that have been cleaned. As indicated by step 606, controller 42 uses information gathered from the signals from cameras 32 to identify those portions of surfaces 26, 28 not satisfactorily cleaned—not satisfying a predefined cleanliness characteristic or measurement threshold. One example of a cleanliness characteristic measurement a threshold may be how well the color of a surface matches a predetermined desirable color for the pool surface (such as original color of the tile or surface). A surface that has been missed entirely by vehicle 30 during a pool cleaning session may be automatically deemed to not satisfy a predetermined cleanliness characteristic.

As indicated by step 608, based upon such determinations, controller 42 generates control signals resulting in the presentation of a graphical depiction of those portions of pool 22 that has not been satisfactorily cleaned. Such graphical representations or depictions may be presented on display 50 or display 468. FIGS. 7 and 8 illustrate examples of graphical depictions that may be presented.

FIG. 7 illustrates display 468 presenting graphical depiction 620. Graphical depiction 620 comprises a first graphic 622 having a first portion 624 representing sides or walls 28 of pool 22 and a second portion 626 representing the floor 26 of pool 22. Graphical depiction 620 further comprises a moving icon 628 representing the current positioning of vehicle 30. In one implementation, the path of vehicle 30 may additionally be depicted by icon 628 shown in broken lines. As shown by FIG. 7, those portions 632 of surfaces 26, 28 of pool 22 (shown in FIG. 1) over which of vehicle 30 has moved are identified by graphical depiction 620 either by color, markings or other various distinctive attributes. Likewise, those portions 634 of surfaces 26, 28 of pool 22 that have not been covered by vehicle 30 are identified by a distinct color col marking or distinctive attribute of depiction 620. As a result, a person may view the current position of vehicle 30, the extent to which pool 22 has been cleaned or covered by vehicle 30 and the extent of pool 22 that remains to be cleaned. In the example illustrated, depiction 620 further identifies those portions 638 of surfaces 26, 28

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that have been cleaned, but which have not been cleaned to a satisfactory degree or extent. In one implementation, portions 638 may be identified by colors, brightness, markings or other visually distinctive attributes that are visually distinct from both portions 632 and portions 634. In other implementations, portions 638 may have the same characteristic of portions 634 in yet other implementations, different portions 638 may have different visual attributes depending upon a degree to which such clean portions have failed to satisfy the predefined cleanliness characteristic threshold. In some implementations, different port 638 may have different visual attributes depending upon different cleaning strategies that may be recommended for the different portions 638. For example, controller 42 may determine and recommend a first cleaning strategy (a first chemical solution jetted at a first rate and scrubbed at a first rate) with respect to a first portion 638 and may recommend a second different cleaning strategy (a second chemical solution jetted at a second rate is about a second rate) with respect to a second portion 638, wherein the different cleaning strategies are represented by different visual attributes presented in depiction 620.

FIG. 8 illustrates display 468 presenting a graphical depiction 720. Graphical depiction 720 comprises a first graphic 622 having a first portion 624 representing sides or walls 28 of pool 22 and a second portion 626 representing the floor 26 of pool 22 (shown in FIG. 1). Graphical depiction 720 is similar to graphical depiction 620 except that graphical depiction 720 omits icon 628 presenting vehicle 30. Like depiction 620, depiction 720 graphically depicts those portions 632 of surfaces 26, 28 over which vehicle 30 has traveled while in a cleaning mode. Depiction 720 also visually depicts those portions 634 that have not been covered by vehicle 30 in the cleaning mode and those portions 638 over which vehicle 30 has traveled while in the cleaning mode, but which have not been cleaned to a satisfactory degree. As illustrated in FIG. 8, different portions 638 may be visibly distinguished from one another through color, text or markings indicating either differences in the cleanliness of such portions 638 or indicating different recommended cleaning strategies or approaches that may be selected by a person using input 466 when vehicle 30 is steered back to such portions 638 for re-cleaning using signals from camera 32.

As indicated by step 610 of FIG. 6, controller 42 generates control signals steering vehicle 30 to re-clean portions of pool 22, such as portions 638. Such steering may be facilitated by using signals from cameras 32. As noted above, in some implementations, a person may be allowed choose a cleaning approach for a particular portion 638 using input 466. The selection may be facilitated by visual inspection of the different visual attributes for the particular portion 638 provided by depiction 720 (or depiction 620). In some implementations, input 466 may additionally be utilized by a person to prioritize an order in which portions 638 are re-cleaned.

FIG. 9 illustrates pool cleaning system 820, an example implementation of pool cleaning system 20. Pool cleaning system 820 is similar to pool cleaning system 520 except the pool cleaning system 820 located controller 42 in dry station 246 and includes pool cleaning vehicle 830, a specific example of vehicle 30. As shown by FIG. 9, in addition to transmitting control signals generated by controller 42 to vehicle 830, dry station 246 further transmits power from power source 831 through a power line or power cable 833 to vehicle 830. In the example illustrated, data communication and communication of control signals, also occurs

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across wired connections within or alongside the same line 833 in the example illustrated, remote server 554 serves as a communication link by which upgrades to controller 42 may be implemented across a wide number of pool cleaning systems and by which information from controller 42 is conveyed to one or more portable electronic devices 464 across network 260.

Vehicle 830 comprises a robotic or automated pool cleaning device vehicle 830 comprises a self-contained onboard filtration system with drive and pump motors. Vehicle 830 utilizes an internal microprocessor guided drive motor to systematically clean surfaces of pool 22. As shown by FIGS. 9 and 10, vehicle 830 utilizes a toothed track drive 900 provide traction and propulsion for vehicle 30. Vehicle 830 comprises rotating brushes 902 to loosen waterline buildup and breakdown large debris while power washing jets 904 flush out dirt from pores, seams in corners where brushes 902 may not be able to reach. The loosened dirt and debris is vacuumed through off-center vacuum ports 906 which passes the vacuumed debris through internally house filter bag. In the example illustrated, vehicle 830 further comprises rollers 908 which inhibit vehicle 830 from becoming impeded or stuck on raised drains or pop-up heads. Although illustrated as being employed with system 820, vehicle 830 may also be utilized with any of systems 20, 120, 220, 320 and 420. In other implementations, other robotic or automated pool cleaning vehicles may be utilized.

Although the present disclosure has been described with reference to example embodiments, workers skilled in the art will recognize that changes may be made in form and detail without departing from the spirit and scope of the claimed subject matter. For example, although different example embodiments may have been described as including one or more features providing one or more benefits, it is contemplated that the described features may be interchanged with one another or alternatively be combined with one another in the described example embodiments or in other alternative embodiments. Because the technology of the present disclosure is relatively complex, not all changes in the technology are foreseeable. The present disclosure described with reference to the example embodiments and set forth in the following claims is manifestly intended to be as broad as possible. For example, unless specifically otherwise noted, the claims reciting a single particular element also encompass a plurality of such particular elements.

What is claimed is:

1. A self-propelled pool cleaner for cleaning debris from a submerged surface of a swimming pool, comprising:
 - a. a vehicle body;
 - b. means for moving the vehicle body within the swimming pool;
 - c. a filter configured to retain debris collected from the submerged surface;
 - d. at least one camera mounted directly or indirectly to the body for capturing an image of at least a first portion of the submerged surface; and
 - e. a controller (i) positioned on or in the body, (ii) in electronic communication with the at least one camera, and (iii) configured to generate, in response to the captured image, at least one control signal to cause movement of the body within the swimming pool to, or away from, the first portion of the submerged surface.
2. A self-propelled pool cleaner for cleaning debris from a submerged surface of a swimming pool, comprising:
 - a. a vehicle body;
 - b. means for moving the vehicle body within the swimming pool;

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- c. a filter configured to retain debris collected from the submerged surface;
 - d. at least one camera carried by the body for capturing an image of at least a first portion of the submerged surface; and
 - e. a controller (i) positioned on or in the body, (ii) in electronic communication with the at least one camera, and (iii) configured to generate, in response to the captured image, at least one control signal to cause movement of the body within the swimming pool to, or away from, the first portion of the submerged surface.
3. A self-propelled pool cleaner for cleaning debris from a submerged surface of a swimming pool, comprising:
- a. a vehicle body;
 - b. means for moving the vehicle body within the swimming pool;
 - c. a filter configured to retain debris collected from the submerged surface;
 - d. at least one camera positioned on or in, or carried by, the body for capturing an image of at least a first portion of the submerged surface; and
 - e. a controller (i) positioned on or in the body, (ii) in electronic communication with the at least one camera and a portable electronic device, and (iii) configured to generate, in response to at least one of the captured image or information from the portable electronic device, at least one control signal to cause movement of the body within the swimming pool to, or away from, the first portion of the submerged surface.
4. A self-propelled pool cleaner for cleaning debris from a submerged surface of a swimming pool, comprising:
- a. a vehicle body;

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- b. means for moving the vehicle body within the swimming pool;
 - c. a filter configured to retain debris collected from the submerged surface;
 - d. at least one camera for capturing an image of at least a first portion of the submerged surface; and
 - e. a controller (i) positioned on or in the body, (ii) in electronic communication with the at least one camera, and (iii) configured to generate, in response to the captured image, at least one control signal to cause movement of the body within the swimming pool to, or away from, the first portion of the submerged surface.
5. A self-propelled pool cleaner for cleaning debris from a submerged surface of a swimming pool, comprising:
- a. a vehicle body;
 - b. means for moving the vehicle body within the swimming pool;
 - c. a filter configured to retain debris collected from the submerged surface;
 - d. a chemical dispenser on, in, or carried by the vehicle body;
 - e. at least one camera on, in, or carried by the vehicle body, for capturing an image of at least a first portion of the submerged surface; and
 - f. a controller (i) on, in, or carried by the vehicle body, (ii) in electronic communication with the at least one camera and (iii) configured to generate, in response to the captured image, at least one control signal to cause movement of the body within the swimming pool to, or away from, the first portion of the submerged surface.

* * * * *

EXHIBIT C

(12) **United States Patent**
Durvasula et al.(10) **Patent No.:** **US 11,003,191 B2**(45) **Date of Patent:** ***May 11, 2021**(54) **POOL CLEANING SYSTEM AND METHOD TO AUTOMATICALLY CLEAN SURFACES OF A POOL USING IMAGES FROM A CAMERA**(58) **Field of Classification Search**CPC .. G05D 1/0246; G05D 1/0016; G05D 1/0033;
G05D 1/0038; G05D 2201/0203;
(Continued)(71) Applicant: **ZODIAC POOL SYSTEMS LLC**,
Carlsbad, CA (US)(56) **References Cited**

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(Continued)(73) Assignee: **ZODIAC POOL SYSTEMS LLC**,
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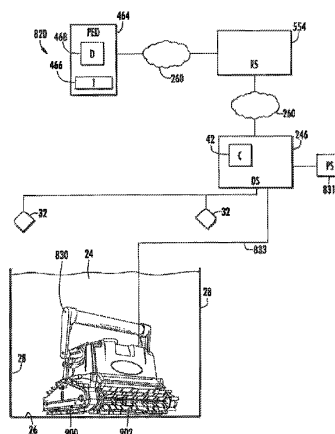
(22) Filed: **Jul. 2, 2020***Primary Examiner* — Allen C Wong(65) **Prior Publication Data**

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(74) *Attorney, Agent, or Firm* — Kilpatrick Townsend &
Stockton LLP; Dean W. Russell**Related U.S. Application Data**(63) Continuation of application No. 16/416,840, filed on
May 20, 2019, now Pat. No. 10,739,785, which is a
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G05D 1/02 (2020.01)
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(Continued)(52) **U.S. Cl.**
CPC **G05D 1/0246** (2013.01); **E04H 4/1654**
(2013.01); **G05D 1/0016** (2013.01);
(Continued)(57) **ABSTRACT**

A pool cleaning system for cleaning debris from a submerged surface of a swimming pool includes a self-propelled pool cleaner having rotatably-mounted supports for supporting and guiding the cleaner on the pool surface; an electric motor for enabling the rotation of the rotatably-mounted supports on the pool surface; at least one camera to capture imagery of the pool surface; a controller, in electronic communication with the at least one camera, to determine a cleanliness characteristic of the pool surface on which the cleaner has passed based on the camera imagery and generate a control signal to direct movement of the cleaner based on the cleanliness characteristic of the pool surface, and a portable electronic device configured to present a graphic on a display, the graphic depicting the

(Continued)



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submerged surface of the pool and those portions of the surface that remain uncleaned as the cleaner traverses the pool surface.

3 Claims, 4 Drawing Sheets

Related U.S. Application Data

continuation of application No. 15/973,983, filed on May 8, 2018, now Pat. No. 10,338,599, which is a continuation of application No. 15/207,065, filed on Jul. 11, 2016, now Pat. No. 9,995,051, which is a continuation of application No. 13/545,918, filed on Jul. 10, 2012, now Pat. No. 9,388,595.

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G05D 1/00 (2006.01)
H04N 5/225 (2006.01)
G06T 7/90 (2017.01)
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(52) **U.S. Cl.**

CPC **G05D 1/0033** (2013.01); **G05D 1/0038** (2013.01); **H04N 5/23203** (2013.01); **H04N 7/18** (2013.01); **G05D 2201/0203** (2013.01); **G06T 7/001** (2013.01); **G06T 7/90** (2017.01); **G06T 2207/10024** (2013.01); **H04N 2005/2255** (2013.01)

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(58) **Field of Classification Search**

CPC H04N 7/18; H04N 5/23203; H04N 2005/2255; E04H 4/1654; G06T 7/001; G06T 7/90; G06T 2207/10024
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See application file for complete search history.

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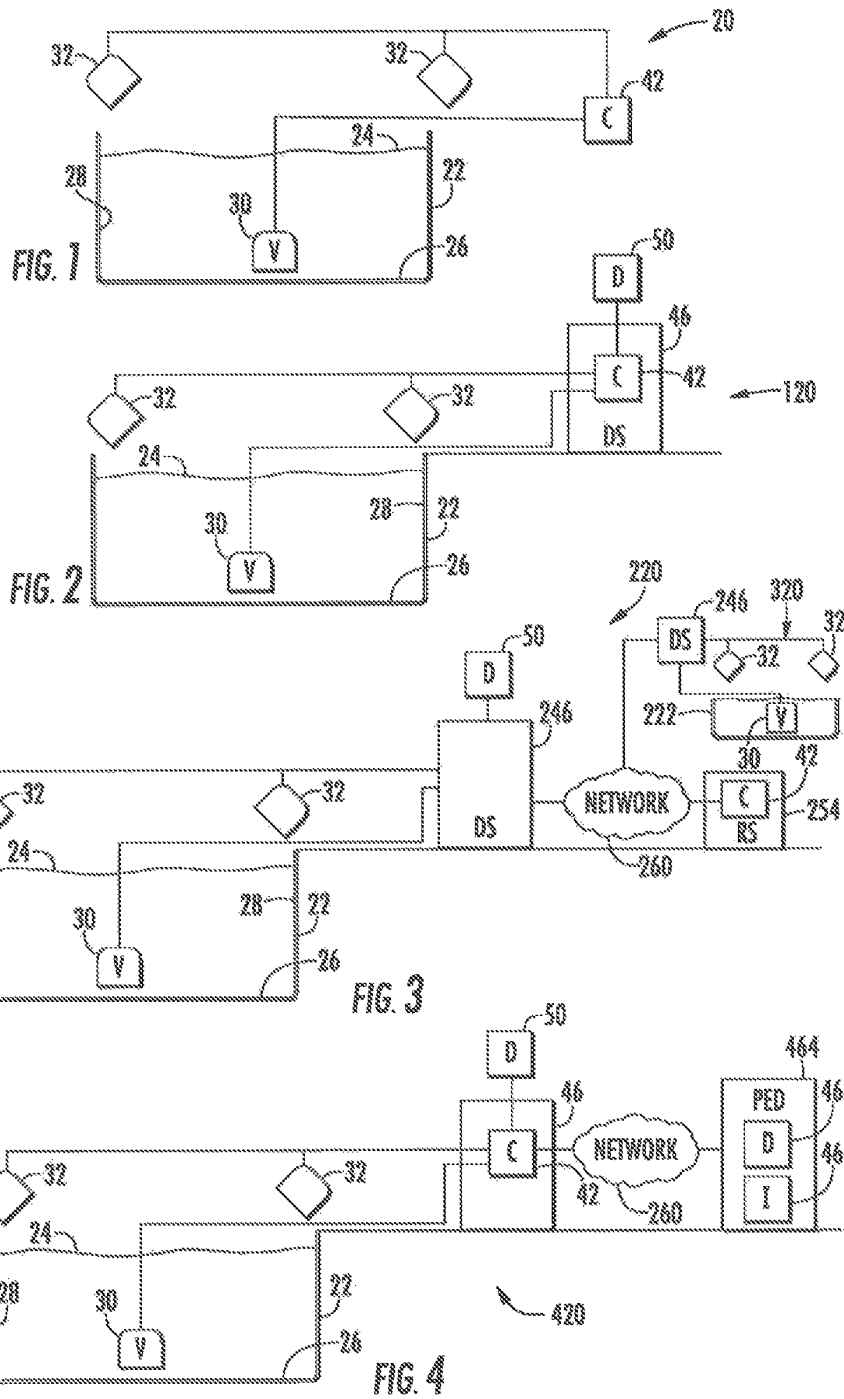
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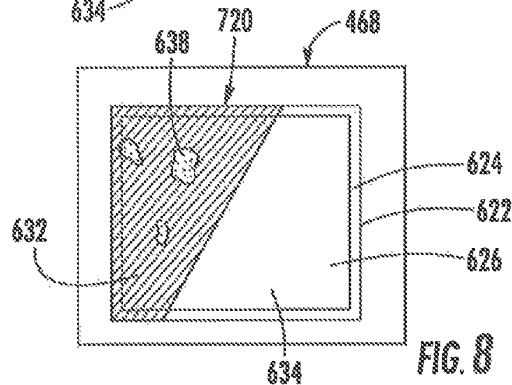
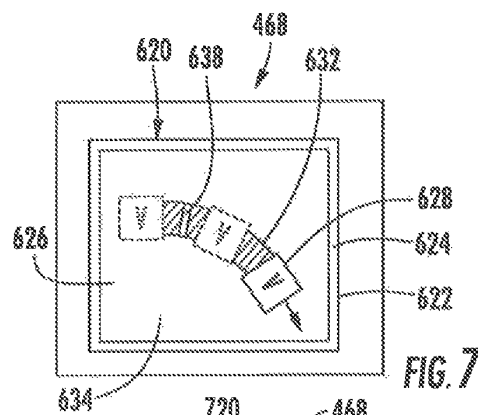
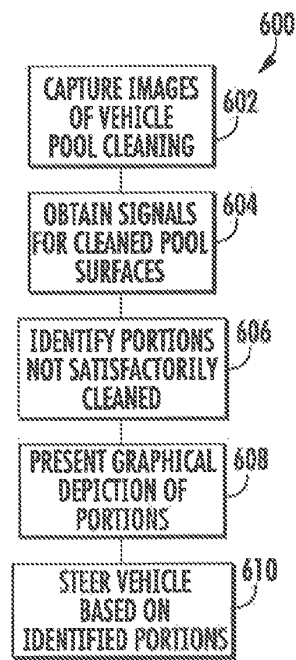
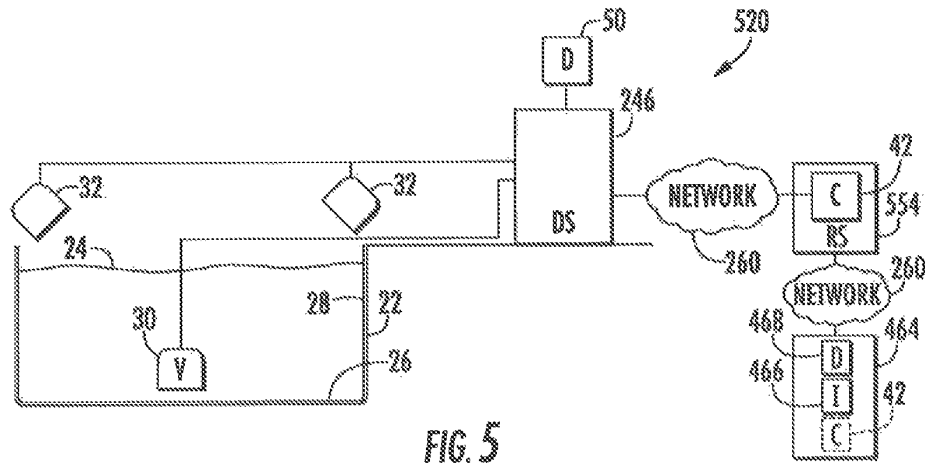


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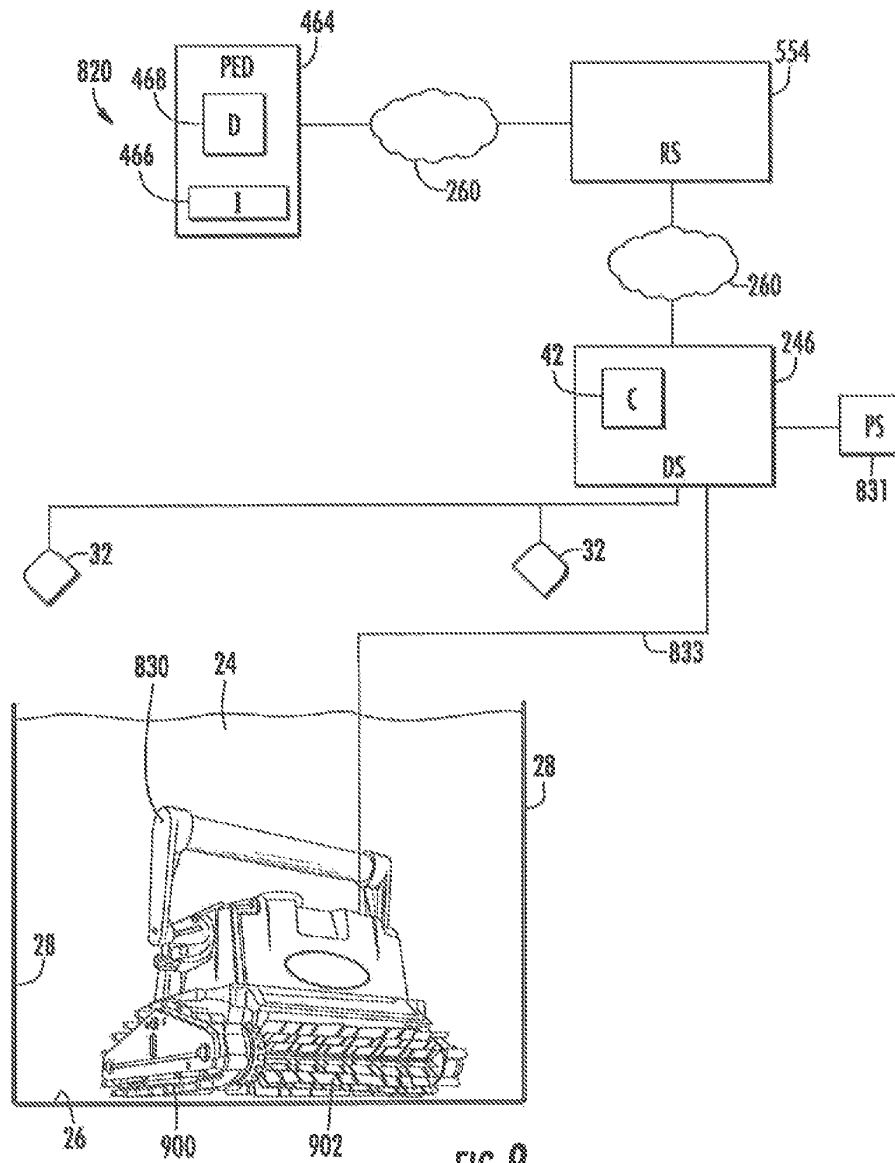


FIG. 9

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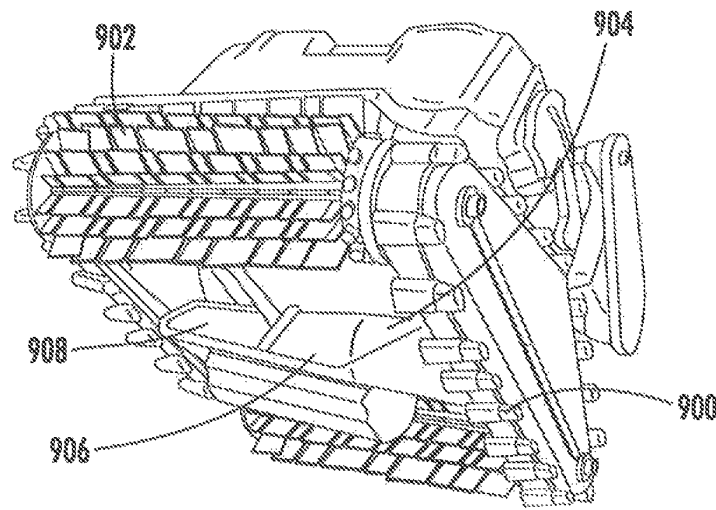


FIG. 10

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**POOL CLEANING SYSTEM AND METHOD
TO AUTOMATICALLY CLEAN SURFACES
OF A POOL USING IMAGES FROM A
CAMERA**

**CROSS-REFERENCE TO RELATED
APPLICATION**

This application is a continuation of U.S. patent application Ser. No. 16/416,840, filed May 20, 2019 (now allowed), which is a continuation of U.S. patent application Ser. No. 15/973,983, filed May 8, 2018 (now U.S. Pat. No. 10,338,599), which is a continuation of U.S. patent application Ser. No. 15/207,065, filed Jul. 11, 2016 (now U.S. Pat. No. 9,995,051), which is a continuation of U.S. patent application Ser. No. 13/545,918, filed Jul. 10, 2012 (now U.S. Pat. No. 9,388,595), the contents of all of which are incorporated herein by reference in their entireties.

BACKGROUND

Manually cleaning the floor and sides of a swimming pool may be a tedious and time-consuming task. As a result, automated robotic pool cleaners have been developed. However, controlling and monitoring such automated robotic pool cleaners to insure that all portions of the pool surfaces are satisfactorily cleaned remains a challenge.

SUMMARY OF THE INVENTION

The disadvantages heretofore associated with the prior art are overcome by the present invention of a pool cleaning system for cleaning debris from a submerged surface of a swimming pool comprising: a self-propelled pool cleaner having rotatably-mounted supports for supporting and guiding the cleaner on the pool surface; a filter configured to retain the debris collected from the submerged surface of the swimming pool; an electric motor for enabling the rotation of the rotatably-mounted supports on the pool surface; at least one camera to capture imagery of the pool surface; a controller, in electronic communication with the at least one camera, to determine a cleanliness characteristic of the pool surface on which the cleaner has passed based on the camera imagery and generate a control signal to direct movement of the cleaner based on the cleanliness characteristic of the pool surface; and a portable electronic device is configured to present a graphic on a display, the graphic depicting the submerged surface of the pool and those portions of the surface that remain uncleared as the cleaner traverses the pool surface.

In one aspect, the at least one camera is carried by the cleaner. In another aspect, the controller is carried by the cleaner. In still another aspect, the electric motor is mechanically connected to at least one of the rotatably-mounted supports.

In yet another aspect, the controller is operable to execute one or more cleaning programs for cleaning the submerged surfaces of the pool. In one aspect, the control signal causes the cleaner to drive in a direction to clean a portion of the pool surface based on the cleanliness characteristic of the pool surface. Alternatively, the control signal causes the cleaner to steer in a direction to clean a portion of the pool surface based on the cleanliness characteristic of the pool surface. In another aspect, the control signal causes the cleaner to drive in a direction to re-clean a portion of the pool surface over which the cleaner has passed. Alternatively,

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tively, the control signal causes the cleaner to steer in a direction to re-clean a portion of the pool surface over which the cleaner has passed.

In one aspect, the captured imagery from the at least one camera is digitally processed by the controller to determine the cleanliness characteristic of the pool surface. Alternatively, the captured imagery from the at least one camera is digitally processed by a remote processor to determine the cleanliness characteristic of the pool surface.

In another aspect, the system further comprises a dry station located remotely from the cleaner and in communication with the cleaner, wherein the dry station includes the controller. Alternatively, the system further comprises a dry station located remotely from the cleaner and in communication with the cleaner, wherein the controller is located remotely from the cleaner and the dry station. In still another aspect, the controller controls electric power provided to the electric motor.

In one aspect, the control signal causes the cleaner to move in a direction of a portion of the pool surface to be cleaned based solely upon signals received from the camera. In another aspect, the control signal causes the cleaner to drive in a direction to clean a portion of the pool surface based on the cleanliness characteristic of the pool surface. Alternatively, the control signal causes the cleaner to steer in a direction to clean a portion of the pool surface based on the cleanliness characteristic of the pool surface. In yet another aspect, the control signal causes the cleaner to drive in a direction to re-clean a portion of the pool surface over which the cleaner has passed. Alternatively, the control signal causes the cleaner to steer in a direction to re-clean a portion of the pool surface over which the cleaner has passed.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a schematic illustration of an example pool cleaning system.

FIG. 2 is a schematic illustration of an implementation of the pool cleaning system of FIG. 1.

FIG. 3 is a schematic illustration of an implementation of the pool cleaning system of FIG. 1.

FIG. 4 is a schematic illustration of an implementation of the pool cleaning system of FIG. 1.

FIG. 5 is a schematic illustration of an implementation of the pool cleaning system of FIG. 1.

FIG. 6 is a flow diagram of an example method that may be carried out with the pool cleaning system of FIG. 2-5.

FIG. 7 is a plan view of an example display with an example graphical depiction.

FIG. 8 is a plan view of another example display with an example graphical depiction.

FIG. 9 is a schematic illustration of an implementation of the pool cleaning system of FIG. 1 with an example pool cleaning vehicle.

FIG. 10 is a bottom perspective view of the example pool cleaning vehicle of the system of FIG. 9.

**DETAILED DESCRIPTION OF THE EXAMPLE
EMBODIMENTS**

FIG. 1 schematically illustrates an example pool cleaning system 20. As schematically shown by FIG. 1, pool cleaning system 20 is adapted to clean submerged surfaces of a pool 22 containing a liquid 24. In particular, pool cleaning system 20 is adapted to clean at least a bottom or floor surface 26 of the pool 22 and possibly to additionally clean surfaces 28 of pool 22. As will be described hereafter, pool cleaning

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system facilitates the control and monitoring of a robotic pool cleaner to better assure that all portions of pool 22 are satisfactorily cleaned.

Pool cleaning system 20 comprises vehicle 30, cameras 32 and controller 42. Vehicle 30 comprises an automated powered device configured to travel adjacent to submerged or water containing surfaces of pool 20 (such as floor 26 and/or side surfaces 28) while cleaning such surfaces. In one implementation, vehicle 30 may include vacuum or suction devices, a liquid circulation system and a filter to draw debris, such as bacterial growth or plant growth, from such pool surfaces, wherein the drawn liquid containing such residue or foreign matter is filtered to collect the debris. In other implementations, vehicle 30 may not collect such debris, wherein vehicle 30 merely loosens such debris on the pool surfaces such that the loosened or separated debris may be subsequently removed using the existing liquid filtering system of pool 22.

To assist in the loosening of debris, in one implementation, vehicle 30 may additionally include a chemical dispenser to closely apply pool cleaning chemicals to the pool surfaces as the vehicle 30 traverses such surfaces. In one implementation, vehicle 30 may additionally or alternatively include one or more scrubbing members, such as active (driven) or passive (undriven or idling) brushes, to assist in the removal of residue or foreign matter from such pool surfaces. In yet another implementation, vehicle 30 may additionally or alternatively include liquid jets to assist in the loosening of debris.

To move along the submerged surfaces of pool 22, vehicle 30 includes one or more propulsion mechanisms. In one implementation, vehicle 30 is propelled along the submerged pool surfaces using wheels, rollers, tracks or other surface contacting members powered by a motor and the like. Such wheels, rollers or tracks may themselves include the scrubbing members used to clean the surfaces. In one implementation vehicle 30 may also alternatively be propelled by means of the vacuum or liquid jets. The vacuum or liquid jets used for such propulsion nozzle facilitate loosening of debris for collection by vehicle 30. In other implementations, vehicle 30 may include other propulsion mechanisms.

Cameras 32 comprise devices configured to capture video or time lapse images of pool 22. In the example illustrated, cameras 32 are mounted on structures external to pool 22. In other words, cameras 32 are not submerged. In other implementations, cameras 32 may alternatively be mounted to vehicle 30. In the example illustrated, cameras 32 capture movement of vehicle 30 while vehicle 30 is submerged within pool 22. In other implementations, cameras 32 merely capture images of submerged surfaces 26, 28 of pool 22.

In the example illustrated, cameras 32 comprise cameras serving as part of a home or pool security system, wherein such cameras detect the presence of a person at pool 22 satisfying a predefined characteristic and wherein an alert is output upon the person's detected presence. For example, in one implementation, cameras 32 are utilized as part of a security system that detects when a person below a predefined age, such as a child, is present at pool 22 without a detected presence of a recognized adult. In another implementation, cameras 32 may detect the presence of an unauthorized person or intruder at pool 22. Identification of the person may be achieved by an off-site human or computerized monitoring system, wherein signals from cameras 32 are transmitted across a wide area network or may be

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achieved with software of controller 42 which includes facial recognition or other identification programming.

Because pool cleaning system 20 utilizes pre-existing cameras 32 provided as part of a security system or shares the use of cameras 32 with such a home or pool security system, pool cleaning system 20 is easier to set up, less complex and less expensive. In other implementations, pool cleaning system 20 may utilize dedicated cameras 22 independent of any cameras associated with a home, facility or pool security system. In such an alternative system, cameras 32 may be more precisely focused upon pool 22 and surfaces 26, 28 while also including appropriate lenses or modifications to account for glare, refraction and the like to better facilitate the capture of surfaces and vehicle 30 which are submerged.

Controller 42 comprises one or more processing units in communication with vehicle 30 and cameras 32. For purposes of this application, the term "processing unit" shall mean a presently developed or future developed processing unit that executes sequences of instructions contained in a memory. Execution of the sequences of instructions causes the processing unit to perform steps such as generating control signals. The instructions may be loaded in a random access memory (RAM) for execution by the processing unit from a read only memory (ROM), a mass storage device, or some other persistent storage. In other embodiments, hard wired circuitry may be used in place of or in combination with software instructions to implement the functions described. For example, controller 42 may be embodied as part of one or more application-specific integrated circuits (ASICs). Unless otherwise specifically noted, the controller is not limited to any specific combination of hardware circuitry and software, nor to any particular source for the instructions executed by the processing unit.

In one implementation, controller 42 communicates with vehicle 30 and cameras 32 entirely across a wired connection. In another implementation, controller 42 communicates with vehicle 30 and cameras 32 across a wireless connection, such as across a local area network (LAN) or a wide area network (WAN) such as the Internet. One of limitation, controller 42 may communicate with vehicle 30 and cameras 32 using a combination of both wired and wireless communication connections.

Controller 42 is configured to generate control signals for steering vehicle 30 based upon signals received from cameras 32. In one implementation, controller 42 provides the sole steering directions for vehicle 30 using signals from cameras 32. Because vehicle 30 is precisely steered under the control of controller 42, rather than traveling in a random manner, entire summer surfaces of pool 22 may be more quickly and efficiently covered and cleaned. Because controller 42 provides the only steering instructions for vehicle 30 and utilizes signals from cameras 32, complex steering algorithms or codes in either vehicle 30 or controller 42 may be omitted to reduce complexity and cost of system 20.

In another implementation, vehicle 30 may cover or travel across surfaces of pool 22 in either a random fashion or according to an automated pool coverage algorithm or pool coverage pattern stored in a memory associated with vehicle 30 or controller 42. In such an implementation, controller 42 utilizes signals from cameras 32 to verify that all of the surfaces of pool 22 have been cleaned, that no spots have been missed. Upon identifying a missed spot, controller 42 utilizes signals from camera 32 to steer vehicle 32 over such missed portions of surfaces 26, 28. According to one example, controller 42 not only uses signals from camera 32 to determine whether any portions of surfaces 26, 28 have

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been missed entirely, but to also determine whether any portions of surfaces 26,28 have been cleaned, but not to a satisfactory degree or extent. In such circumstances, controller 42 uses signals from cameras 32 to steer vehicle 34 such areas to re-clean such portions until such portions have been satisfactorily cleaned such that the portions have a cleanliness characteristic satisfying a predefined threshold.

FIG. 2 schematically illustrates pool cleaning system 120, the particular example of pool cleaning system 20 described above. Pool cleaning system 120 is similar to pool cleaning system 20 except that pool cleaning system 120 additionally comprises dry station 46 and display 50. Those remaining components of pool cleaning system 120 which correspond to components of pool cleaning system 20 are numbered similarly.

Dry station 46 comprises a station in communication with vehicle 30 and cameras 32 outside of pool 22. Dry station 46 incorporates controller 42. In one implementation, dry station 46 communicates with vehicle 30 in a wired fashion. In such an implementation, dry station 46 further provides electrical power to vehicle 30 in a wired fashion. Dry station 46 communicates with cameras 32 and either a wired or wireless fashion.

Display 50 comprises a device to present a graphical images and text on a display screen. In one implementation, display 58 may be incorporated as part of dry station 46. In another implementation, display 50 may be provided on a portable electronic device, a computer, a television and the like. Display 50 is utilized by pool cleaning system 120 to present information regarding the cleaning of pool 22 to facilitate control of vehicle 30 by controller 42. In one implementation, display 50 is utilized by pool cleaning system 120 and a controller 42 to present a graphical depiction of those portions of surfaces 26, 28 of pool 22 have not been satisfactorily cleaned so as to satisfy a predefined cleanliness characteristic threshold. Such portions may comprise portions that have been completely missed by vehicle 30 as well as those portions that have been covered by vehicle 30 but have not been satisfactorily cleaned with the given number of passes of vehicle 30 or the existing cleaning settings of vehicle 30. The graphical depiction presented on display 50 enables a person view the quality of the prior cleaning session and to input commands causing controller 42 to generate control signals using signals from camera 32 to steer vehicle 30 back to such identified portions where such portions may be cleaned at the same or elevated cleaning aggressiveness settings.

Another implementation, display 50 may be further utilized by controller 42 to depict the progress of vehicle 30 in cleaning pool 22. Such a display 50 allows a person to visually determine how much of the pool has been currently cleaned and to estimate the remaining time before the pool cleaning task is completed. In certain circumstances, using display 50, a person may adjust a setting of vehicle 30 to accelerate a rate at which surfaces 26, 20 of pool 22 are cleaned to meet an earlier desired completion time for such pool cleaning.

FIG. 3 schematically illustrates pool cleaning system 220, another example implementation of pool cleaning system 20. Pool cleaning system 220 is similar to pool cleaning system 20 except that pool cleaning system 220 additionally comprises dry station 246, display 50, and remote server 254. Those remaining components of pool cleaning system 220 which correspond to components of pool cleaning system 20 or pool cleaning system 120 are numbered similarly.

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Dry station 246 is similar to dry station 46, described above, except that dry station 246 serves as a local interface for communication with controller 42 across a network 260. In one implementation, network 260 may comprise a local area network. In another implementation, network 260 may comprise a wide area network, such as the Internet. For example, in one implementation, dry station 246 may incorporate a modem. In one implementation, dry station 246 may communicate across a local area network to controller 42. In another implementation, dry station 246 may communicate through a router, across a local area network, to a local modem which communicates across a network 260. The example illustrated, dry station 246 further provides part of vehicle 30 across a wired cable or wired connection. Display 50 is described above with respect to system 120.

Remote server 254 comprises a server remote from dry station 246 which is in communication with dry station 246 across network 260. Remote server 254 includes controller 42. During operation, signals from cameras 32 are transmitted across dry station 246 across network 260 to controller 42 of remote server 254. Based upon such signals from cameras 32, controller 42 generates control signals which are transmitted back across network 260 and through dry station 246 to vehicle 30 to steer vehicle 30.

As shown by FIG. 3, remote server 254 and network 260 may be shared as part of other pool cleaning systems 320, wherein controller 42 generates control signals for steering the pool cleaning vehicle 30 of system 320 based upon signals from cameras 32 transmitted across dry station 246 of system 320. In such an implementation, the cost and complexity of pool cleaning system 220 is reduced since controller 42 is remotely provided at remote server 254 which services multiple pool cleaning systems 220,320. Upgrades to controller 42 and its software are also more easily achieved for all pool cleaning systems to 20, 320 and their pools 22, 222 being serviced. In one implementation, the supervised cleaning, inspection and possible re-cleaning facilitated by the use of cameras 32 may be provided as part of a subscription to users of vehicle 30. In such an implementation, a pool 22 having security cameras 32 may be upgraded with appropriate software or an appropriate software module added to dry station 246 to make a network connection with controller 42 which directs the security cameras 32 to capture vehicle 30 utilizes such signals for steering vehicle 30.

FIG. 4 schematically illustrates pool cleaning system 420, another particular implementation of pool cleaning system 20. Pool cleaning system 420 is similar to pool cleaning system 120 except that pool cleaning system 420 additionally comprises a portable electronic device 464. Those remaining components of pool cleaning system 420 which correspond to components of pool cleaning system 120 are numbered similarly.

Portable electronic device 464 comprises a portable handheld electronic device in communication with controller 42 and/or dry station 46 across network 260. Examples of such a portable electronic device (PED) 300 include, but are not limited to, a smart phone, a personal data assistant (PDA), laptop, notebook computer, tablet computer (e.g. IPAD) and MP3 player (e.g., IPOD TOUCH). In the example illustrated, PED 464 comprises input 466 and display 468.

Input 466 serves as a user interface for PED 464 by which inputs are made to PED 464. Input 466 facilitates entry of inputs or commands by a person to cause controller 42 to generate control signals varying the control of vehicle 30. In one implementation, input 466 comprise a keyboard in other implementations, input 466 may comprise a touchpad, a

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stylus, a microphone with associated speech recognition software or programming, a touch screen, buttons, switches and the like. In some implementations, input 466 may comprise a touch screen incorporated as part of display 468.

Display 468 comprises a user interface by which graphical or textual data is presented to a user. Display 468 may present the same or similar information as presented at dry station 246 by display 50 as described above. In one implementation, display 468 comprises a liquid crystal display. In other implementations, display 468 may comprise other types of display technology such as a light emitting diode display, an organic light emitting diode display (OLED), an electronic ink (e-ink) display or other types of display technology in present use or developed in the future. Although system 420 is illustrated as including controller 422 is part of dry station 46, in some implementations, controller 42 may alternatively be located as part of PED 464.

PED 464 enables a person located remote from pool 22 to monitor the progress of the cleaning of pool 22 by vehicle 30 of system 420. PED 464 provides a person with a graphical presentation (described above with respect to display 50) indicating those portions of surfaces 26, 28 of pool 22 that have been completed as well as those portions 26, 20 and that remain to be cleaned. The person may also be provided with a graphical indication of what portions need to be re-cleaned to meet predetermined cleanliness thresholds. In the example illustrated, input 466 enables a person to enter commands or selections which are transmitted across network 260 to controller 42 to adjust operation of vehicle 30. For example, the path or route of vehicle 30 may be changed, the aggressiveness of the cleaning chemicals or mechanical cleaning devices may be adjusted, the speed at which vehicle 30 traverses surfaces 26, 28 may be adjusted. In response to such adjustment signals from PED 464, controller 42 may utilize signals from cameras 32 to adjust the steering of vehicle 30.

FIG. 5 schematically illustrates pool cleaning system 520, another example implementation of pool cleaning system 20. Pool cleaning system 520 is similar to pool cleaning system 420 except that pool cleaning system 520 additionally comprises a remote server 554. Those remaining components of pool cleaning system 520 which correspond to components of pool cleaning system 420 are numbered similarly.

Remote server 554 is similar to remote server 254 described above with respect to system 220. Remote server 554 comprises a server remote from dry station 246 which is in communication with dry station 246 across network 260. Remote server 254 includes controller 42. During operation, signals from cameras 32 are transmitted across dry station 246 across network 260 to controller 42 of remote server 254. Based upon such signals from cameras 32, controller 42 generates control signals which are transmitted back across network 260 and through dry station 246 to vehicle 30 to steer vehicle 30. Controller 42 further relays either the raw signals from camera 32 or image signals generated based upon signals from cameras 32 to PED 464, wherein such images (described above) are presented on display 468. As noted above, PED may further receive commands through input 466, wherein such commands are transmitted to controller 42 which generates control signals that are ultimately transmitted to vehicle 30 for steering vehicle 30.

As with remote server 254, remote server 554 and network 260 may be shared as part of other pool cleaning systems 320 (shown in FIG. 3), wherein controller 42

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generates control signals for steering the pool cleaning vehicle 30 of system 320 based upon signals from cameras 32 transmitted across dry station 246 of system 320. In such implementations, controller 42 of remote server 554 may interact with other PEDs 464. In such an implementation, the cost and complexity of pool cleaning system 220 is reduced since controller 42 is remotely provided at remote server 254 which services multiple pool cleaning systems 220, 320. Upgrades to controller 42 and its software are also more easily achieved for all pool cleaning systems to 20, 320 and their pools 22, 222 being serviced. In one implementation, the supervised cleaning, inspection and possible re-cleaning facilitated by the use of cameras 32 may be provided as part of a subscription to users of vehicle 30. In such an implementation, a pool 22 having security cameras 32 may be upgraded with appropriate software or an appropriate software module added to dry station 246 to make a network connection with controller 42 which directs the security cameras 32 to capture vehicle 30 utilizes such signals for steering vehicle 30. As indicated by broken lines, in other implementations, the controller 42 for generating control signals steering vehicle 30 based upon signals from cameras 32 may alternatively be relocated in PED 464.

FIG. 6 is a flow diagram illustrating an example method 600 that may be carried out by any of systems 120-520. As indicated by step 602, cameras 32 capture images of pool cleaning by vehicle 30. As indicated by step 604, controller 42 obtain such signals from cameras 32 for the surfaces of pool 22 that have been cleaned. As indicated by step 606, controller 42 uses information gathered from the signals from cameras 32 to identify those portions of surfaces 26, 28 not satisfactorily cleaned—not satisfying a predefined cleanliness characteristic or measurement threshold. One example of a cleanliness characteristic measurement a threshold may be how well the color of a surface matches a predetermined desirable color for the pool surface (such as original color of the tile or surface). A surface that has been missed entirely by vehicle 30 during a pool cleaning session may be automatically deemed to not satisfy a predetermined cleanliness characteristic.

As indicated by step 608, based upon such determinations, controller 42 generates control signals resulting in the presentation of a graphical depiction of those portions of pool 22 that has not been satisfactorily cleaned. Such graphical representations or depictions may be presented on display 50 or display 468. FIGS. 7 and 8 illustrate examples of graphical depictions that may be presented.

FIG. 7 illustrates display 468 presenting graphical depiction 620. Graphical depiction 620 comprises a first graphic 622 having a first portion 624 representing sides or walls 28 of pool 22 and a second portion 626 representing the floor 26 of pool 22. Graphical depiction 620 further comprises a moving icon 628 representing the current positioning of vehicle 30. In one implementation, the path of vehicle 30 may additionally be depicted by icon 628 shown in broken lines. As shown by FIG. 7, those portions 632 of surfaces 26, 28 of pool 22 (shown in FIG. 1) over which of vehicle 30 has moved are identified by graphical depiction 620 either by color, markings or other various distinctive attributes. Likewise, those portions 634 of surfaces 26, 28 of pool 22 that have not been covered by vehicle 30 are identified by a distinct color col marking or distinctive attribute of depiction 620. As a result, a person may view the current position of vehicle 30, the extent to which pool 22 has been cleaned or covered by vehicle 30 and the extent of pool 22 that remains to be cleaned. In the example illustrated, depiction 620 further identifies those portions 638 of surfaces 26, 28

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that have been cleaned, but which have not been cleaned to a satisfactory degree or extent. In one implementation, portions 638 may be identified by colors, brightness, markings or other visually distinctive attributes that are visually distinct from both portions 632 and portions 634. In other implementations, portions 638 may have the same characteristic of portions 634. In yet other implementations, different portions 638 may have different visual attributes depending upon a degree to which such clean portions have failed to satisfy the predefined cleanliness characteristic threshold. In some implementations, different port 638 may have different visual attributes depending upon different cleaning strategies that may be recommended for the different portions 638. For example, controller 42 may determine and recommend a first cleaning strategy (a first chemical solution jetted at a first rate and scrubbed at a first rate) with respect to a first portion 638 and may recommend a second different cleaning strategy (a second chemical solution jetted at a second rate is about a second rate) with respect to a second portion 638, wherein the different cleaning strategies are represented by different visual attributes presented in depiction 620.

FIG. 8 illustrates display 468 presenting a graphical depiction 720. Graphical depiction 720 comprises a first graphic 622 having a first portion 624 representing sides or walls 28 of pool 22 and a second portion 626 representing the floor 26 of pool 22 (shown in FIG. 1). Graphical depiction 720 is similar to graphical depiction 620 except that graphical depiction 720 omits icon 628 representing vehicle 30. Like depiction 620, depiction 720 graphically depicts those portions 632 of surfaces 26, 28 over which vehicle 30 has traveled while in a cleaning mode. Depiction 720 also visually depicts those portions 634 that have not been covered by vehicle 30 in the cleaning mode and those portions 638 over which vehicle 30 has traveled while in the cleaning mode, but which have not been cleaned to a satisfactory degree. As illustrated in FIG. 8, different portions 638 may be visibly distinguished from one another through color, text or markings indicating either differences in the cleanliness of such portions 638 or indicating different recommended cleaning strategies or approaches that may be selected by a person using input 466 when vehicle 30 is steered back to such portions 638 for re-cleaning using signals from camera 32.

As indicated by step 610 of FIG. 6, controller 42 generates control signals steering vehicle 30 to re-clean portions of pool 22, such as portions 638. Such steering may be facilitated by using signals from cameras 32. As noted above, in some implementations, a person may be allowed choose a cleaning approach for a particular portion 638 using input 466. The selection may be facilitated by visual inspection of the different visual attributes for the particular portion 638 provided by depiction 720 (or depiction 620). In some implementations, input 466 may additionally be utilized by a person to prioritize an order in which portions 638 are re-cleaned.

FIG. 9 illustrates pool cleaning system 820, an example implementation of pool cleaning system 20. Pool cleaning system 820 is similar to pool cleaning system 520 except the pool cleaning system 820 located controller 42 in dry station 246 and includes pool cleaning vehicle 830, a specific example of vehicle 30. As shown by FIG. 9, in addition to transmitting control signals generated by controller 42 to vehicle 830, dry station 246 further transmits power from power source 831 through a power line or power cable 833 to vehicle 830. In the example illustrated, data communication and communication of control signals, also occurs

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across wired connections within or alongside the same line 833. In the example illustrated, remote server 554 serves as a communication link by which upgrades to controller 42 may be implemented across a wide number of pool cleaning systems and by which information from controller 42 is conveyed to one or more portable electronic devices 464 across network 260.

Vehicle 830 comprises a robotic or automated pool cleaning device. Vehicle 830 comprises a self-contained onboard filtration system with drive and pump motors. Vehicle 830 utilizes an internal microprocessor guided drive motor to systematically clean surfaces of pool 22. As shown by FIGS. 9 and 10, vehicle 830 utilizes a toothed track drive 900 provide traction and propulsion for vehicle 30. Vehicle 830 comprises rotating brushes 902 to loosen waterline buildup and breakdown large debris while power washing jets 904 flush out dirt from pores, seams in corners where brushes 902 may not be able to reach. The loosened dirt and debris is vacuumed through off-center vacuum ports 906 which passes the vacuumed debris through internally house filter bag. In the example illustrated, vehicle 830 further comprises rollers 908 which inhibit vehicle 830 from becoming impeded or stuck on raised drains or pop-up heads. Although illustrated as being employed with system 820, vehicle 830 may also be utilized with any of systems 20, 120, 220, 320 and 420. In other implementations, other robotic or automated pool cleaning vehicles may be utilized.

Although the present disclosure has been described with reference to example embodiments, workers skilled in the art will recognize that changes may be made in form and detail without departing from the spirit and scope of the claimed subject matter. For example, although different example embodiments may have been described as including one or more features providing one or more benefits, it is contemplated that the described features may be interchanged with one another or alternatively be combined with one another in the described example embodiments or in other alternative embodiments. Because the technology of the present disclosure is relatively complex, not all changes in the technology are foreseeable. The present disclosure described with reference to the example embodiments and set forth in the following claims is manifestly intended to be as broad as possible. For example, unless specifically otherwise noted, the claims reciting a single particular element also encompass a plurality of such particular elements.

What is claimed is:

1. A self-propelled pool cleaner for cleaning debris from a submerged surface of a swimming pool, comprising:
 - a. a vehicle body;
 - b. means for moving the vehicle body within the swimming pool;
 - c. a filter configured to retain debris collected from the submerged surface;
 - d. at least one camera positioned on or in the body for capturing an image of at least a first portion of the submerged surface; and
 - e. a controller (i) positioned on or in the body, (ii) in electronic communication with the at least one camera, and (iii) configured to generate, in response to the captured image, at least one control signal to cause movement of the body within the swimming pool to, or away from, the first portion of the submerged surface.
2. A system for cleaning debris from a submerged surface of a swimming pool, comprising:

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- a. a self-propelled pool cleaner comprising:
 - i. a vehicle body;
 - ii. means for moving the vehicle body within the swimming pool;
 - iii. at least one camera positioned on or in the body for capturing an image of at least a first portion of the submerged surface; and
 - iv. a controller (i) positioned on or in the body, (ii) in electronic communication with the at least one camera, and (iii) configured to generate, in response to the captured image, at least one control signal to cause movement of the body within the swimming pool to, or away from, the first portion of the submerged surface; and
 - b. a filter configured to retain debris collected from the submerged surface by the self-propelled pool cleaner.
3. A system for cleaning debris from a submerged surface of a swimming pool, comprising:

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- a. a self-propelled pool cleaner comprising:
 - i. a vehicle body;
 - ii. means for moving the vehicle body within the swimming pool;
 - iii. a filter configured to retain debris collected from the submerged surface; and
 - iv. at least one camera positioned on or in the body for capturing an image of at least a first portion of the submerged surface; and
- b. a controller (i) in electronic communication with the at least one camera and (ii) configured to generate, in response to the captured image, at least one control signal to cause movement of the body within the swimming pool to, or away from, the first portion of the submerged surface.

* * * * *

EXHIBIT D

(12) **United States Patent**
Durvasula et al.(10) **Patent No.:** **US 10,739,785 B2**(45) **Date of Patent:** ***Aug. 11, 2020**(54) **POOL CLEANING SYSTEM AND METHOD TO AUTOMATICALLY CLEAN SURFACES OF A POOL USING IMAGES FROM A CAMERA**(58) **Field of Classification Search**CPC .. G05D 1/0246; G05D 1/0016; G05D 1/0033;
G05D 1/0038; G05D 1/0206;

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(71) Applicant: **AQUA PRODUCTS, INC.**, Cedar Grove, NJ (US)(56) **References Cited**

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(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 0 days.

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This patent is subject to a terminal disclaimer.

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(21) Appl. No.: **16/416,840**(22) Filed: **May 20, 2019***Primary Examiner* — Allen C Wong(65) **Prior Publication Data**

US 2019/0271987 A1 Sep. 5, 2019

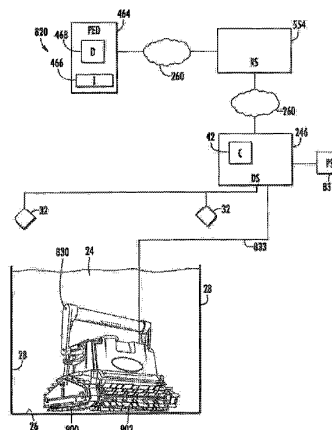
(74) *Attorney, Agent, or Firm* — Kilpatrick Townsend & Stockton LLP; Dean W. Russell**Related U.S. Application Data**

(63) Continuation of application No. 15/973,983, filed on May 8, 2018, now Pat. No. 10,338,599, which is a (Continued)

(51) **Int. Cl.**
G05D 1/02 (2020.01)
H04N 7/18 (2006.01)
(Continued)(52) **U.S. Cl.**
CPC **G05D 1/0246** (2013.01); **E04H 4/1654** (2013.01); **G05D 1/0016** (2013.01);
(Continued)(57) **ABSTRACT**

A pool cleaning system for cleaning debris from a submerged surface of a swimming pool includes a self-propelled pool cleaner having rotatably-mounted supports for supporting and guiding the cleaner on the pool surface; an electric motor for enabling the rotation of the rotatably-mounted supports on the pool surface; at least one camera to capture imagery of the pool surface; a controller, in electronic communication with the at least one camera, to determine a cleanliness characteristic of the pool surface on which the cleaner has passed based on the camera imagery and generate a control signal to direct movement of the cleaner based on the cleanliness characteristic of the pool surface, and a portable electronic device configured to present a graphic on a display, the graphic depicting the

(Continued)



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submerged surface of the pool and those portions of the surface that remain uncleaned as the cleaner traverses the pool surface.

6 Claims, 4 Drawing Sheets

Related U.S. Application Data

continuation of application No. 15/207,065, filed on Jul. 11, 2016, now Pat. No. 9,995,051, which is a continuation of application No. 13/545,918, filed on Jul. 10, 2012, now Pat. No. 9,388,595.

- (51) **Int. Cl.**
H04N 5/232 (2006.01)
E04H 4/16 (2006.01)
G05D 1/00 (2006.01)
H04N 5/225 (2006.01)
G06T 7/90 (2017.01)
G06T 7/00 (2017.01)
- (52) **U.S. Cl.**
CPC **G05D 1/0033** (2013.01); **G05D 1/0038** (2013.01); **H04N 5/23203** (2013.01); **H04N 7/18** (2013.01); **G05D 2201/0203** (2013.01); **G06T 7/001** (2013.01); **G06T 7/90** (2017.01); **G06T 2207/10024** (2013.01); **H04N 2005/2255** (2013.01)

- (58) **Field of Classification Search**
CPC G05D 1/0253; G05D 2201/0203; H04N 5/23203; H04N 7/18; H04N 2005/2255; E04H 4/1654; G06T 7/90; G06T 7/001; G06T 2207/10024; B08B 9/08; B08B 9/46
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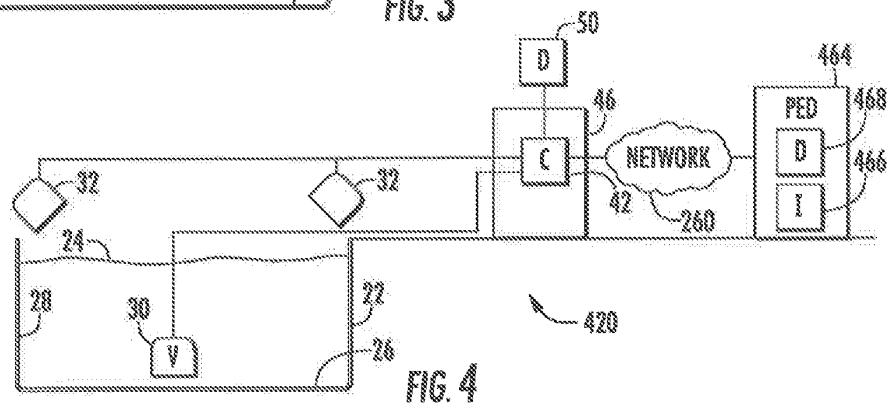
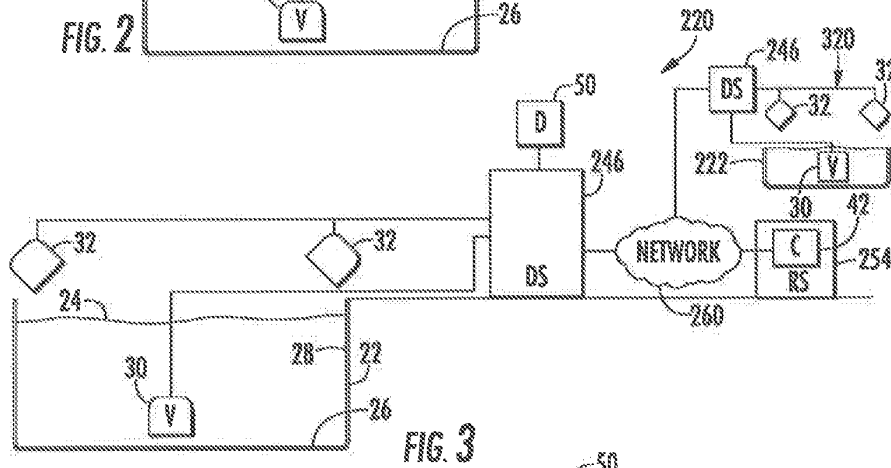
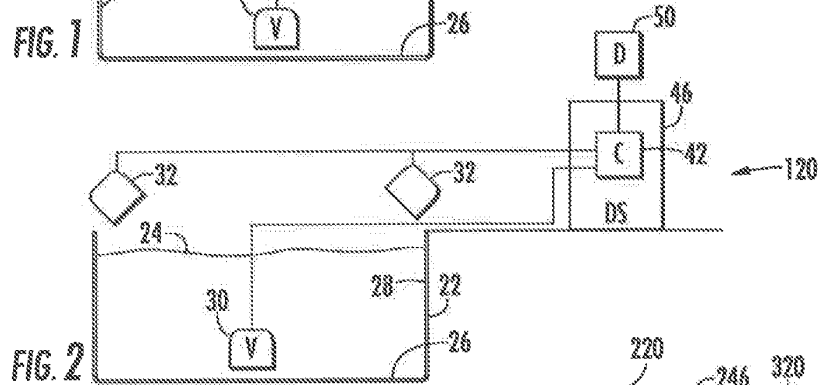
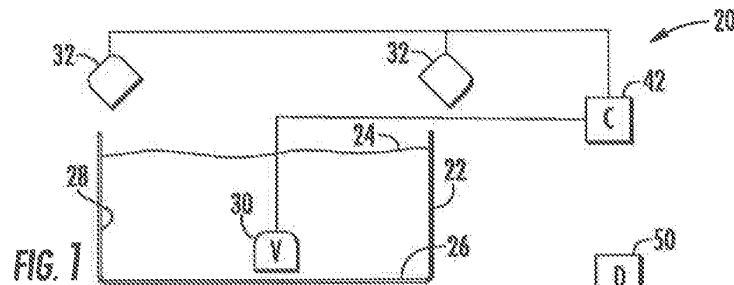
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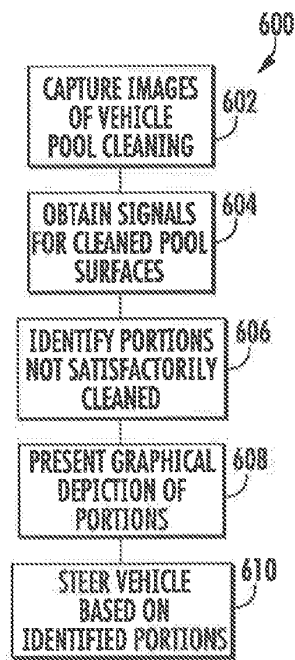
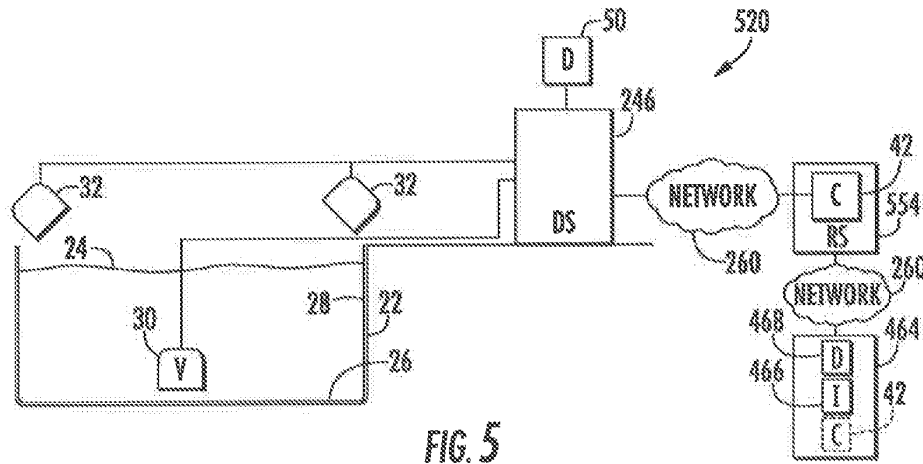


FIG. 6

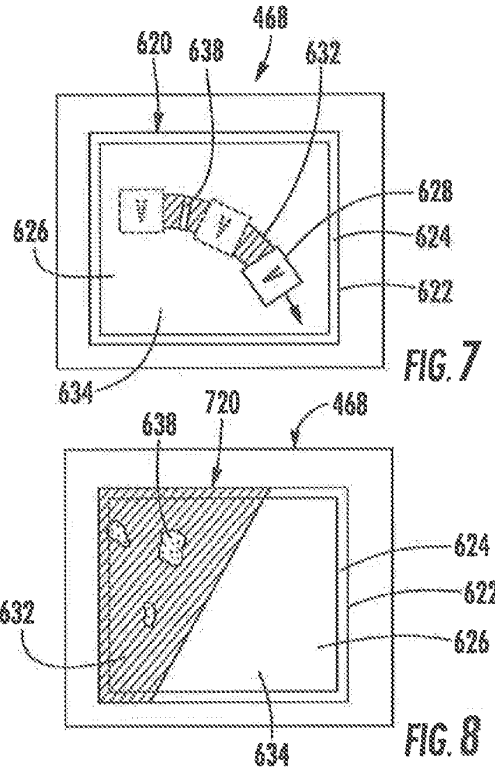


FIG. 7

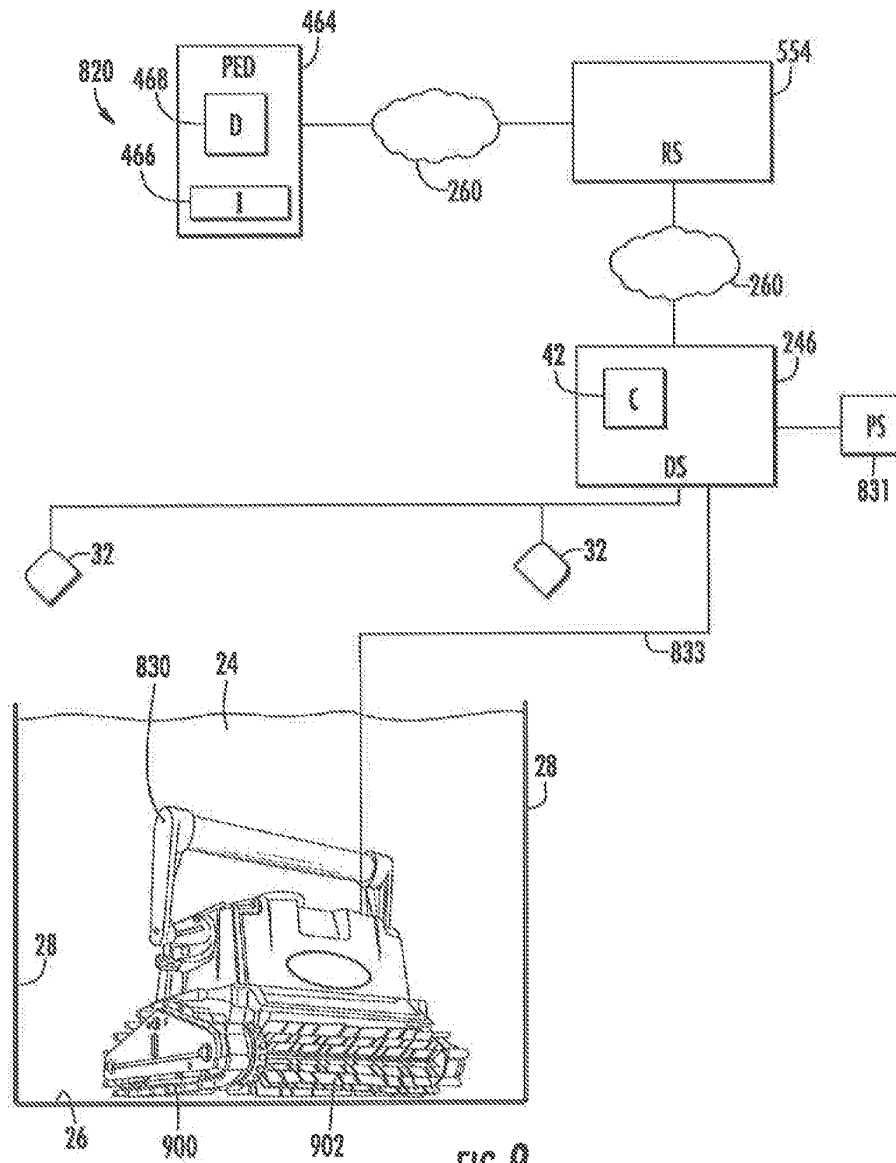
FIG. 8

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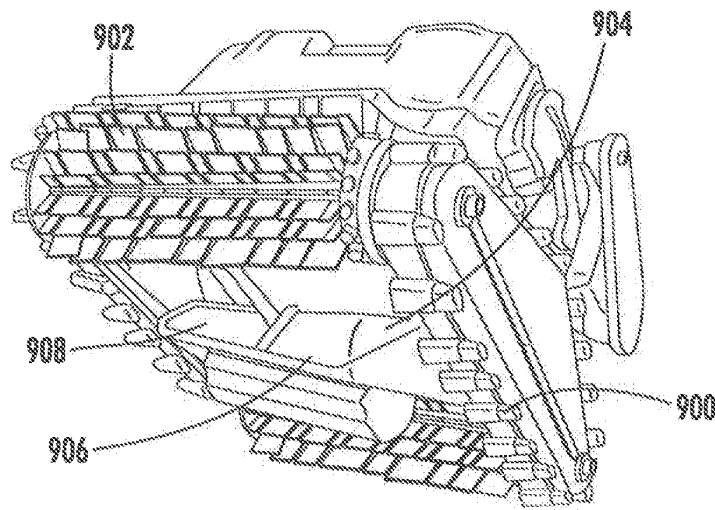


FIG. 10

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**POOL CLEANING SYSTEM AND METHOD
TO AUTOMATICALLY CLEAN SURFACES
OF A POOL USING IMAGES FROM A
CAMERA**

**CROSS-REFERENCE TO RELATED
APPLICATION**

This application is a continuation of commonly owned U.S. patent application Ser. No. 15/973,983, filed May 8, 2018, which is a continuation of U.S. patent application Ser. No. 15/207,065, filed Jul. 11, 2016 (now U.S. Pat. No. 9,995,051), which is a continuation of U.S. patent application Ser. No. 13/545,918, filed Jul. 10, 2012 (now U.S. Pat. No. 9,388,595), the contents of all of which are incorporated herein by reference in their entireties.

BACKGROUND

Manually cleaning the floor and sides of a swimming pool may be a tedious and time-consuming task. As a result, automated robotic pool cleaners have been developed. However, controlling and monitoring such automated robotic pool cleaners to insure that all portions of the pool surfaces are satisfactorily cleaned remains a challenge.

SUMMARY OF THE INVENTION

The disadvantages heretofore associated with the prior art are overcome by the present invention of a pool cleaning system for cleaning debris from a submerged surface of a swimming pool comprising: a self-propelled pool cleaner having rotatably-mounted supports for supporting and guiding the cleaner on the pool surface; a filter configured to retain the debris collected from the submerged surface of the swimming pool; an electric motor for enabling the rotation of the rotatably-mounted supports on the pool surface; at least one camera to capture imagery of the pool surface; a controller, in electronic communication with the at least one camera, to determine a cleanliness characteristic of the pool surface on which the cleaner has passed based on the camera imagery and generate a control signal to direct movement of the cleaner based on the cleanliness characteristic of the pool surface; and a portable electronic device is configured to present a graphic on a display, the graphic depicting the submerged surface of the pool and those portions of the surface that remain uncleaned as the cleaner traverses the pool surface.

In one aspect, the at least one camera is carried by the cleaner. In another aspect, the controller is carried by the cleaner. In still another aspect, the electric motor is mechanically connected to at least one of the rotatably-mounted supports.

In yet another aspect, the controller is operable to execute one or more cleaning programs for cleaning the submerged surfaces of the pool. In one aspect, the control signal causes the cleaner to drive in a direction to clean a portion of the pool surface based on the cleanliness characteristic of the pool surface. Alternatively, the control signal causes the cleaner to steer in a direction to clean a portion of the pool surface based on the cleanliness characteristic of the pool surface. In another aspect, the control signal causes the cleaner to drive in a direction to re-clean a portion of the pool surface over which the cleaner has passed. Alternatively, the control signal causes the cleaner to steer in a direction to re-clean a portion of the pool surface over which the cleaner has passed.

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In one aspect, the captured imagery from the at least one camera is digitally processed by the controller to determine the cleanliness characteristic of the pool surface. Alternatively, the captured imagery from the at least one camera is digitally processed by a remote processor to determine the cleanliness characteristic of the pool surface.

In another aspect, the system further comprises a dry station located remotely from the cleaner and in communication with the cleaner, wherein the dry station includes the controller. Alternatively, the system further comprises a dry station located remotely from the cleaner and in communication with the cleaner, wherein the controller is located remotely from the cleaner and the dry station. In still another aspect, the controller controls electric power provided to the electric motor.

In one aspect, the control signal causes the cleaner to move in a direction of a portion of the pool surface to be cleaned based solely upon signals received from the camera. In another aspect, the control signal causes the cleaner to drive in a direction to clean a portion of the pool surface based on the cleanliness characteristic of the pool surface. Alternatively, the control signal causes the cleaner to steer in a direction to clean a portion of the pool surface based on the cleanliness characteristic of the pool surface. In yet another aspect, the control signal causes the cleaner to drive in a direction to re-clean a portion of the pool surface over which the cleaner has passed. Alternatively, the control signal causes the cleaner to steer in a direction to re-clean a portion of the pool surface over which the cleaner has passed.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a schematic illustration of an example pool cleaning system.

FIG. 2 is a schematic illustration of an implementation of the pool cleaning system of FIG. 1.

FIG. 3 is a schematic illustration of an implementation of the pool cleaning system of FIG. 1.

FIG. 4 is a schematic illustration of an implementation of the pool cleaning system of FIG. 1.

FIG. 5 is a schematic illustration of an implementation of the pool cleaning system of FIG. 1.

FIG. 6 is a flow diagram of an example method that may be carried out with the pool cleaning system of FIG. 2-5.

FIG. 7 is a plan view of an example display with an example graphical depiction.

FIG. 8 is a plan view of another example display with an example graphical depiction.

FIG. 9 is a schematic illustration of an implementation of the pool cleaning system of FIG. 1 with an example pool cleaning vehicle.

FIG. 10 is a bottom perspective view of the example pool cleaning vehicle of the system of FIG. 9.

**DETAILED DESCRIPTION OF THE EXAMPLE
EMBODIMENTS**

FIG. 1 schematically illustrates an example pool cleaning system 20. As schematically shown by FIG. 1, pool cleaning system 20 is adapted to clean submerged surfaces of a pool 22 containing a liquid 24. In particular, pool cleaning system 20 is adapted to clean at least a bottom or floor surface 26 of the pool 22 and possibly to additionally clean surfaces 28 of pool 22. As will be described hereafter, pool cleaning system facilitates the control and monitoring of a robotic pool cleaner to better assure that all portions of pool 22 are satisfactorily cleaned.

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Pool cleaning system 20 comprises vehicle 30, cameras 32 and controller 42. Vehicle 30 comprises an automated powered device configured to travel adjacent to submerged or water containing surfaces of pool 20 (such as floor 26 and/or side surfaces 28) while cleaning such surfaces. In one implementation, vehicle 30 may include vacuum or suction devices, a liquid circulation system and a filter to draw debris, such as bacterial growth or plant growth, from such pool surfaces, wherein the drawn liquid containing such residue or foreign matter is filtered to collect the debris. In other implementations, vehicle 30 may not collect such debris, wherein vehicle 30 merely loosens such debris on the pool surfaces such that the loosened or separated debris may be subsequently removed using the existing liquid filtering system of pool 22.

To assist in the loosening of debris, in one implementation, vehicle 30 may additionally include a chemical dispenser to closely apply pool cleaning chemicals to the pool surfaces as the vehicle 30 traverses such surfaces. In one implementation, vehicle 30 may additionally or alternatively include one or more scrubbing members, such as active (driven) or passive (undriven or idling) brushes, to assist in the removal of residue or foreign matter from such pool surfaces. In yet another implementation, vehicle 30 may additionally or alternatively include liquid jets to assist in the loosening of debris.

To move along the submerged surfaces of pool 22, vehicle 30 includes one or more propulsion mechanisms. In one implementation, vehicle 30 is propelled along the submerged pool surfaces using wheels, rollers, tracks or other surface contacting members powered by a motor and the like. Such wheels, rollers or tracks may themselves include the scrubbing members used to clean the surfaces. In one implementation vehicle 30 may also alternatively be propelled by means of the vacuum or liquid jets. The vacuum or liquid jets used for such propulsion nozzle facilitate loosening of debris for collection by vehicle 30. In other implementations, vehicle 30 may include other propulsion mechanisms.

Cameras 32 comprise devices configured to capture video or time lapse images of pool 22. In the example illustrated, cameras 32 are mounted on structures external to pool 22. In other words, cameras 32 are not submerged. In other implementations, cameras 32 may alternatively be mounted to vehicle 30. In the example illustrated, cameras 32 capture movement of vehicle 30 while vehicle 30 is submerged within pool 22. In other implementations, cameras 32 merely capture images of submerged surfaces 26, 28 of pool 22.

In the example illustrated, cameras 32 comprise cameras serving as part of a home or pool security system, wherein such cameras detect the presence of a person at pool 22 satisfying a predefined characteristic and wherein an alert is output upon the person's detected presence. For example, in one implementation, cameras 32 are utilized as part of a security system that detects when a person below a predefined age, such as a child, is present at pool 22 without a detected presence of a recognized adult. In another implementation, cameras 32 may detect the presence of an unauthorized person or intruder at pool 22. Identification of the person may be achieved by an off-site human or computerized monitoring system, wherein signals from cameras 32 are transmitted across a wide area network or may be achieved with software of controller 42 which includes facial recognition or other identification programming.

Because pool cleaning system 20 utilizes pre-existing cameras 32 provided as part of a security system or shares

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the use of cameras 32 with such a home or pool security system, pool cleaning system 20 is easier to set up, less complex and less expensive. In other implementations, pool cleaning system 20 may utilize dedicated cameras 22 independent of any cameras associated with a home, facility or pool security system. In such an alternative system, cameras 32 may be more precisely focused upon pool 22 and surfaces 26, 28 while also including appropriate lenses or modifications to account for glare, refraction and the like to better facilitate the capture of surfaces and vehicle 30 which are submerged.

Controller 42 comprises one or more processing units in communication with vehicle 30 and cameras 32. For purposes of this application, the term "processing unit" shall mean a presently developed or future developed processing unit that executes sequences of instructions contained in a memory. Execution of the sequences of instructions causes the processing unit to perform steps such as generating control signals. The instructions may be loaded in a random access memory (RAM) for execution by the processing unit from a read only memory (ROM), a mass storage device, or some other persistent storage. In other embodiments, hard wired circuitry may be used in place of or in combination with software instructions to implement the functions described. For example, controller 42 may be embodied as part of one or more application-specific integrated circuits (ASICs). Unless otherwise specifically noted, the controller is not limited to any specific combination of hardware circuitry and software, nor to any particular source for the instructions executed by the processing unit.

In one implementation, controller 42 communicates with vehicle 30 and cameras 32 entirely across a wired connection. In another implementation, controller 42 communicates with vehicle 30 and cameras 32 across a wireless connection, such as across a local area network (LAN) or a wide area network (WAN) such as the Internet. One of limitation, controller 42 may communicate with vehicle 30 and cameras 32 using a combination of both wired and wireless communication connections.

Controller 42 is configured to generate control signals for steering vehicle 30 based upon signals received from cameras 32. In one implementation, controller 42 provides the sole steering directions for vehicle 30 using signals from cameras 32. Because vehicle 30 is precisely steered under the control of controller 42, rather than traveling in a random manner, entire summer surfaces of pool 22 may be more quickly and efficiently covered and cleaned. Because controller 42 provides the only steering instructions for vehicle 30 and utilizes signals from cameras 32, complex steering algorithms or codes in either vehicle 30 or controller 42 may be omitted to reduce complexity and cost of system 20.

In another implementation, vehicle 30 may cover or travel across surfaces of pool 22 in either a random fashion or according to an automated pool coverage algorithm or pool coverage pattern stored in a memory associated with vehicle 30 or controller 42. In such an implementation, controller 42 utilizes signals from cameras 32 to verify that all of the surfaces of pool 22 have been cleaned, that no spots have been missed. Upon identifying a missed spot, controller 42 utilizes signals from camera 32 to steer vehicle 32 over such missed portions of surfaces 26, 28. According to one example, controller 42 not only uses signals from camera 32 to determine whether any portions of surfaces 26, 28 have been missed entirely, but to also determine whether any portions of surfaces 26, 28 have been cleaned, but not to a satisfactory degree or extent. In such circumstances, controller 42 uses signals from cameras 32 to steer vehicle 34

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such areas to re-clean such portions until such portions have been satisfactorily cleaned such that the portions have a cleanliness characteristic satisfying a predefined threshold.

FIG. 2 schematically illustrates pool cleaning system 120, the particular example of pool cleaning system 20 described above. Pool cleaning system 120 is similar to pool cleaning system 20 except that pool cleaning system 120 additionally comprises dry station 46 and display 50. Those remaining components of pool cleaning system 120 which correspond to components of pool cleaning system 20 are numbered similarly.

Dry station 46 comprises a station in communication with vehicle 30 and cameras 32 outside of pool 22. Dry station 46 incorporates controller 42. In one implementation, dry station 46 communicates with vehicle 30 in a wired fashion. In such an implementation, dry station 46 further provides electrical power to vehicle 30 in a wired fashion. Dry station 46 communicates with cameras 32 and either a wired or wireless fashion.

Display 50 comprises a device to present a graphical images and text on a display screen. In one implementation, display 58 may be incorporated as part of dry station 46. In another implementation, display 50 may be provided on a portable electronic device, a computer, a television and the like. Display 50 is utilized by pool cleaning system 120 to present information regarding the cleaning of pool 22 to facilitate control of vehicle 30 by controller 42. In one implementation, display 50 is utilized by pool cleaning system 120 and a controller 42 to present a graphical depiction of those portions of surfaces 26, 28 of pool 22 have not been satisfactorily cleaned so as to satisfy a predefined cleanliness characteristic threshold. Such portions may comprise portions that have been completely missed by vehicle 30 as well as those portions that have been covered by vehicle 30 but have not been satisfactorily cleaned with the given number of passes of vehicle 30 or the existing cleaning settings of vehicle 30. The graphical depiction presented on display 50 enables a person view the quality of the prior cleaning session and to input commands causing controller 42 to generate control signals using signals from camera 32 to steer vehicle 30 back to such identified portions where such portions may be cleaned at the same or elevated cleaning aggressiveness settings.

Another implementation, display 50 may be further utilized by controller 42 to depict the progress of vehicle 30 in cleaning pool 22. Such a display 50 allows a person to visually determine how much of the pool has been currently cleaned and to estimate the remaining time before the pool cleaning task is completed. In certain circumstances, using display 50, a person may adjust a setting of vehicle 30 to accelerate a rate at which surfaces 26, 28 of pool 22 are cleaned to meet an earlier desired completion time for such pool cleaning.

FIG. 3 schematically illustrates pool cleaning system 220, another example implementation of pool cleaning system 20. Pool cleaning system 220 is similar to pool cleaning system 20 except that pool cleaning system 220 additionally comprises dry station 246, display 50, and remote server 254. Those remaining components of pool cleaning system 220 which correspond to components of pool cleaning system 20 or pool cleaning system 120 are numbered similarly.

Dry station 246 is similar to dry station 46, described above, except that dry station 246 serves as a local interface for communication with controller 42 across a network 260. In one implementation, network 260 may comprise a local area network. In another implementation, network 260 may

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comprise a wide area network, such as the Internet. For example, in one implementation, dry station 246 may incorporate a modem. In one implementation, dry station 246 may communicate across a local area network to controller 42. In another implementation, dry station 246 may communicate through a router, across a local area network, to a local modem which communicates across a network 260. The example illustrated, dry station 246 further provides part of vehicle 30 across a wired cable or wired connection. Display 50 is described above with respect to system 120.

Remote server 254 comprises a server remote from dry station 246 which is in communication with dry station 246 across network 260. Remote server 254 includes controller 42. During operation, signals from cameras 32 are transmitted across dry station 246 across network 260 to controller 42 of remote server 254. Based upon such signals from cameras 32, controller 42 generates control signals which are transmitted back across network 260 and through dry station 246 to vehicle 30 to steer vehicle 30.

As shown by FIG. 3, remote server 254 and network 260 may be shared as part of other pool cleaning systems 320, wherein controller 42 generates control signals for steering the pool cleaning vehicle 30 of system 320 based upon signals from cameras 32 transmitted across dry station 246 of system 320. In such an implementation, the cost and complexity of pool cleaning system 220 is reduced since controller 42 is remotely provided at remote server 254 which services multiple pool cleaning systems 220, 320. Upgrades to controller 42 and its software are also more easily achieved for all pool cleaning systems to 20, 320 and their pools 22, 222 being serviced. In one implementation, the supervised cleaning, inspection and possible re-cleaning facilitated by the use of cameras 32 may be provided as part of a subscription to users of vehicle 30. In such an implementation, a pool 22 having security cameras 32 may be upgraded with appropriate software or an appropriate software module added to dry station 246 to make a network connection with controller 42 which directs the security cameras 32 to capture vehicle 30 utilizes such signals for steering vehicle 30.

FIG. 4 schematically illustrates pool cleaning system 420, another particular implementation of pool cleaning system 20. Pool cleaning system 420 is similar to pool cleaning system 120 except that pool cleaning system 420 additionally comprises a portable electronic device 464. Those remaining components of pool cleaning system 420 which correspond to components of pool cleaning system 120 are numbered similarly.

Portable electronic device 464 comprises a portable handheld electronic device in communication with controller 42 and/or dry station 46 across network 260. Examples of such a portable electronic device (PED) 300 include, but are not limited to, a smart phone, a personal data assistant (PDA), laptop, notebook computer, tablet computer (e.g. IPAD) and MP3 player (e.g., IPOD TOUCH). In the example illustrated, PED 464 comprises input 466 and display 468.

Input 466 serves as a user interface for PED 464 by which inputs are made to PED 464. Input 466 facilitates entry of inputs or commands by a person to cause controller 42 to generate control signals varying the control of vehicle 30. In one implementation, input 466 comprise a keyboard. In other implementations, input 466 may comprise a touchpad, a stylus, a microphone with associated speech recognition software or programming, a touch screen, buttons, switches and the like. In some implementations, input 466 may comprise a touch screen incorporated as part of display 468.

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Display 468 comprises a user interface by which graphical or textual data is presented to a user. Display 468 may present the same or similar information as presented at dry station 246 by display 50 as described above. In one implementation, display 468 comprises a liquid crystal display. In other implementations, display 468 may comprise other types of display technology such as a light emitting diode display, an organic light emitting diode display (OLED), an electronic ink (e-ink) display or other types of display technology in present use or developed in the future. Although system 420 is illustrated as including controller 422 is part of dry station 46, in some implementations, controller 42 may alternatively be located as part of PED 464.

PED 464 enables a person located remote from pool 22 to monitor the progress of the cleaning of pool 22 by vehicle 30 of system 420. PED 464 provides a person with a graphical presentation (described above with respect to display 50) indicating those portions of surfaces 26, 28 of pool 22 that have been completed as well as those portions 26, 20 and that remain to be cleaned. The person may also be provided with a graphical indication of what portions need to be re-cleaned to meet predetermined cleanliness thresholds. In the example illustrated, input 466 enables a person to enter commands or selections which are transmitted across network 260 to controller 42 to adjust operation of vehicle 30. For example, the path or route of vehicle 30 may be changed, the aggressiveness of the cleaning chemicals or mechanical cleaning devices may be adjusted, the speed at which vehicle 30 traverses surfaces 26, 28 may be adjusted. In response to such adjustment signals from PED 464, controller 42 may utilize signals from cameras 32 to adjust the steering of vehicle 30.

FIG. 5 schematically illustrates pool cleaning system 520, another example implementation of pool cleaning system 20. Pool cleaning system 520 is similar to pool cleaning system 420 except that pool cleaning system 520 additionally comprises a remote server 554. Those remaining components of pool cleaning system 520 which correspond to components of pool cleaning system 420 are numbered similarly.

Remote server 554 is similar to remote server 254 described above with respect to system 220. Remote server 554 comprises a server remote from dry station 246 which is in communication with dry station 246 across network 260. Remote server 254 includes controller 42. During operation, signals from cameras 32 are transmitted across dry station 246 across network 260 to controller 42 of remote server 254. Based upon such signals from cameras 32, controller 42 generates control signals which are transmitted back across network 260 and through dry station 246 to vehicle 30 to steer vehicle 30. Controller 42 further relays either the raw signals from camera 32 or image signals generated based upon signals from cameras 32 to PED 464, wherein such images (described above) are presented on display 468. As noted above, PED may further receive commands through input 466, wherein such commands are transmitted to controller 42 which generates control signals that are ultimately transmitted to vehicle 30 for steering vehicle 30.

As with remote server 254, remote server 554 and network 260 may be shared as part of other pool cleaning systems 320 (shown in FIG. 3), wherein controller 42 generates control signals for steering the pool cleaning vehicle 30 of system 320 based upon signals from cameras 32 transmitted across dry station 246 of system 320. In such implementations, controller 42 of remote server 554 may

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interact with other PEDs 464. In such an implementation, the cost and complexity of pool cleaning system 220 is reduced since controller 42 is remotely provided at remote server 254 which services multiple pool cleaning systems 220, 320. Upgrades to controller 42 and its software are also more easily achieved for all pool cleaning systems to 20, 320 and their pools 22, 222 being serviced. In one implementation, the supervised cleaning, inspection and possible re-cleaning facilitated by the use of cameras 32 may be provided as part of a subscription to users of vehicle 30. In such an implementation, a pool 22 having security cameras 32 may be upgraded with appropriate software or an appropriate software module added to dry station 246 to make a network connection with controller 42 which directs the security cameras 32 to capture vehicle 30 utilizes such signals for steering vehicle 30. As indicated by broken lines, in other implementations, the controller 42 for generating control signals steering vehicle 30 based upon signals from cameras 32 may alternatively be relocated in PED 464.

FIG. 6 is a flow diagram illustrating an example method 600 that may be carried out by any of systems 120-520. As indicated by step 602, cameras 32 capture images of pool cleaning by vehicle 30. As indicated by step 604, controller 42 obtain such signals from cameras 32 for the surfaces of pool 22 that have been cleaned. As indicated by step 606, controller 42 uses information gathered from the signals from cameras 32 to identify those portions of surfaces 26, 28 not satisfactorily cleaned—not satisfying a predefined cleanliness characteristic or measurement threshold. One example of a cleanliness characteristic measurement a threshold may be how well the color of a surface matches a predetermined desirable color for the pool surface (such as original color of the tile or surface). A surface that has been missed entirely by vehicle 30 during a pool cleaning session may be automatically deemed to not satisfy a predetermined cleanliness characteristic.

As indicated by step 608, based upon such determinations, controller 42 generates control signals resulting in the presentation of a graphical depiction of those portions of pool 22 that has not been satisfactorily cleaned. Such graphical representations or depictions may be presented on display 50 or display 468. FIGS. 7 and 8 illustrate examples of graphical depictions that may be presented.

FIG. 7 illustrates display 468 presenting graphical depiction 620. Graphical depiction 620 comprises a first graphic 622 having a first portion 624 representing sides or walls 28 of pool 22 and a second portion 626 representing the floor 26 of pool 22. Graphical depiction 620 further comprises a moving icon 628 representing the current positioning of vehicle 30. In one implementation, the path of vehicle 30 may additionally be depicted by icon 628 shown in broken lines. As shown by FIG. 7, those portions 632 of surfaces 26, 28 of pool 22 (shown in FIG. 1) over which of vehicle 30 has moved are identified by graphical depiction 620 either by color, markings or other various distinctive attributes. Likewise, those portions 634 of surfaces 26, 28 of pool 22 that have not been covered by vehicle 30 are identified by a distinct color col marking or distinctive attribute of depiction 620. As a result, a person may view the current position of vehicle 30, the extent to which pool 22 has been cleaned or covered by vehicle 30 and the extent of pool 22 that remains to be cleaned. In the example illustrated, depiction 620 further identifies those portions 638 of surfaces 26, 28 that have been cleaned, but which have not been cleaned to a satisfactory degree or extent. In one implementation, portions 638 may be identified by colors, brightness, markings or other visually distinctive attributes that are visually

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distinct from both portions 632 and portions 634. In other implementations, portions 638 may have the same characteristic of portions 634. In yet other implementations, different portions 638 may have different visual attributes depending upon a degree to which such clean portions have failed to satisfy the predefined cleanliness characteristic threshold. In some implementations, different port 638 may have different visual attributes depending upon different cleaning strategies that may be recommended for the different portions 638. For example, controller 42 may determine and recommend a first cleaning strategy (a first chemical solution jetted at a first rate and scrubbed at a first rate) with respect to a first portion 638 and may recommend a second different cleaning strategy (a second chemical solution jetted at a second rate is about a second rate) with respect to a second portion 638, wherein the different cleaning strategies are represented by different visual attributes presented in depiction 620.

FIG. 8 illustrates display 468 presenting a graphical depiction 720. Graphical depiction 720 comprises a first graphic 622 having a first portion 624 representing sides or walls 28 of pool 22 and a second portion 626 representing the floor 26 of pool 22 (shown in FIG. 1). Graphical depiction 720 is similar to graphical depiction 620 except that graphical depiction 720 omits icon 628 presenting vehicle 30. Like depiction 620, depiction 720 graphically depicts those portions 632 of surfaces 26, 28 over which vehicle 30 has traveled while in a cleaning mode. Depiction 720 also visually depicts those portions 634 that have not been covered by vehicle 30 in the cleaning mode and those portions 638 over which vehicle 30 has traveled while in the cleaning mode, but which have not been cleaned to a satisfactory degree. As illustrated in FIG. 8, different portions 638 may be visibly distinguished from one another through color, text or markings indicating either differences in the cleanliness of such portions 638 or indicating different recommended cleaning strategies or approaches that may be selected by a person using input 466 when vehicle 30 is steered back to such portions 638 for re-cleaning using signals from camera 32.

As indicated by step 610 of FIG. 6, controller 42 generates control signals steering vehicle 30 to re-clean portions of pool 22, such as portions 638. Such steering may be facilitated by using signals from cameras 32. As noted above, in some implementations, a person may be allowed choose a cleaning approach for a particular portion 638 using input 466. The selection may be facilitated by visual inspection of the different visual attributes for the particular portion 638 provided by depiction 720 (or depiction 620). In some implementations, input 466 may additionally be utilized by a person to prioritize an order in which portions 638 are re-cleaned.

FIG. 9 illustrates pool cleaning system 820, an example implementation of pool cleaning system 20. Pool cleaning system 820 is similar to pool cleaning system 520 except the pool cleaning system 820 located controller 42 in dry station 246 and includes pool cleaning vehicle 830, a specific example of vehicle 30. As shown by FIG. 9, in addition to transmitting control signals generated by controller 42 to vehicle 830, dry station 246 further transmits power from power source 831 through a power line or power cable 833 to vehicle 830. In the example illustrated, data communication and communication of control signals, also occurs across wired connections within or alongside the same line 833. In the example illustrated, remote server 554 serves as a communication link by which upgrades to controller 42 may be implemented across a wide number of pool cleaning

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systems and by which information from controller 42 is conveyed to one or more portable electronic devices 464 across network 260.

Vehicle 830 comprises a robotic or automated pool cleaning device. Vehicle 830 comprises a self-contained onboard filtration system with drive and pump motors. Vehicle 830 utilizes an internal microprocessor guided drive motor to systematically clean surfaces of pool 22. As shown by FIGS. 9 and 10, vehicle 830 utilizes a toothed track drive 900 provide traction and propulsion for vehicle 30. Vehicle 830 comprises rotating brushes 902 to loosen waterline buildup and breakdown large debris while power washing jets 904 flush out dirt from pores, seams in corners where brushes 902 may not be able to reach. The loosened dirt and debris is vacuumed through off-center vacuum ports 906 which passes the vacuumed debris through internally house filter bag. In the example illustrated, vehicle 830 further comprises rollers 908 which inhibit vehicle 830 from becoming impeded or stuck on raised drains or pop-up heads. Although illustrated as being employed with system 820, vehicle 830 may also be utilized with any of systems 20, 120, 220, 320 and 420. In other implementations, other robotic or automated pool cleaning vehicles may be utilized.

Although the present disclosure has been described with reference to example embodiments, workers skilled in the art will recognize that changes may be made in form and detail without departing from the spirit and scope of the claimed subject matter. For example, although different example embodiments may have been described as including one or more features providing one or in ore benefits, it is contemplated that the described features may be interchanged with one another or alternatively be combined with one another in the described example embodiments or in other alternative embodiments. Because the technology of the present disclosure is relatively complex, not all changes in the technology are foreseeable. The present disclosure described with reference to the example embodiments and set forth in the following claims is manifestly intended to be as broad as possible. For example, unless specifically otherwise noted, the claims reciting a single particular element also encompass a plurality of such particular elements.

What is claimed is:

1. A self-propelled pool cleaner for cleaning debris from a submerged surface of a swimming pool, comprising:

- a. a vehicle body;
- b. means for moving the vehicle body within the swimming pool;
- c. a filter configured to retain debris collected from the submerged surface;
- d. at least one camera positioned on or in the body for capturing an image of at least a first portion of the submerged surface; and
- e. a controller (i) positioned on or in the body, (ii) in electronic communication with the at least one camera, and (iii) configured to generate at least one control signal to cause movement of the body within the swimming pool to the first portion of the submerged surface when the captured image fails to satisfy a predefined threshold.

2. A self-propelled pool cleaner according to claim 1 in which the means for moving the vehicle body comprises a propulsion mechanism selected from the group consisting of at least one jet or at least one rotatably-mounted support.

3. A self-propelled pool cleaner according to claim 2 in which the propulsion mechanism is at least one rotatably-mounted support selected from the group consisting of a wheel, a roller, a track, or a scrubbing member.

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4. A self-propelled pool cleaner according to claim 1 further comprising an electric motor for driving the means for moving the vehicle body.

5. A self-propelled pool cleaner according to claim 4 in which the controller controls electric power provided to the electric motor.

6. A self-propelled pool cleaner according to claim 1 in which the controller is operable to execute a cleaning program for cleaning the submerged surface.

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surface that remain uncleaned as the cleaner traverses the (56)
pool surface.

19 Claims, 4 Drawing Sheets

Related U.S. Application Data

continuation of application No. 13/545,918, filed on
Jul. 10, 2012, now Pat. No. 9,388,595.

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H04N 5/232 (2006.01)

G05D 1/00 (2006.01)

H04N 5/225 (2006.01)

G06T 7/90 (2017.01)

G06T 7/00 (2017.01)

(52) **U.S. Cl.**

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(2013.01); **H04N 5/23203** (2013.01); **H04N**
7/18 (2013.01); **G05D 2201/0203** (2013.01);
G06T 7/001 (2013.01); **G06T 7/90** (2017.01);
G06T 2207/10024 (2013.01); **H04N 2005/2255**
(2013.01)

(58) **Field of Classification Search**

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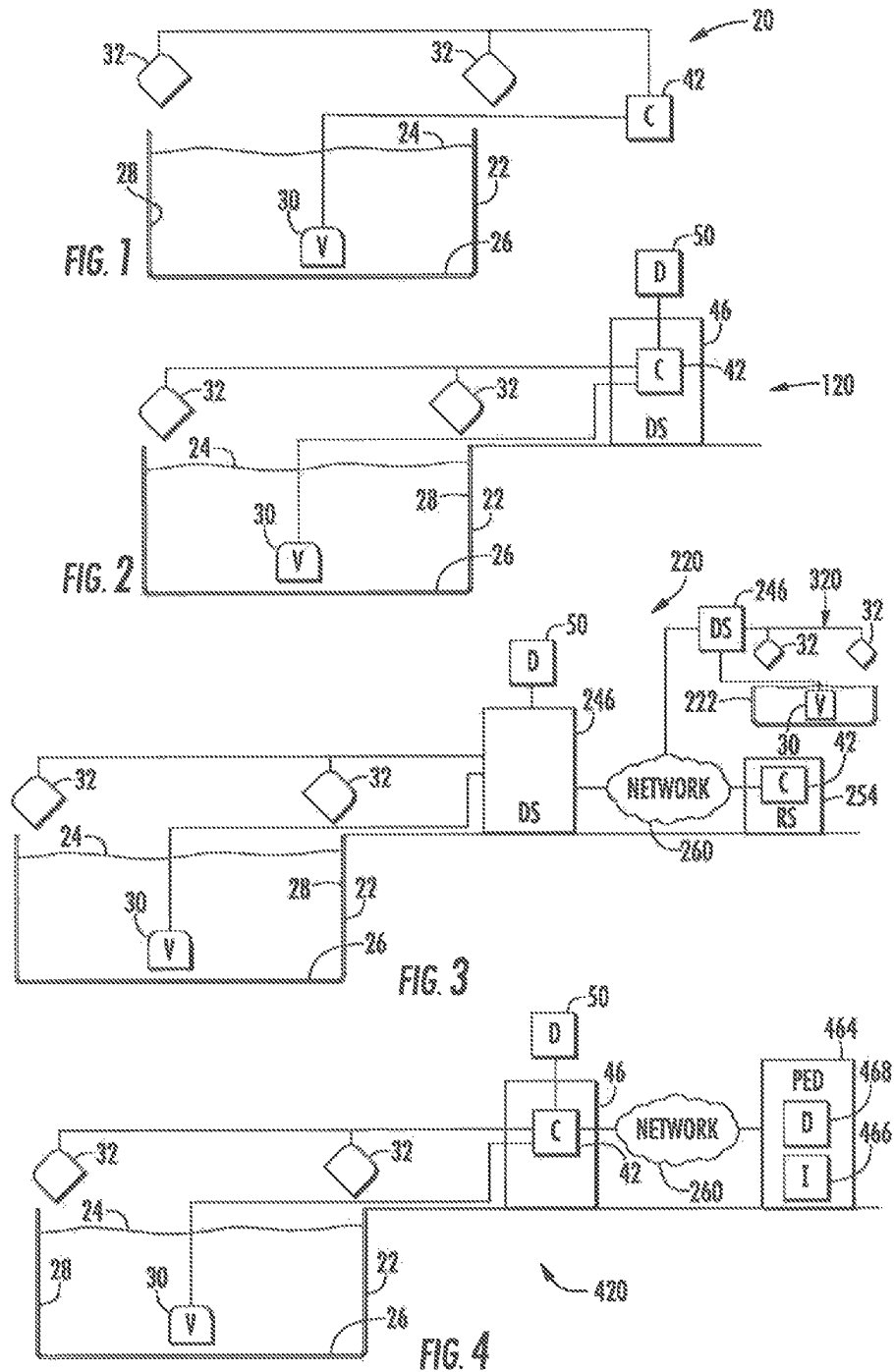
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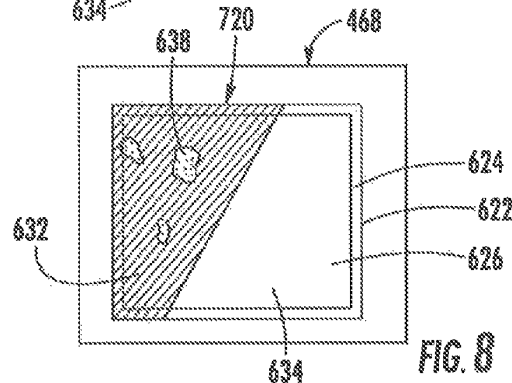
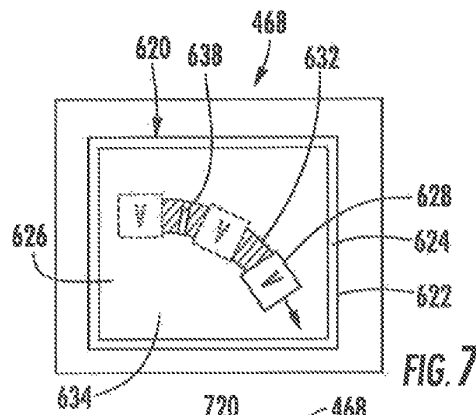
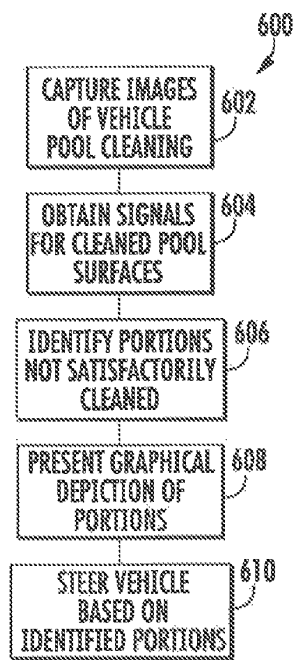
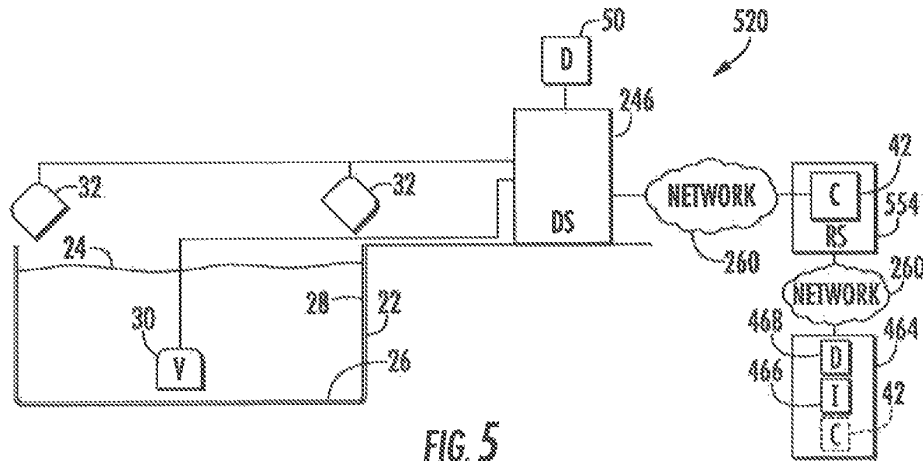


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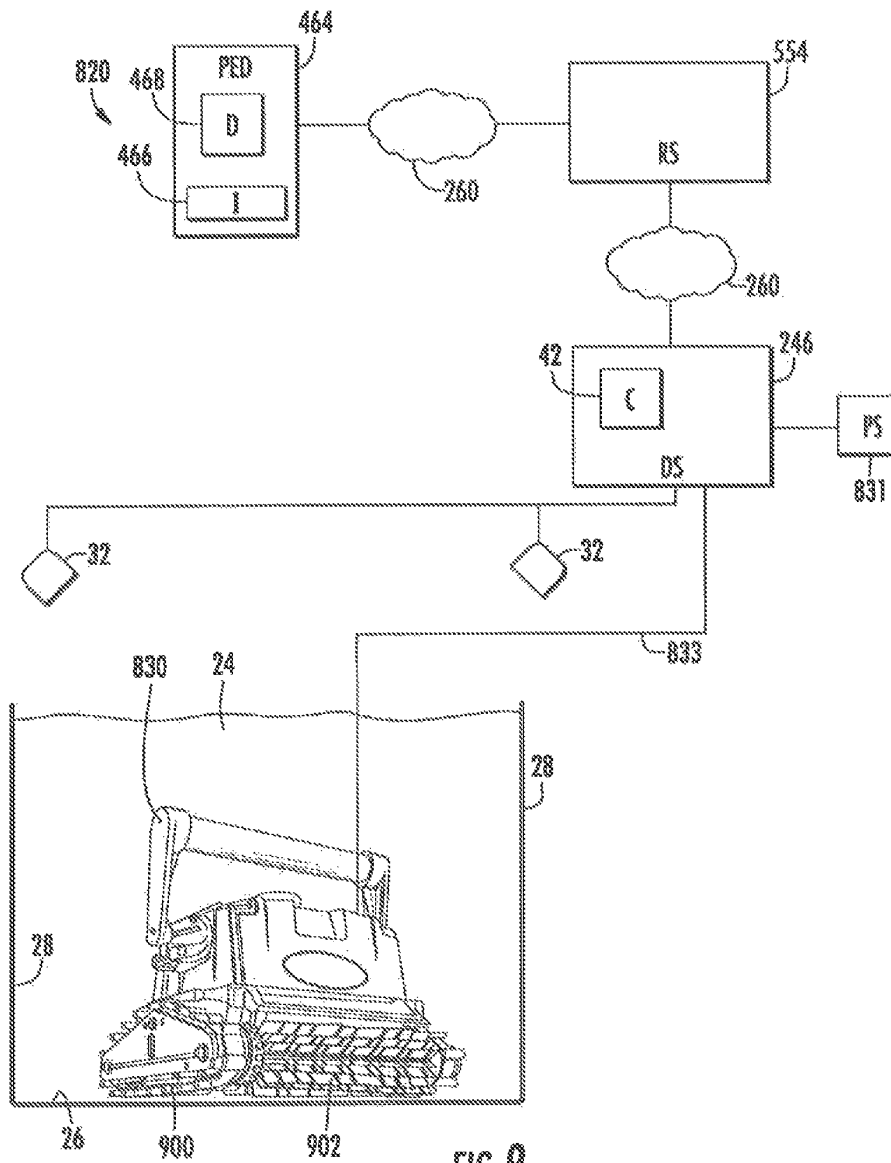


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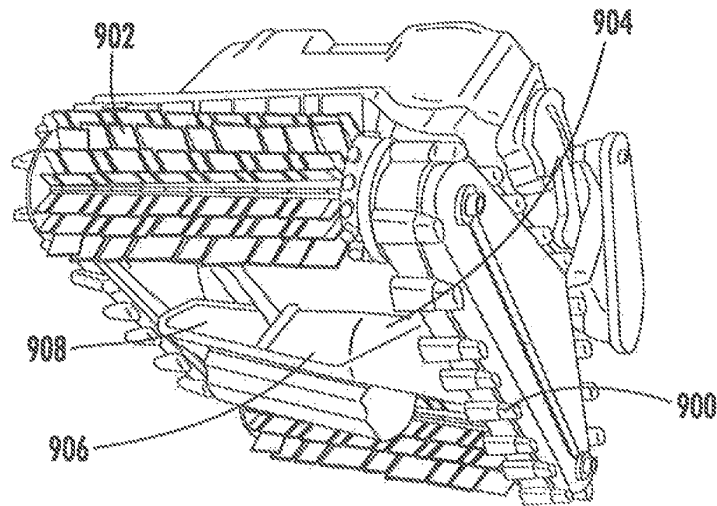


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**POOL CLEANING SYSTEM AND METHOD
TO AUTOMATICALLY CLEAN SURFACES
OF A POOL USING IMAGES FROM A
CAMERA**

**CROSS-REFERENCE TO RELATED
APPLICATION**

This patent application is a continuation of commonly owned U.S. patent application Ser. No. 15/207,065, filed Jul. 11, 2016, which is a continuation of U.S. patent application Ser. No. 13/545,918, filed Jul. 10, 2012 (now U.S. Pat. No. 9,388,595), the content of which are incorporated by reference herein in their entirety.

BACKGROUND

Manually cleaning the floor and sides of a swimming pool may be a tedious and time-consuming task. As a result, automated robotic pool cleaners have been developed. However, controlling and monitoring such automated robotic pool cleaners to insure that all portions of the pool surfaces are satisfactorily cleaned remains a challenge.

SUMMARY OF THE INVENTION

The disadvantages heretofore associated with the prior art are overcome by the present invention of a pool cleaning system for cleaning debris from a submerged surface of a swimming pool comprising: a self-propelled pool cleaner having rotatably-mounted supports for supporting and guiding the cleaner on the pool surface; a filter configured to retain the debris collected from the submerged surface of the swimming pool; an electric motor for enabling the rotation of the rotatably-mounted supports on the pool surface; at least one camera to capture imagery of the pool surface; a controller, in electronic communication with the at least one camera, to determine a cleanliness characteristic of the pool surface on which the cleaner has passed based on the camera imagery and generate a control signal to direct movement of the cleaner based on the cleanliness characteristic of the pool surface; and a portable electronic device is configured to present a graphic on a display, the graphic depicting the submerged surface of the pool and those portions of the surface that remain uncleared as the cleaner traverses the pool surface.

In one aspect, the at least one camera is carried by the cleaner. In another aspect, the controller is carried by the cleaner. In still another aspect, the electric motor is mechanically connected to at least one of the rotatably-mounted supports.

In yet another aspect, the controller is operable to execute one or more cleaning programs for cleaning the submerged surfaces of the pool. In one aspect, the control signal causes the cleaner to drive in a direction to clean a portion of the pool surface based on the cleanliness characteristic of the pool surface. Alternatively, the control signal causes the cleaner to steer in a direction to clean a portion of the pool surface based on the cleanliness characteristic of the pool surface. In another aspect, the control signal causes the cleaner to drive in a direction to re-clean a portion of the pool surface over which the cleaner has passed. Alternatively, the control signal causes the cleaner to steer in a direction to re-clean a portion of the pool surface over which the cleaner has passed.

In one aspect, the captured imagery from the at least one camera is digitally processed by the controller to determine

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the cleanliness characteristic of the pool surface. Alternatively, the captured imagery from the at least one camera is digitally processed by a remote processor to determine the cleanliness characteristic of the pool surface.

In another aspect, the system further comprises a dry station located remotely from the cleaner and in communication with the cleaner, wherein the dry station includes the controller. Alternatively, the system further comprises a dry station located remotely from the cleaner and in communication with the cleaner, wherein the controller is located remotely from the cleaner and the dry station. In still another aspect, the controller controls electric power provided to the electric motor.

In one aspect, the control signal causes the cleaner to move in a direction of a portion of the pool surface to be cleaned based solely upon signals received from the camera. In another aspect, the control signal causes the cleaner to drive in a direction to clean a portion of the pool surface based on the cleanliness characteristic of the pool surface. Alternatively, the control signal causes the cleaner to steer in a direction to clean a portion of the pool surface based on the cleanliness characteristic of the pool surface. In yet another aspect, the control signal causes the cleaner to drive in a direction to re-clean a portion of the pool surface over which the cleaner has passed. Alternatively, the control signal causes the cleaner to steer in a direction to re-clean a portion of the pool surface over which the cleaner has passed.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a schematic illustration of an example pool cleaning system.

FIG. 2 is a schematic illustration of an implementation of the pool cleaning system of FIG. 1.

FIG. 3 is a schematic illustration of an implementation of the pool cleaning system of FIG. 1.

FIG. 4 is a schematic illustration of an implementation of the pool cleaning system of FIG. 1.

FIG. 5 is a schematic illustration of an implementation of the pool cleaning system of FIG. 1.

FIG. 6 is a flow diagram of an example method that may be carried out with the pool cleaning system of FIG. 2-5.

FIG. 7 is a plan view of an example display with an example graphical depiction.

FIG. 8 is a plan view of another example display with an example graphical depiction.

FIG. 9 is a schematic illustration of an implementation of the pool cleaning system of FIG. 1 with an example pool cleaning vehicle.

FIG. 10 is a bottom perspective view of the example pool cleaning vehicle of the system of FIG. 9.

**DETAILED DESCRIPTION OF THE EXAMPLE
EMBODIMENTS**

FIG. 1 schematically illustrates an example pool cleaning system 20. As schematically shown by FIG. 1, pool cleaning system 20 is adapted to clean submerged surfaces of a pool 22 containing a liquid 24. In particular, pool cleaning system 20 is adapted to clean at least a bottom or floor surface 26 of the pool 22 and possibly to additionally clean surfaces 28 of pool 22. As will be described hereafter, pool cleaning system facilitates the control and monitoring of a robotic pool cleaner to better assure that all portions of pool 22 are satisfactorily cleaned.

Pool cleaning system 20 comprises vehicle 30, cameras 32 and controller 42. Vehicle 30 comprises an automated

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powered device configured to travel adjacent to submerged or water containing surfaces of pool 20 (such as floor 26 and/or side surfaces 28) while cleaning such surfaces. In one implementation, vehicle 30 may include vacuum or suction devices, a liquid circulation system and a filter to draw debris, such as bacterial growth or plant growth, from such pool surfaces, wherein the drawn liquid containing such residue or foreign matter is filtered to collect the debris. In other implementations, vehicle 30 may not collect such debris, wherein vehicle 30 merely loosens such debris on the pool surfaces such that the loosened or separated debris may be subsequently removed using the existing liquid filtering system of pool 22.

To assist in the loosening of debris, in one implementation, vehicle 30 may additionally include a chemical dispenser to closely apply pool cleaning chemicals to the pool surfaces as the vehicle 30 traverses such surfaces. In one implementation, vehicle 30 may additionally or alternatively include one or more scrubbing members, such as active (driven) or passive (undriven or idling) brushes, to assist in the removal of residue or foreign matter from such pool surfaces. In yet another implementation, vehicle 30 may additionally or alternatively include liquid jets to assist in the loosening of debris.

To move along the submerged surfaces of pool 22, vehicle 30 includes one or more propulsion mechanisms. In one implementation, vehicle 30 is propelled along the submerged pool surfaces using wheels, rollers, tracks or other surface contacting members powered by a motor and the like. Such wheels, rollers or tracks may themselves include the scrubbing members used to clean the surfaces. In one implementation vehicle 30 may also alternatively be propelled by means of the vacuum or liquid jets. The vacuum or liquid jets used for such propulsion nozzle facilitate loosening of debris for collection by vehicle 30. In other implementations, vehicle 30 may include other propulsion mechanisms.

Cameras 32 comprise devices configured to capture video or time lapse images of pool 22. In the example illustrated, cameras 32 are mounted on structures external to pool 22. In other words, cameras 32 are not submerged. In other implementations, cameras 32 may alternatively be mounted to vehicle 30. In the example illustrated, cameras 32 capture movement of vehicle 30 while vehicle 30 is submerged within pool 22. In other implementations, cameras 32 merely capture images of submerged surfaces 26, 28 of pool 22.

In the example illustrated, cameras 32 comprise cameras serving as part of a home or pool security system, wherein such cameras detect the presence of a person at pool 22 satisfying a predefined characteristic and wherein an alert is output upon the person's detected presence. For example, in one implementation, cameras 32 are utilized as part of a security system that detects when a person below a predefined age, such as a child, is present at pool 22 without a detected presence of a recognized adult. In another implementation, cameras 32 may detect the presence of an unauthorized person or intruder at pool 22. Identification of the person may be achieved by an off-site human or computerized monitoring system, wherein signals from cameras 32 are transmitted across a wide area network or may be achieved with software of controller 42 which includes facial recognition or other identification programming.

Because pool cleaning system 20 utilizes pre-existing cameras 32 provided as part of a security system or shares the use of cameras 32 with such a home or pool security system, pool cleaning system 20 is easier to set up, less

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complex and less expensive. In other implementations, pool cleaning system 20 may utilize dedicated cameras 22 independent of any cameras associated with a home, facility or pool security system. In such an alternative system, cameras 32 may be more precisely focused upon pool 22 and surfaces 26, 28 while also including appropriate lenses or modifications to account for glare, refraction and the like to better facilitate the capture of surfaces and vehicle 30 which are submerged.

Controller 42 comprises one or more processing units in communication with vehicle 30 and cameras 32. For purposes of this application, the term "processing unit" shall mean a presently developed or future developed processing unit that executes sequences of instructions contained in a memory. Execution of the sequences of instructions causes the processing unit to perform steps such as generating control signals. The instructions may be loaded in a random access memory (RAM) for execution by the processing unit from a read only memory (ROM), a mass storage device, or some other persistent storage. In other embodiments, hard wired circuitry may be used in place of or in combination with software instructions to implement the functions described. For example, controller 42 may be embodied as part of one or more application-specific integrated circuits (ASICs). Unless otherwise specifically noted, the controller is not limited to any specific combination of hardware circuitry and software, nor to any particular source for the instructions executed by the processing unit.

In one implementation, controller 42 communicates with vehicle 30 and cameras 32 entirely across a wired connection. In another implementation, controller 42 communicates with vehicle 30 and cameras 32 across a wireless connection, such as across a local area network (LAN) or a wide area network (WAN) such as the Internet. One of limitation, controller 42 may communicate with vehicle 30 and cameras 32 using a combination of both wired and wireless communication connections.

Controller 42 is configured to generate control signals for steering vehicle 30 based upon signals received from cameras 32. In one implementation, controller 42 provides the sole steering directions for vehicle 30 using signals from cameras 32. Because vehicle 30 is precisely steered under the control of controller 42, rather than traveling in a random manner, entire summer surfaces of pool 22 may be more quickly and efficiently covered and cleaned. Because controller 42 provides the only steering instructions for vehicle 30 and utilizes signals from cameras 32, complex steering algorithms or codes in either vehicle 30 or controller 42 may be omitted to reduce complexity and cost of system 20.

In another implementation, vehicle 30 may cover or travel across surfaces of pool 22 in either a random fashion or according to an automated pool coverage algorithm or pool coverage pattern stored in a memory associated with vehicle 30 or controller 42. In such an implementation, controller 42 utilizes signals from cameras 32 to verify that all of the surfaces of pool 22 have been cleaned, that no spots have been missed. Upon identifying a missed spot, controller 42 utilizes signals from camera 32 to steer vehicle 32 over such missed portions of surfaces 26, 28. According to one example, controller 42 not only uses signals from camera 32 to determine whether any portions of surfaces 26, 28 have been missed entirely, but to also determine whether any portions of surfaces 26, 28 have been cleaned, but not to a satisfactory degree or extent. In such circumstances, controller 42 uses signals from cameras 32 to steer vehicle 34 such areas to re-clean such portions until such portions have

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been satisfactorily cleaned such that the portions have a cleanliness characteristic satisfying a predefined threshold.

FIG. 2 schematically illustrates pool cleaning system 120, the particular example of pool cleaning system 20 described above. Pool cleaning system 120 is similar to pool cleaning system 20 except that pool cleaning system 120 additionally comprises dry station 46 and display 50. Those remaining components of pool cleaning system 120 which correspond to components of pool cleaning system 20 are numbered similarly.

Dry station 46 comprises a station in communication with vehicle 30 and cameras 32 outside of pool 22. Dry station 46 incorporates controller 42. In one implementation, dry station 46 communicates with vehicle 30 in a wired fashion. In such an implementation, dry station 46 further provides electrical power to vehicle 30 in a wired fashion. Dry station 46 communicates with cameras 32 and either a wired or wireless fashion.

Display 50 comprises a device to present a graphical images and text on a display screen. In one implementation, display 58 may be incorporated as part of dry station 46. In another implementation, display 50 may be provided on a portable electronic device, a computer, a television and the like. Display 50 is utilized by pool cleaning system 120 to present information regarding the cleaning of pool 22 to facilitate control of vehicle 30 by controller 42. In one implementation, display 50 is utilized by pool cleaning system 120 and a controller 42 to present a graphical depiction of those portions of surfaces 26, 28 of pool 22 have not been satisfactorily cleaned so as to satisfy a predefined cleanliness characteristic threshold. Such portions may comprise portions that have been completely missed by vehicle 30 as well as those portions that have been covered by vehicle 30 but have not been satisfactorily cleaned with the given number of passes of vehicle 30 or the existing cleaning settings of vehicle 30. The graphical depiction presented on display 50 enables a person view the quality of the prior cleaning session and to input commands causing controller 42 to generate control signals using signals from camera 32 to steer vehicle 30 back to such identified portions where such portions may be cleaned at the same or elevated cleaning aggressiveness settings.

Another implementation, display 50 may be further utilized by controller 42 to depict the progress of vehicle 30 in cleaning pool 22. Such a display 50 allows a person to visually determine how much of the pool has been currently cleaned and to estimate the remaining time before the pool cleaning task is completed. In certain circumstances, using display 50, a person may adjust a setting of vehicle 30 to accelerate a rate at which surfaces 26, 28 of pool 22 are cleaned to meet an earlier desired completion time for such pool cleaning.

FIG. 3 schematically illustrates pool cleaning system 220, another example implementation of pool cleaning system 20. Pool cleaning system 220 is similar to pool cleaning system 20 except that pool cleaning system 220 additionally comprises dry station 246, display 50, and remote server 254. Those remaining components of pool cleaning system 220 which correspond to components of pool cleaning system 20 or pool cleaning system 120 are numbered similarly.

Dry station 246 is similar to dry station 46, described above, except that dry station 246 serves as a local interface for communication with controller 42 across a network 260. In one implementation, network 260 may comprise a local area network. In another implementation, network 260 may comprise a wide area network, such as the Internet. For

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example, in one implementation, dry station 246 may incorporate a modem. In one implementation, dry station 246 may communicate across a local area network to controller 42. In another implementation, dry station 246 may communicate through a router, across a local area network, to a local modem which communicates across a network 260. The example illustrated, dry station 246 further provides part of vehicle 30 across a wired cable or wired connection. Display 50 is described above with respect to system 120.

Remote server 254 comprises a server remote from dry station 246 which is in communication with dry station 246 across network 260. Remote server 254 includes controller 42. During operation, signals from cameras 32 are transmitted across dry station 246 across network 260 to controller 42 of remote server 254. Based upon such signals from cameras 32, controller 42 generates control signals which are transmitted back across network 260 and through dry station 246 to vehicle 30 to steer vehicle 30.

As shown by FIG. 3, remote server 254 and network 260 may be shared as part of other pool cleaning systems 320, wherein controller 42 generates control signals for steering the pool cleaning vehicle 30 of system 320 based upon signals from cameras 32 transmitted across dry station 246 of system 320. In such an implementation, the cost and complexity of pool cleaning system 220 is reduced since controller 42 is remotely provided at remote server 254 which services multiple pool cleaning systems 220, 320. Upgrades to controller 42 and its software are also more easily achieved for all pool cleaning systems to 220, 320 and their pools 22, 222 being serviced. In one implementation, the supervised cleaning, inspection and possible re-cleaning facilitated by the use of cameras 32 may be provided as part of a subscription to users of vehicle 30. In such an implementation, a pool 22 having security cameras 32 may be upgraded with appropriate software or an appropriate software module added to dry station 246 to make a network connection with controller 42 which directs the security cameras 32 to capture vehicle 30 utilizes such signals for steering vehicle 30.

FIG. 4 schematically illustrates pool cleaning system 420, another particular implementation of pool cleaning system 20. Pool cleaning system 420 is similar to pool cleaning system 120 except that pool cleaning system 420 additionally comprises a portable electronic device 464. Those remaining components of pool cleaning system 420 which correspond to components of pool cleaning system 120 are numbered similarly.

Portable electronic device 464 comprises a portable handheld electronic device in communication with controller 42 and/or dry station 46 across network 260. Examples of such a portable electronic device (PED) 300 include, but are not limited to, a smart phone, a personal data assistant (PDA), laptop, notebook computer, tablet computer (e.g. IPAD) and MP3 player (e.g., IPOD TOUCH). In the example illustrated, PED 464 comprises input 466 and display 468.

Input 466 serves as a user interface for PED 464 by which inputs are made to PEI) 464. Input 466 facilitates entry of inputs or commands by a person to cause controller 42 to generate control signals varying the control of vehicle 30. In one implementation, input 466 comprise a keyboard. In other implementations, input 466 may comprise a touchpad, a stylus, a microphone with associated speech recognition software or programming, a touch screen, buttons, switches and the like. In some implementations, input 466 may comprise a touch screen incorporated as part of display 468.

Display 468 comprises a user interface by which graphical or textual data is presented to a user. Display 468 may

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present the same or similar information as presented at dry station 246 by display 50 as described above. In one implementation, display 468 comprises a liquid crystal display. In other implementations, display 468 may comprise other types of display technology such as a light emitting diode display, an organic light emitting diode display (OLED), an electronic ink (e-ink) display or other types of display technology in present use or developed in the future. Although system 420 is illustrated as including controller 422 is part of dry station 46, in some implementations, controller 42 may alternatively be located as part of PEI) 464.

PED 464 enables a person located remote from pool 22 to monitor the progress of the cleaning of pool 22 by vehicle 30 of system 420. PEI) 464 provides a person with a graphical presentation (described above with respect to display 50) indicating those portions of surfaces 26, 28 of pool 22 that have been completed as well as those portions 26, 20 and that remain to be cleaned. The person may also be provided with a graphical indication of what portions need to be re-cleaned to meet predetermined cleanliness thresholds. In the example illustrated, input 466 enables a person to enter commands or selections which are transmitted across network 260 to controller 42 to adjust operation of vehicle 30. For example, the path or route of vehicle 30 may be changed, the aggressiveness of the cleaning chemicals or mechanical cleaning devices may be adjusted, the speed at which vehicle 30 traverses surfaces 26, 28 may be adjusted. In response to such adjustment signals from PED 464, controller 42 may utilize signals from cameras 32 to adjust the steering of vehicle 30.

FIG. 5 schematically illustrates pool cleaning system 520, another example implementation of pool cleaning system 20. Pool cleaning system 520 is similar to pool cleaning system 420 except that pool cleaning system 520 additionally comprises a remote server 554. Those remaining components of pool cleaning system 520 which correspond to components of pool cleaning system 420 are numbered similarly.

Remote server 554 is similar to remote server 254 described above with respect to system 220. Remote server 554 comprises a server remote from dry station 246 which is in communication with dry station 246 across network 260. Remote server 254 includes controller 42. During operation, signals from cameras 32 are transmitted across dry station 246 across network 260 to controller 42 of remote server 254. Based upon such signals from cameras 32, controller 42 generates control signals which are transmitted back across network 260 and through dry station 246 to vehicle 30 to steer vehicle 30. Controller 42 further relays either the raw signals from camera 32 or image signals generated based upon signals from cameras 32 to PEI) 464, wherein such images (described above) are presented on display 468. As noted above, PED may further receive commands through input 466, wherein such commands are transmitted to controller 42 which generates control signals that are ultimately transmitted to vehicle 30 for steering vehicle 30.

As with remote server 254, remote server 554 and network 260 may be shared as part of other pool cleaning systems 320 (shown in FIG. 3), wherein controller 42 generates control signals for steering the pool cleaning vehicle 30 of system 320 based upon signals from cameras 32 transmitted across dry station 246 of system 320. In such implementations, controller 42 of remote server 554 may interact with other PEDs 464. In such an implementation, the cost and complexity of pool cleaning system 220 is

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reduced since controller 42 is remotely provided at remote server 254 which services multiple pool cleaning systems 220, 320. Upgrades to controller 42 and its software are also more easily achieved for all pool cleaning systems to 20, 320 and their pools 22, 222 being serviced. In one implementation, the supervised cleaning, inspection and possible re-cleaning facilitated by the use of cameras 32 may be provided as part of a subscription to users of vehicle 30. In such an implementation, a pool 22 having security cameras 32 may be upgraded with appropriate software or an appropriate software module added to dry station 246 to make a network connection with controller 42 which directs the security cameras 32 to capture vehicle 30 utilizes such signals for steering vehicle 30. As indicated by broken lines, in other implementations, the controller 42 for generating control signals steering vehicle 30 based upon signals from cameras 32 may alternatively be relocated in PED 464.

FIG. 6 is a flow diagram illustrating an example method 600 that may be carried out by any of systems 120-520. As indicated by step 602, cameras 32 capture images of pool cleaning by vehicle 30. As indicated by step 604, controller 42 obtain such signals from cameras 32 for the surfaces of pool 22 that have been cleaned. As indicated by step 606, controller 42 uses information gathered from the signals from cameras 32 to identify those portions of surfaces 26, 28 not satisfactorily cleaned—not satisfying a predefined cleanliness characteristic or measurement threshold. One example of a cleanliness characteristic measurement a threshold may be how well the color of a surface matches a predetermined desirable color for the pool surface (such as original color of the tile or surface). A surface that has been missed entirely by vehicle 30 during a pool cleaning session may be automatically deemed to not satisfy a predetermined cleanliness characteristic.

As indicated by step 608, based upon such determinations, controller 42 generates control signals resulting in the presentation of a graphical depiction of those portions of pool 22 that has not been satisfactorily cleaned. Such graphical representations or depictions may be presented on display 50 or display 468. FIGS. 7 and 8 illustrate examples of graphical depictions that may be presented.

FIG. 7 illustrates display 468 presenting graphical depiction 620. Graphical depiction 620 comprises a first graphic 622 having a first portion 624 representing sides or walls 28 of pool 22 and a second portion 626 representing the floor 26 of pool 22. Graphical depiction 620 further comprises a moving icon 628 representing the current positioning of vehicle 30. In one implementation, the path of vehicle 30 may additionally be depicted by icon 628 shown in broken lines. As shown by FIG. 7, those portions 632 of surfaces 26, 28 of pool 22 (shown in FIG. 1) over which of vehicle 30 has moved are identified by graphical depiction 620 either by color, markings or other various distinctive attributes. Likewise, those portions 634 of surfaces 26, 28 of pool 22 that have not been covered by vehicle 30 are identified by a distinct color col marking or distinctive attribute of depiction 620. As a result, a person may view the current position of vehicle 30, the extent to which pool 22 has been cleaned or covered by vehicle 30 and the extent of pool 22 that remains to be cleaned. In the example illustrated, depiction 620 further identifies those portions 638 of surfaces 26, 28 that have been cleaned, but which have not been cleaned to a satisfactory degree or extent. In one implementation, portions 638 may be identified by colors, brightness, markings or other visually distinctive attributes that are visually distinct from both portions 632 and portions 634. In other implementations, portions 638 may have the same charac-

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teristic of portions 634. In yet other implementations, different portions 638 may have different visual attributes depending upon a degree to which such clean portions have failed to satisfy the predefined cleanliness characteristic threshold. In some implementations, different port 638 may have different visual attributes depending upon different cleaning strategies that may be recommended for the different portions 638. For example, controller 42 may determine and recommend a first cleaning strategy (a first chemical solution jetted at a first rate and scrubbed at a first rate) with respect to a first portion 638 and may recommend a second different cleaning strategy (a second chemical solution jetted at a second rate is about a second rate) with respect to a second portion 638, wherein the different cleaning strategies are represented by different visual attributes presented in depiction 620.

FIG. 8 illustrates display 468 presenting a graphical depiction 720. Graphical depiction 720 comprises a first graphic 622 having a first portion 624 representing sides or walls 28 of pool 22 and a second portion 626 representing the floor 26 of pool 22 (shown in FIG. 1). Graphical depiction 720 is similar to graphical depiction 620 except that graphical depiction 720 omits icon 628 presenting vehicle 30. Like depiction 620, depiction 720 graphically depicts those portions 632 of surfaces 26, 28 over which vehicle 30 has traveled while in a cleaning mode. Depiction 720 also visually depicts those portions 634 that have not been covered by vehicle 30 in the cleaning mode and those portions 638 over which vehicle 30 has traveled while in the cleaning mode, but which have not been cleaned to a satisfactory degree. As illustrated in FIG. 8, different portions 638 may be visibly distinguished from one another through color, text or markings indicating either differences in the cleanliness of such portions 638 or indicating different recommended cleaning strategies or approaches that may be selected by a person using input 466 when vehicle 30 is steered back to such portions 638 for re-cleaning using signals from camera 32.

As indicated by step 610 of FIG. 6, controller 42 generates control signals steering vehicle 30 to re-clean portions of pool 22, such as portions 638. Such steering may be facilitated by using signals from cameras 32. As noted above, in some implementations, a person may be allowed choose a cleaning approach for a particular portion 638 using input 466. The selection may be facilitated by visual inspection of the different visual attributes for the particular portion 638 provided by depiction 720 (or depiction 620). In some implementations, input 466 may additionally be utilized by a person to prioritize an order in which portions 638 are re-cleaned.

FIG. 9 illustrates pool cleaning system 820, an example implementation of pool cleaning system 20. Pool cleaning system 820 is similar to pool cleaning system 520 except the pool cleaning system 820 located controller 42 in dry station 246 and includes pool cleaning vehicle 830, a specific example of vehicle 30. As shown by FIG. 9, in addition to transmitting control signals generated by controller 42 to vehicle 830, dry station 246 further transmits power from power source 831 through a power line or power cable 833 to vehicle 830. In the example illustrated, data communication and communication of control signals, also occurs across wired connections within or alongside the same line 833. In the example illustrated, remote server 554 serves as a communication link by which upgrades to controller 42 may be implemented across a wide number of pool cleaning

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systems and by which information from controller 42 is conveyed to one or more portable electronic devices 464 across network 260.

Vehicle 830 comprises a robotic or automated pool cleaning device. Vehicle 830 comprises a self-contained onboard filtration system with drive and pump motors. Vehicle 830 utilizes an internal microprocessor guided drive motor to systematically clean surfaces of pool 22. As shown by FIGS. 9 and 10, vehicle 830 utilizes a toothed track drive 900 provide traction and propulsion for vehicle 30. Vehicle 830 comprises rotating brushes 902 to loosen waterline buildup and breakdown large debris while power washing jets 904 flush out dirt from pores, seams in corners where brushes 902 may not be able to reach. The loosened dirt and debris is vacuumed through off-center vacuum ports 906 which passes the vacuumed debris through internally house filter bag. In the example illustrated, vehicle 830 further comprises rollers 908 which inhibit vehicle 830 from becoming impeded or stuck on raised drains or pop-up heads. Although illustrated as being employed with system 820, vehicle 830 may also be utilized with any of systems 20, 120, 220, 320 and 420. In other implementations, other robotic or automated pool cleaning vehicles may be utilized.

Although the present disclosure has been described with reference to example embodiments, workers skilled in the art will recognize that changes may be made in form and detail without departing from the spirit and scope of the claimed subject matter. For example, although different example embodiments may have been described as including one or more features providing one or more benefits, it is contemplated that the described features may be interchanged with one another or alternatively be combined with one another in the described example embodiments or in other alternative embodiments. Because the technology of the present disclosure is relatively complex, not all changes in the technology are foreseeable. The present disclosure described with reference to the example embodiments and set forth in the following claims is manifestly intended to be as broad as possible. For example, unless specifically otherwise noted, the claims reciting a single particular element also encompass a plurality of such particular elements.

What is claimed is:

1. A pool cleaning system for cleaning debris from a submerged surface of a swimming pool comprising:

- a self-propelled pool cleaner having rotatably-mounted supports for supporting and guiding the cleaner on the pool surface;
- a filter configured to retain the debris collected from the submerged surface of the swimming pool;
- an electric motor for enabling the rotation of the rotatably-mounted supports on the pool surface;
- at least one camera to capture imagery of the pool surface;
- a controller, in electronic communication with the at least one camera, to determine a cleanliness characteristic of the pool surface on which the cleaner has passed based on the camera imagery and generate a control signal to direct movement of the cleaner based on the cleanliness characteristic of the pool surface; and
- a portable electronic device configured to present a graphic on a display, the graphic depicting the submerged surface of the pool and those portions of the surface that remain uncleaned as the cleaner traverses the pool surface.

2. The system of claim 1, wherein the at least one camera is carried by the cleaner.

3. The system of claim 1, wherein the controller is carried by the cleaner.

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4. The system of claim 1, wherein the electric motor is mechanically connected to at least one of the rotatably-mounted supports.

5. The system of claim 1, wherein the controller is operable to execute one or more cleaning programs for cleaning the submerged surfaces of the pool.

6. The system of claim 5, wherein the control signal causes the cleaner to drive in a direction to clean a portion of the pool surface based on the cleanliness characteristic of the pool surface.

7. The system of claim 5, wherein the control signal causes the cleaner to steer in a direction to clean a portion of the pool surface based on the cleanliness characteristic of the pool surface.

8. The system of claim 5, wherein the control signal causes the cleaner to drive in a direction to re-clean a portion of the pool surface over which the cleaner has passed.

9. The system of claim 5, wherein the control signal causes the cleaner to steer in a direction to re-clean a portion of the pool surface over which the cleaner has passed.

10. The system of claim 1, wherein the captured imagery from the at least one camera is digitally processed by the controller to determine the cleanliness characteristic of the pool surface.

11. The system of claim 1, wherein the captured imagery from the at least one camera is digitally processed by a remote processor to determine the cleanliness characteristic of the pool surface.

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12. The system of claim 1 further comprising a dry station located remotely from the cleaner and in communication with the cleaner, wherein the dry station includes the controller.

13. The system of claim 1 further comprising a dry station located remotely from the cleaner and in communication with the cleaner, wherein the controller is located remotely from the cleaner and the dry station.

14. The system of claim 1, wherein the controller controls electric power provided to the electric motor.

15. The system of claim 1, wherein the control signal causes the cleaner to move in a direction of a portion of the pool surface to be cleaned based solely upon signals received from the camera.

16. The system of claim 15, wherein the control signal causes the cleaner to drive in a direction to clean a portion of the pool surface based on the cleanliness characteristic of the pool surface.

17. The system of claim 15, wherein the control signal causes the cleaner to steer in a direction to clean a portion of the pool surface based on the cleanliness characteristic of the pool surface.

18. The system of claim 15, wherein the control signal causes the cleaner to drive in a direction to re-clean a portion of the pool surface over which the cleaner has passed.

19. The system of claim 15, wherein the control signal causes the cleaner to steer in a direction to re-clean a portion of the pool surface over which the cleaner has passed.

* * * * *

EXHIBIT F

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(12) **United States Patent**
Durvasula et al.(10) **Patent No.:** **US 9,995,051 B2**
(45) **Date of Patent:** ***Jun. 12, 2018**(54) **POOL CLEANING SYSTEM AND METHOD TO AUTOMATICALLY CLEAN SURFACES OF A POOL USING IMAGES FROM A CAMERA**(71) Applicant: **AQUA PRODUCTS, INC.**, Cedar Grove, NJ (US)(72) Inventors: **Kameshwar Durvasula**, Garfield, NJ (US); **William Londono Correa**, Bloomfield, NJ (US)(73) Assignee: **Aqua Products, Inc.**, Cedar Grove, NJ (US)

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 47 days.

This patent is subject to a terminal disclaimer.

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E04H 4/16 (2006.01)

(Continued)

(52) **U.S. Cl.**
CPC **E04H 4/1654** (2013.01); **H04N 5/23203** (2013.01); **H04N 7/18** (2013.01); **H04N 2005/2255** (2013.01)(58) **Field of Classification Search**
CPC **E04H 4/1654**; **H04N 5/23203**; **H04N 7/18**; **H04N 2005/2255**

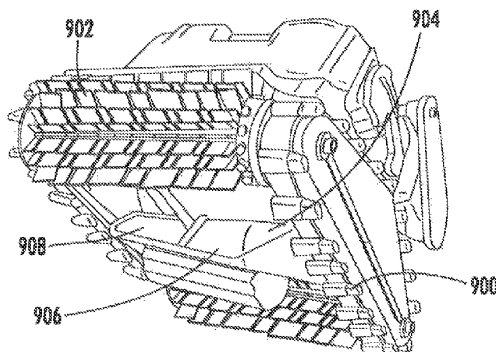
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Spanish Patent No. P201331047—State of Art Search Report from the ES Patent and Trademark Office; dated Feb. 3, 2015; 1 page.

Primary Examiner — Allen Wong(74) *Attorney, Agent, or Firm* — Abelman, Frayne & Schwab(57) **ABSTRACT**

A pool cleaning system for cleaning debris from a submerged surface of a swimming pool includes a self-propelled pool cleaner having rotatably-mounted supports for supporting and guiding the cleaner on the pool surface; an electric motor for enabling the rotation of the rotatably-mounted supports on the pool surface; at least one camera to capture imagery of the pool surface; a controller, in electronic communication with the at least one camera, to determine a cleanliness characteristic of the pool surface on which the cleaner has passed based on the camera imagery and generate a control signal to direct movement of the cleaner based on the cleanliness characteristic of the pool surface, wherein the control signal directs movement of the cleaner to reclean a portion of the pool surface where the cleanliness characteristic fails to satisfy a predefined threshold.

22 Claims, 4 Drawing Sheets

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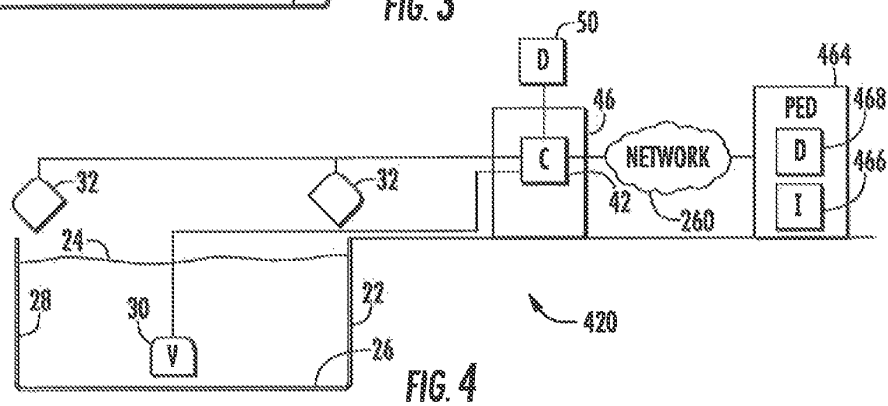
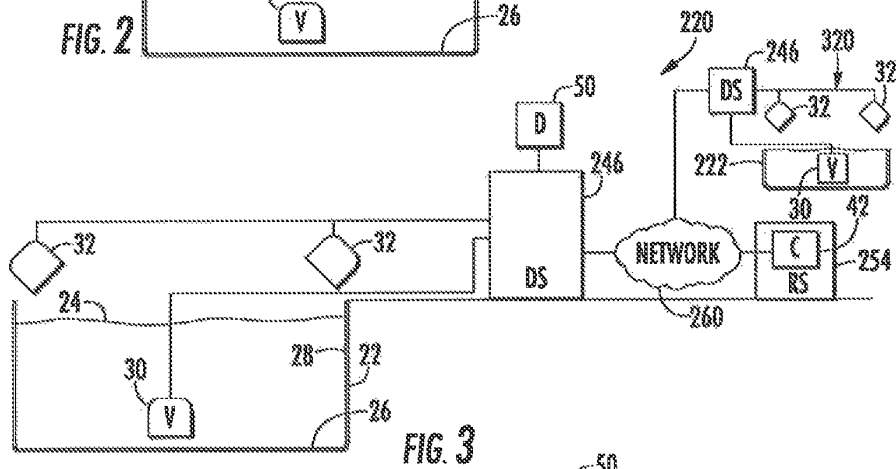
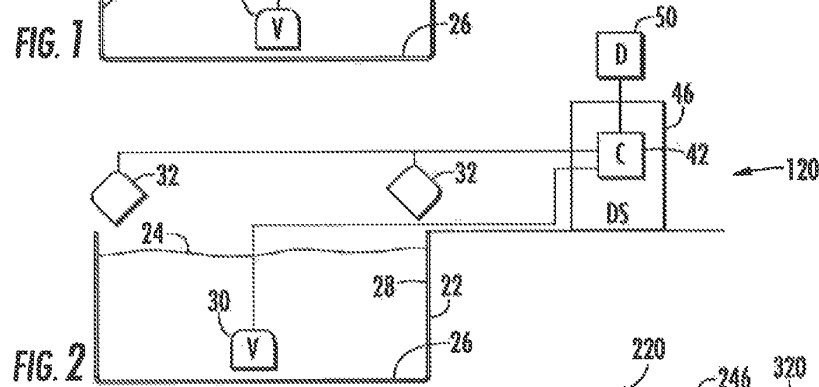
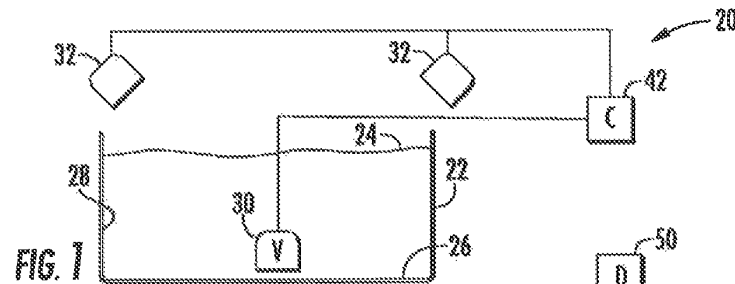
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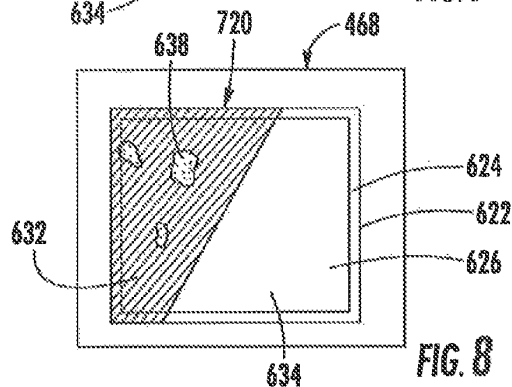
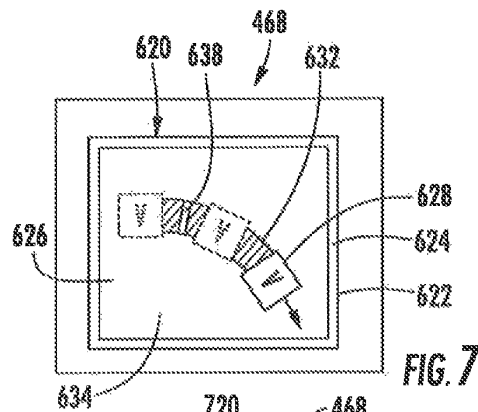
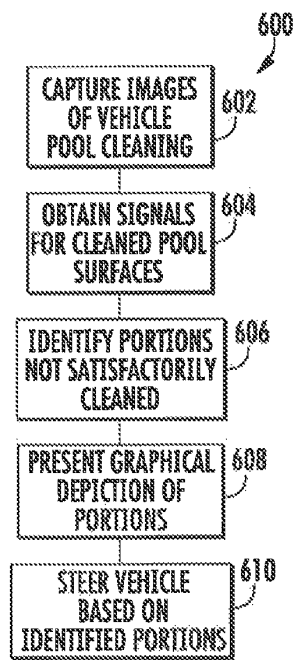
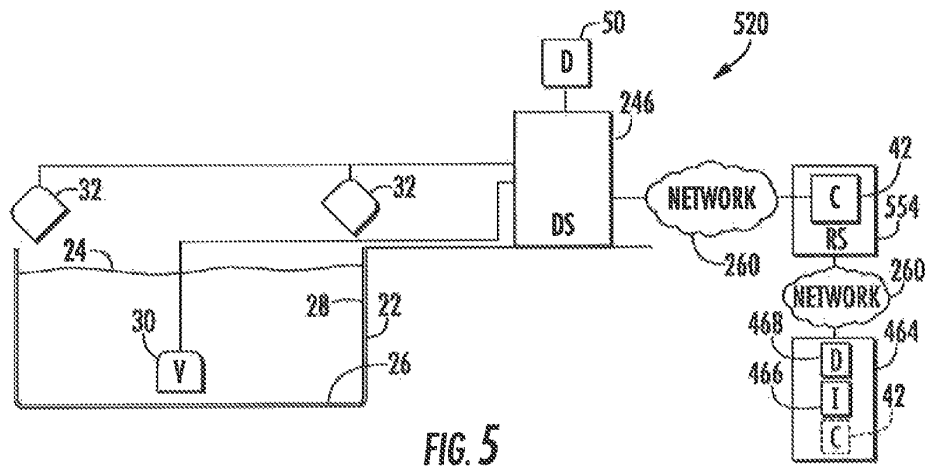


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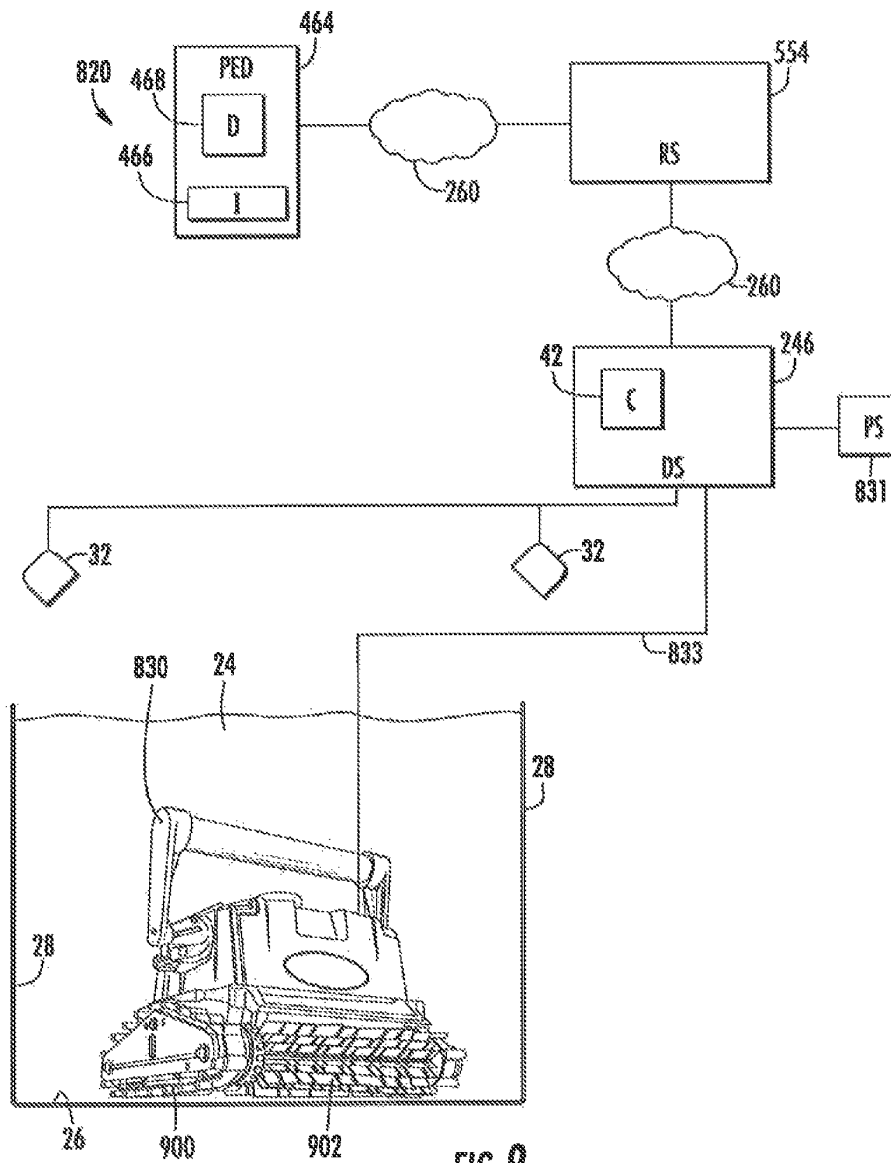


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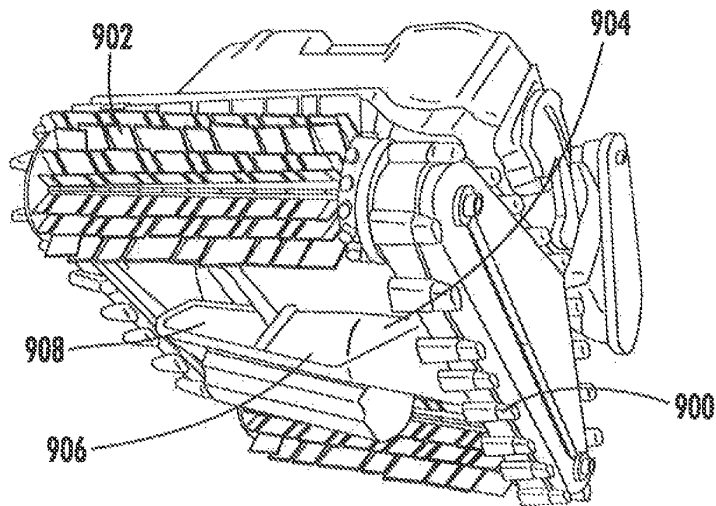


FIG. 10

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**POOL CLEANING SYSTEM AND METHOD
TO AUTOMATICALLY CLEAN SURFACES
OF A POOL USING IMAGES FROM A
CAMERA**

**CROSS-REFERENCE TO RELATED
APPLICATION**

This patent application is a Continuation of commonly owned U.S. patent application Ser. No. 13/545,918, filed Jul. 10, 2012, the contents of which are incorporated by reference herein in its entirety.

BACKGROUND

Manually cleaning the floor and sides of a swimming pool may be a tedious and time-consuming task. As a result, automated robotic pool cleaners have been developed. However, controlling and monitoring such automated robotic pool cleaners to insure that all portions of the pool surfaces are satisfactorily cleaned remains a challenge.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a schematic illustration of an example pool cleaning system.

FIG. 2 is a schematic illustration of an implementation of the pool cleaning system of FIG. 1.

FIG. 3 is a schematic illustration of an implementation of the pool cleaning system of FIG. 1.

FIG. 4 is a schematic illustration of an implementation of the pool cleaning system of FIG. 1.

FIG. 5 is a schematic illustration of an implementation of the pool cleaning system of FIG. 1.

FIG. 6 is a flow diagram of an example method that may be carried out with the pool cleaning system of FIG. 2-5.

FIG. 7 is a plan view of an example display with an example graphical depiction.

FIG. 8 is a plan view of another example display with an example graphical depiction.

FIG. 9 is a schematic illustration of an implementation of the pool cleaning system of FIG. 1 with an example pool cleaning vehicle.

FIG. 10 is a bottom perspective view of the example pool cleaning vehicle of the system of FIG. 9.

**DETAILED DESCRIPTION OF THE EXAMPLE
EMBODIMENTS**

FIG. 1 schematically illustrates an example pool cleaning system 20. As schematically shown by FIG. 1, pool cleaning system 20 is adapted to clean submerged surfaces of a pool 22 containing a liquid 24. In particular, pool cleaning system 20 is adapted to clean at least a bottom or floor surface 26 of the pool 22 and possibly to additionally clean surfaces 28 of pool 22. As will be described hereafter, pool cleaning system facilitates the control and monitoring of a robotic pool cleaner to better assure that all portions of pool 22 are satisfactorily cleaned.

Pool cleaning system 20 comprises vehicle 30, cameras 32 and controller 42. Vehicle 30 comprises an automated powered device configured to travel adjacent to submerged or water containing surfaces of pool 20 (such as floor 26 and/or side surfaces 28) while cleaning such surfaces. In one implementation, vehicle 30 may include vacuum or suction devices, a liquid circulation system and a filter to draw debris, such as bacterial growth or plant growth, from such

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pool surfaces, wherein the drawn liquid containing such residue or foreign matter is filtered to collect the debris. In other implementations, vehicle 30 may not collect such debris, wherein vehicle 30 merely loosens such debris on the pool surfaces such that the loosened or separated debris may be subsequently removed using the existing liquid filtering system of pool 22.

To assist in the loosening of debris, in one implementation, vehicle 30 may additionally include a chemical dispenser to closely apply pool cleaning chemicals to the pool surfaces as the vehicle 30 traverses such surfaces. In one implementation, vehicle 30 may additionally or alternatively include one or more scrubbing members, such as active (driven) or passive (undriven or idling) brushes, to assist in the removal of residue or foreign matter from such pool surfaces. In yet another implementation, vehicle 30 may additionally or alternatively include liquid jets to assist in the loosening of debris.

To move along the submerged surfaces of pool 22, vehicle 30 includes one or more propulsion mechanisms. In one implementation, vehicle 30 is propelled along the submerged pool surfaces using wheels, rollers, tracks or other surface contacting members powered by a motor and the like. Such wheels, rollers or tracks may themselves include the scrubbing members used to clean the surfaces. In one implementation vehicle 30 may also alternatively be propelled by means of the vacuum or liquid jets. The vacuum or liquid jets used for such propulsion nozzle facilitate loosening of debris for collection by vehicle 30. In other implementations, vehicle 30 may include other propulsion mechanisms.

Cameras 32 comprise devices configured to capture video or time lapse images of pool 22. In the example illustrated, cameras 32 are mounted on structures external to pool 22. In other words, cameras 32 are not submerged. In other implementations, cameras 32 may alternatively be mounted to vehicle 30. In the example illustrated, cameras 32 capture movement of vehicle 30 while vehicle 30 is submerged within pool 22. In other implementations, cameras 32 merely capture images of submerged surfaces 26, 28 of pool 22.

In the example illustrated, cameras 32 comprise cameras serving as part of a home or pool security system, wherein such cameras detect the presence of a person at pool 22 satisfying a predefined characteristic and wherein an alert is output upon the person's detected presence. For example, in one implementation, cameras 32 are utilized as part of a security system that detects when a person below a predefined age, such as a child, is present at pool 22 without a detected presence of a recognized adult. In another implementation, cameras 32 may detect the presence of an unauthorized person or intruder at pool 22. Identification of the person may be achieved by an off-site human or computerized monitoring system, wherein signals from cameras 32 are transmitted across a wide area network or may be achieved with software of controller 42 which includes facial recognition or other identification programming.

Because pool cleaning system 20 utilizes pre-existing cameras 32 provided as part of a security system or shares the use of cameras 32 with such a home or pool security system, pool cleaning system 20 is easier to set up, less complex and less expensive. In other implementations, pool cleaning system 20 may utilize dedicated cameras 22 independent of any cameras associated with a home, facility or pool security system. In such an alternative system, cameras 32 may be more precisely focused upon pool 22 and surfaces 26, 28 while also including appropriate lenses or modifica-

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tions to account for glare, refraction and the like to better facilitate the capture of surfaces and vehicle 30 which are submerged.

Controller 42 comprises one or more processing units in communication with vehicle 30 and cameras 32. For purposes of this application, the term “processing unit” shall mean a presently developed or future developed processing unit that executes sequences of instructions contained in a memory. Execution of the sequences of instructions causes the processing unit to perform steps such as generating control signals. The instructions may be loaded in a random access memory (RAM) for execution by the processing unit from a read only memory (ROM), a mass storage device, or some other persistent storage. In other embodiments, hard wired circuitry may be used in place of or in combination with software instructions to implement the functions described. For example, controller 42 may be embodied as part of one or more application-specific integrated circuits (ASICs). Unless otherwise specifically noted, the controller is not limited to any specific combination of hardware circuitry and software, nor to any particular source for the instructions executed by the processing unit.

In one implementation, controller 42 communicates with vehicle 30 and cameras 32 entirely across a wired connection. In another implementation, controller 42 communicates with vehicle 30 and cameras 32 across a wireless connection, such as across a local area network (LAN) or a wide area network (WAN) such as the Internet. One of limitation, controller 42 may communicate with vehicle 30 and cameras 32 using a combination of both wired and wireless communication connections.

Controller 42 is configured to generate control signals for steering vehicle 30 based upon signals received from cameras 32. In one implementation, controller 42 provides the sole steering directions for vehicle 30 using signals from cameras 32. Because vehicle 30 is precisely steered under the control of controller 42, rather than traveling in a random manner, entire summer surfaces of pool 22 may be more quickly and efficiently covered and cleaned. Because controller 42 provides the only steering instructions for vehicle 30 and utilizes signals from cameras 32, complex steering algorithms or codes in either vehicle 30 or controller 42 may be omitted to reduce complexity and cost of system 20.

In another implementation, vehicle 30 may cover or travel across surfaces of pool 22 in either a random fashion or according to an automated pool coverage algorithm or pool coverage pattern stored in a memory associated with vehicle 30 or controller 42. In such an implementation, controller 42 utilizes signals from cameras 32 to verify that all of the surfaces of pool 22 have been cleaned, that no spots have been missed. Upon identifying a missed spot, controller 42 utilizes signals from camera 32 to steer vehicle 32 over such missed portions of surfaces 26, 28. According to one example, controller 42 not only uses signals from camera 32 to determine whether any portions of surfaces 26, 28 have been missed entirely, but to also determine whether any portions of surfaces 26, 28 have been cleaned, but not to a satisfactory degree or extent. In such circumstances, controller 42 uses signals from cameras 32 to steer vehicle 34 such areas to re-clean such portions until such portions have been satisfactorily cleaned such that the portions have a cleanliness characteristic satisfying a predefined threshold.

FIG. 2 schematically illustrates pool cleaning system 120, the particular example of pool cleaning system 20 described above. Pool cleaning system 120 is similar to pool cleaning system 20 except that pool cleaning system 120 additionally comprises dry station 46 and display 50. Those remaining

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components of pool cleaning system 120 which correspond to components of pool cleaning system 20 are numbered similarly.

Dry station 46 comprises a station in communication with vehicle 30 and cameras 32 outside of pool 22. Dry station 46 incorporates controller 42. In one implementation, dry station 46 communicates with vehicle 30 in a wired fashion. In such an implementation, dry station 46 further provides electrical power to vehicle 30 in a wired fashion. Dry station 46 communicates with cameras 32 and either a wired or wireless fashion.

Display 50 comprises a device to present a graphical images and text on a display screen. In one implementation, display 58 may be incorporated as part of dry station 46. In another implementation, display 50 may be provided on a portable electronic device, a computer, a television and the like. Display 50 is utilized by pool cleaning system 120 to present information regarding the cleaning of pool 22 to facilitate control of vehicle 30 by controller 42. In one implementation, display 50 is utilized by pool cleaning system 120 and a controller 42 to present a graphical depiction of those portions of surfaces 26, 28 of pool 22 have not been satisfactorily cleaned so as to satisfy a predefined cleanliness characteristic threshold. Such portions may comprise portions that have been completely missed by vehicle 30 as well as those portions that have been covered by vehicle 30 but have not been satisfactorily cleaned with the given number of passes of vehicle 30 or the existing cleaning settings of vehicle 30. The graphical depiction presented on display 50 enables a person view the quality of the prior cleaning session and to input commands causing controller 42 to generate control signals using signals from camera 32 to steer vehicle 30 back to such identified portions where such portions may be cleaned at the same or elevated cleaning aggressiveness settings.

Another implementation, display 50 may be further utilized by controller 42 to depict the progress of vehicle 30 in cleaning pool 22. Such a display 50 allows a person to visually determine how much of the pool has been currently cleaned and to estimate the remaining time before the pool cleaning task is completed. In certain circumstances, using display 50, a person may adjust a setting of vehicle 30 to accelerate a rate at which surfaces 26, 28 of pool 22 are cleaned to meet an earlier desired completion time for such pool cleaning.

FIG. 3 schematically illustrates pool cleaning system 220, another example implementation of pool cleaning system 20. Pool cleaning system 220 is similar to pool cleaning system 20 except that pool cleaning system 220 additionally comprises dry station 246, display 50, and remote server 254. Those remaining components of pool cleaning system 220 which correspond to components of pool cleaning system 20 or pool cleaning system 120 are numbered similarly.

Dry station 246 is similar to dry station 46, described above, except that dry station 246 serves as a local interface for communication with controller 42 across a network 260. In one implementation, network 260 may comprise a local area network. In another implementation, network 260 may comprise a wide area network, such as the Internet. For example, in one implementation, dry station 246 may incorporate a modem. In one implementation, dry station 246 may communicate across a local area network to controller 42. In another implementation, dry station 246 may communicate through a router, across a local area network, to a local modem which communicates across a network 260. The example illustrated, dry station 246 further provides

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part of vehicle 30 across a wired cable or wired connection. Display 50 is described above with respect to system 120.

Remote server 254 comprises a server remote from dry station 246 which is in communication with dry station 246 across network 260. Remote server 254 includes controller 42. During operation, signals from cameras 32 are transmitted across dry station 246 across network 260 to controller 42 of remote server 254. Based upon such signals from cameras 32, controller 42 generates control signals which are transmitted back across network 260 and through dry station 246 to vehicle 30 to steer vehicle 30.

As shown by FIG. 3, remote server 254 and network 260 may be shared as part of other pool cleaning systems 320, wherein controller 42 generates control signals for steering the pool cleaning vehicle 30 of system 320 based upon signals from cameras 32 transmitted across dry station 246 of system 320. In such an implementation, the cost and complexity of pool cleaning system 220 is reduced since controller 42 is remotely provided at remote server 254 which services multiple pool cleaning systems 220, 320. Upgrades to controller 42 and its software are also more easily achieved for all pool cleaning systems to 20, 320 and their pools 22, 222 being serviced. In one implementation, the supervised cleaning, inspection and possible re-cleaning facilitated by the use of cameras 32 may be provided as part of a subscription to users of vehicle 30. In such an implementation, a pool 22 having security cameras 32 may be upgraded with appropriate software or an appropriate software module added to dry station 246 to make a network connection with controller 42 which directs the security cameras 32 to capture vehicle 30. 20 utilizes such signals for steering vehicle 30.

FIG. 4 schematically illustrates pool cleaning system 420, another particular implementation of pool cleaning system 20. Pool cleaning system 420 is similar to pool cleaning system 120 except that pool cleaning system 420 additionally comprises a portable electronic device 464. Those remaining components of pool cleaning system 420 which correspond to components of pool cleaning system 120 are numbered similarly.

Portable electronic device 464 comprises a portable handheld electronic device in communication with controller 42 and/or dry station 46 across network 260. Examples of such a portable electronic device (PED) 300 include, but are not limited to, a smart phone, a personal data assistant (PDA), laptop, notebook computer, tablet computer (e.g., IPAD) and MP3 player (e.g., IPOD TOUCH). In the example illustrated, PED 464 comprises input 466 and display 468.

Input 466 serves as a user interface for PED 464 by which inputs are made to PED 464. Input 466 facilitates entry of inputs or commands by a person to cause controller 42 to generate control signals varying the control of vehicle 30. In one implementation, input 466 comprise a keyboard. In other implementations, input 466 may comprise a touchpad, a stylus, a microphone with associated speech recognition software or programming, a touch screen, buttons, switches and the like. In some implementations, input 466 may comprise a touch screen incorporated as part of display 468.

Display 468 comprises a user interface by which graphical or textual data is presented to a user. Display 468 may present the same or similar information as presented at dry station 246 by display 50 as described above. In one implementation, display 468 comprises a liquid crystal display. In other implementations, display 468 may comprise other types of display technology such as a light emitting diode display, an organic light emitting diode display (OLED), an electronic ink (e-ink) display or other

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types of display technology in present use or developed in the future. Although system 420 is illustrated as including controller 422 is part of dry station 46, in some implementations, controller 42 may alternatively be located as part of PED 464.

PED 464 enables a person located remote from pool 22 to monitor the progress of the cleaning of pool 22 by vehicle 30 of system 420. PED 464 provides a person with a graphical presentation (described above with respect to display 50) indicating those portions of surfaces 26 28 of pool 22 that have been completed as well as those portions 26, 20 and that remain to be cleaned. The person may also be provided with a graphical indication of what portions need to be re-cleaned to meet predetermined cleanliness thresholds. In the example illustrated, input 466 enables a person to enter commands or selections which are transmitted across network 260 to controller 42 to adjust operation of vehicle 30. For example, the path or route of vehicle 30 may be changed, the aggressiveness of the cleaning chemicals or mechanical cleaning devices may be adjusted, the speed at which vehicle 30 traverses surfaces 26, 28 may be adjusted. In response to such adjustment signals from PED 464, controller 42 may utilize signals from cameras 32 to adjust the steering of vehicle 30.

FIG. 5 schematically illustrates pool cleaning system 520, another example implementation of pool cleaning system 20. Pool cleaning system 520 is similar to pool cleaning system 420 except that pool cleaning system 520 additionally comprises a remote server 554. Those remaining components of pool cleaning system 520 which correspond to components of pool cleaning system 420 are numbered similarly.

Remote server 554 is similar to remote server 254 described above with respect to system 220. Remote server 554 comprises a server remote from dry station 246 which is in communication with dry station 246 across network 260. Remote server 554 includes controller 42. During operation, signals from cameras 32 are transmitted across dry station 246 across network 260 to controller 42 of remote server 554. Based upon such signals from cameras 32, controller 42 generates control signals which are transmitted back across network 260 and through dry station 246 to vehicle 30 to steer vehicle 30. Controller 42 further relays either the raw signals from camera 32 or image signals generated based upon signals from cameras 32 to PED 464, wherein such images (described above) are presented on display 468. As noted above, PED may further receive commands through input 466, wherein such commands are transmitted to controller 42 which generates control signals that are ultimately transmitted to vehicle 30 for steering vehicle 30.

As with remote server 254, remote server 554 and network 260 may be shared as part of other pool cleaning systems 320 (shown in FIG. 3), wherein controller 42 generates control signals for steering the pool cleaning vehicle 30 of system 320 based upon signals from cameras 32 transmitted across dry station 246 of system 320. In such implementations, controller 42 of remote server 554 may interact with other PEDs 464. In such an implementation, the cost and complexity of pool cleaning system 220 is reduced since controller 42 is remotely provided at remote server 254 which services multiple pool cleaning systems 220, 320. Upgrades to controller 42 and its software are also more easily achieved for all pool cleaning systems to 20, 320 and their pools 22, 222 being serviced. In one implementation, the supervised cleaning, inspection and possible re-cleaning facilitated by the use of cameras 32 may be

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provided as part of a subscription to users of vehicle 30. In such an implementation, a pool 22 having security cameras 32 may be upgraded with appropriate software or an appropriate software module added to dry station 246 to make a network connection with controller 42 which directs the security cameras 32 to capture vehicle 30. As indicated by broken lines, in other implementations, the controller 42 for generating control signals steering vehicle 30 based upon signals from cameras 32 may alternatively be relocated in PED 464.

FIG. 6 is a flow diagram illustrating an example method 600 that may be carried out by any of systems 120-520. As indicated by step 602, cameras 32 capture images of pool cleaning by vehicle 30. As indicated by step 604, controller 42 obtain such signals from cameras 32 for the surfaces of pool 22 that have been cleaned. As indicated by step 606, controller 42 uses information gathered from the signals from cameras 32 to identify those portions of surfaces 26, 28 not satisfactorily cleaned—not satisfying a predefined cleanliness characteristic or measurement threshold. One example of a cleanliness characteristic measurement a threshold may be how well the color of a surface matches a predetermined desirable color for the pool surface (such as original color of the tile or surface). A surface that has been missed entirely by vehicle 30 during a pool cleaning session may be automatically deemed to not satisfy a predetermined cleanliness characteristic.

As indicated by step 608, based upon such determinations, controller 42 generates control signals resulting in the presentation of a graphical depiction of those portions of pool 22 that has not been satisfactorily cleaned. Such graphical representations or depictions may be presented on display 50 or display 468. FIGS. 7 and 8 illustrate examples of graphical depictions that may be presented.

FIG. 7 illustrates display 468 presenting graphical depiction 620. Graphical depiction 620 comprises a first graphic 622 having a first portion 624 representing sides or walls 28 of pool 22 and a second portion 626 representing the floor 26 of pool 22. Graphical depiction 620 further comprises a moving icon 628 representing the current positioning of vehicle 30. In one implementation, the path of vehicle 30 may additionally be depicted by icon 628 shown in broken lines. As shown by FIG. 7, those portions 632 of surfaces 26, 28 of pool 22 (shown in FIG. 1) over which of vehicle 30 has moved are identified by graphical depiction 620 either by color, markings or other various distinctive attributes. Likewise, those portions 634 of surfaces 26, 28 of pool 22 that have not been covered by vehicle 30 are identified by a distinct color or marking or distinctive attribute of depiction 620. As a result, a person may view the current position of vehicle 30, the extent to which pool 22 has been cleaned or covered by vehicle 30 and the extent of pool 22 that remains to be cleaned. In the example illustrated, depiction 620 further identifies those portions 638 of surfaces 26, 28 that have been cleaned, but which have not been cleaned to a satisfactory degree or extent. In one implementation, portions 638 may be identified by colors, brightness, markings or other visually distinctive attributes that are visually distinct from both portions 632 and portions 634. In other implementations, portions 638 may have the same characteristic of portions 634. In yet other implementations, different portions 638 may have different visual attributes depending upon a degree to which such clean portions have failed to satisfy the predefined cleanliness characteristic threshold. In some implementations, different portions 638 may have different visual attributes depending upon different cleaning strategies that may be recommended for the dif-

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ferent portions 638. For example, controller 42 may determine and recommend a first cleaning strategy (a first chemical solution jetted at a first rate and scrubbed at a first rate) with respect to a first portion 638 and may recommend a second different cleaning strategy (a second chemical solution jetted at a second rate is about a second rate) with respect to a second portion 638, wherein the different cleaning strategies are represented by different visual attributes presented in depiction 620.

FIG. 8 illustrates display 468 presenting a graphical depiction 720. Graphical depiction 720 comprises a first graphic 622 having a first portion 624 representing sides or walls 28 of pool 22 and a second portion 626 representing the floor 26 of pool 22 (shown in FIG. 1). Graphical depiction 720 is similar to graphical depiction 620 except that graphical depiction 720 omits icon 628 presenting vehicle 30. Like depiction 620, depiction 720 graphically depicts those portions 632 of surfaces 26, 28 over which vehicle 30 has traveled while in a cleaning mode. Depiction 720 also visually depicts those portions 634 that have not been covered by vehicle 30 in the cleaning mode and those portions 638 over which vehicle 30 has traveled while in the cleaning mode, but which have not been cleaned to a satisfactory degree. As illustrated in FIG. 8, different portions 638 may be visibly distinguished from one another through color, text or markings indicating either differences in the cleanliness of such portions 638 or indicating different recommended cleaning strategies or approaches that may be selected by a person using input 466 when vehicle 30 is steered back to such portions 638 for re-cleaning using signals from camera 32.

As indicated by step 610 of FIG. 6, controller 42 generates control signals steering vehicle 30 to re-clean portions of pool 22, such as portions 638. Such steering may be facilitated by using signals from cameras 32. As noted above, in some implementations, a person may be allowed choose a cleaning approach for a particular portion 638 using input 466. The selection may be facilitated by visual inspection of the different visual attributes for the particular portion 638 provided by depiction 720 (or depiction 620). In some implementations, input 466 may additionally be utilized by a person to prioritize an order in which portions 638 are re-cleaned.

FIG. 9 illustrates pool cleaning system 820, an example implementation of pool cleaning system 20. Pool cleaning system 820 is similar to pool cleaning system 520 except the pool cleaning system 820 located controller 42 in dry station 246 and includes pool cleaning vehicle 830, a specific example of vehicle 30. As shown by FIG. 9, in addition to transmitting control signals generated by controller 42 to vehicle 830, dry station 246 further transmits power from power source 831 through a power line or power cable 833 to vehicle 830. In the example illustrated, data communication and communication of control signals, also occurs across wired connections within or alongside the same line 833. In the example illustrated, remote server 554 serves as a communication link by which upgrades to controller 42 may be implemented across a wide number of pool cleaning systems and by which information from controller 42 is conveyed to one or more portable electronic devices 464 across network 260.

Vehicle 830 comprises a robotic or automated pool cleaning device. Vehicle 830 comprises a self-contained onboard filtration system with drive and pump motors. Vehicle 830 utilizes an internal microprocessor guided drive motor to systematically clean surfaces of pool 22. As shown by FIGS. 9 and 10, vehicle 830 utilizes a toothed track drive 900

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provide traction and propulsion for vehicle 30. Vehicle 830 comprises rotating brushes 902 to loosen waterline buildup and breakdown large debris while power washing jets 904 flush out dirt from pores, seems in corners where brushes 902 may not be able to reach. The loosened dirt and debris is vacuumed through off-center vacuum ports 906 which passes the vacuumed debris through internally house filter bag. In the example illustrated, vehicle 830 further comprises rollers 908 which inhibit vehicle 830 from becoming impeded or stuck on raised drains or pop-up heads. Although illustrated as being employed with system 820, vehicle 830 may also be utilized with any of systems 20, 120, 220, 320 and 420. In other implementations, other robotic or automated pool cleaning vehicles may be utilized.

Although the present disclosure has been described with reference to example embodiments, workers skilled in the art will recognize that changes may be made in form and detail without departing from the spirit and scope of the claimed subject matter. For example, although different example embodiments may have been described as including one or more features providing one or more benefits, it is contemplated that the described features may be interchanged with one another or alternatively be combined with one another in the described example embodiments or in other alternative embodiments. Because the technology of the present disclosure is relatively complex, not all changes in the technology are foreseeable. The present disclosure described with reference to the example embodiments and set forth in the following claims is manifestly intended to be as broad as possible. For example, unless specifically otherwise noted, the claims reciting a single particular element also encompass a plurality of such particular elements.

What is claimed is:

1. A pool cleaning system for cleaning debris from a submerged surface of a swimming pool comprising:

- a self-propelled pool cleaner having rotatably-mounted supports for supporting and guiding the cleaner on the pool surface;
- a filter configured to retain the debris collected from the submerged surface of the swimming pool;
- an electric motor for enabling the rotation of the rotatably-mounted supports on the pool surface;
- at least one camera to capture imagery of the pool surface;
- a controller, in electronic communication with the at least one camera, to determine a cleanliness characteristic of the pool surface on which the cleaner has passed based on the camera imagery and generate a control signal to direct movement of the cleaner based on the cleanliness characteristic of the pool surface, wherein the control signal directs movement of the cleaner to reclean a portion of the pool surface where the cleanliness characteristic fails to satisfy a predefined threshold.

2. The system of claim 1, wherein the at least one camera is carried by the cleaner.

3. The system of claim 1, wherein the controller is carried by the cleaner.

4. The system of claim 1, wherein the electric motor is mechanically connected to at least one of the rotatably-mounted supports.

5. The system of claim 1, wherein the controller is operable to execute one or more cleaning programs for cleaning the submerged surfaces of the pool.

6. The system of claim 1, wherein the captured imagery from the at least one camera is digitally processed by the controller to determine the cleanliness characteristic of the pool surface.

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7. The system of claim 1, wherein the captured imagery from the at least one camera is digitally processed by a remote processor to determine the cleanliness characteristic of the pool surface.

8. The system of claim 1 further comprising at least one sensor to detect the cleanliness characteristic of the pool surface on which the cleaner has passed.

9. The system of claim 8, wherein the at least one sensor is carried by the cleaner.

10. The system of claim 1, wherein the control signal causes the cleaner to drive in the direction of the portion of the pool surface to be recleaned.

11. The system of claim 1, wherein the control signal causes the cleaner to steer in the direction of the portion of the pool surface to be recleaned.

12. The system of claim 1 further comprising a dry station located remotely from the cleaner and in communication with the cleaner, wherein the dry station includes the controller.

13. The system of claim 1 further comprising a dry station located remotely from the cleaner and in communication with the cleaner, wherein the controller is located remotely from the cleaner and the dry station.

14. The system of claim 1 further comprising a portable electronic device having a display, wherein the portable electronic device is configured to present a graphic on the display, the graphic depicting the submerged surface of the pool and those portions of the surface that remain uncleaned as the cleaner traverses the pool surface.

15. The system of claim 1, wherein the controller controls electric power provided to the electric motor.

16. A pool cleaning system for cleaning debris from a submerged surface of a swimming pool comprising:

- a self-propelled pool cleaner having rotatably-mounted supports for supporting and guiding the cleaner on the pool surface;
- an electric motor for enabling the rotation of the rotatably-mounted supports on the pool surface;
- a filter configured to retain the debris collected from the submerged surface of the swimming pool;
- at least one camera to capture imagery of the pool surface;
- at least one sensor to detect a cleanliness characteristic of the pool surface on which the cleaner has passed;
- a controller in electronic communication with the at least one camera and the at least one sensor to generate a control signal to direct movement of the cleaner based on the cleanliness characteristic of the pool surface; and
- wherein the control signal directs movement of the cleaner to reclean a portion of the pool surface where the cleanliness characteristic fails to satisfy a predefined threshold.

17. The system of claim 16, wherein the at least one camera and at least one sensor are carried by the cleaner.

18. The system of claim 16, wherein the controller is operable to execute one or more cleaning programs for cleaning the submerged surfaces of the pool.

19. The system of claim 16, wherein the at least one camera captures the imagery during a pass of the cleaner on the submerged surface and the captured imagery from the at least one camera is utilized to determine the cleanliness characteristic of the pool surface.

20. The system of claim 16, wherein the captured imagery from the at least one camera is digitally processed by the controller to determine the cleanliness characteristic of the pool surface.

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21. The system of claim **16**, wherein the control signal causes the cleaner to drive in the direction of the portion of the pool surface to be recleaned.

22. The system of claim **16**, wherein the controller controls electric power provided to the electric motor.

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EXHIBIT G

(12) **United States Patent**
Durvasula et al.(10) **Patent No.:** **US 9,388,595 B2**
(45) **Date of Patent:** **Jul. 12, 2016**(54) **POOL CLEANING SYSTEM AND METHOD TO AUTOMATICALLY CLEAN SURFACES OF A POOL USING IMAGES FROM A CAMERA**(75) Inventors: **Kameshwar Durvasula**, Lyndhurst, NJ (US); **William Londono Correa**, Bloomfield, NJ (US)(73) Assignee: **Aqua Products, Inc.**, Cedar Grove, NJ (US)

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 909 days.

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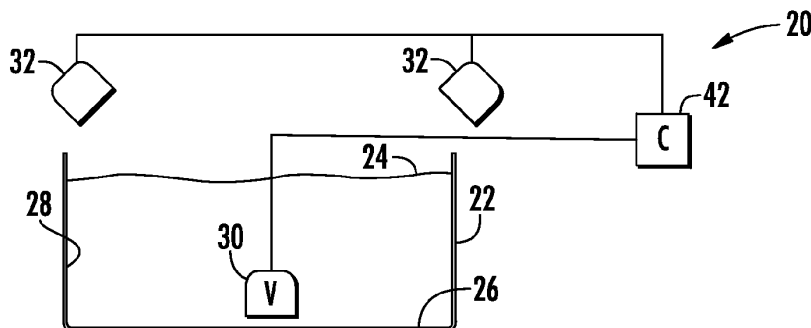
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(57) **ABSTRACT**

A pool cleaning system utilizes a powered robotic surface cleaning vehicle to travel adjacent water containing surfaces of a pool while submerged within the pool. In one implementation, a camera captures movement of the vehicle. In one implementation, a dry station serve the intermediary across a wide area network between the vehicle and a server which communicates with the portable electronic device.

22 Claims, 4 Drawing Sheets

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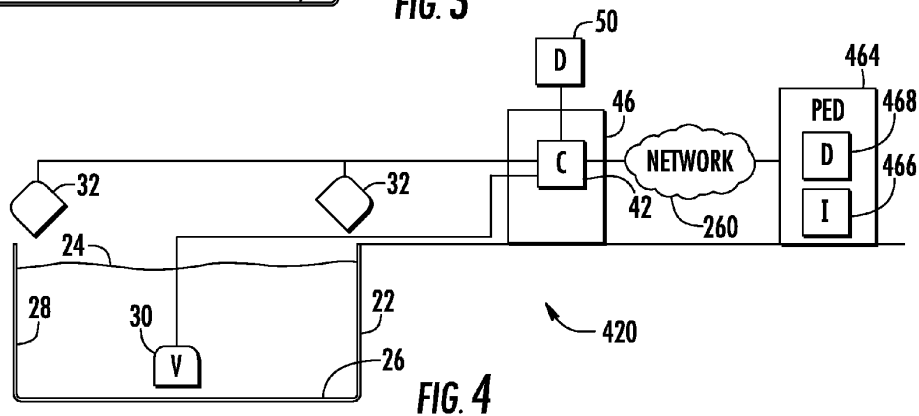
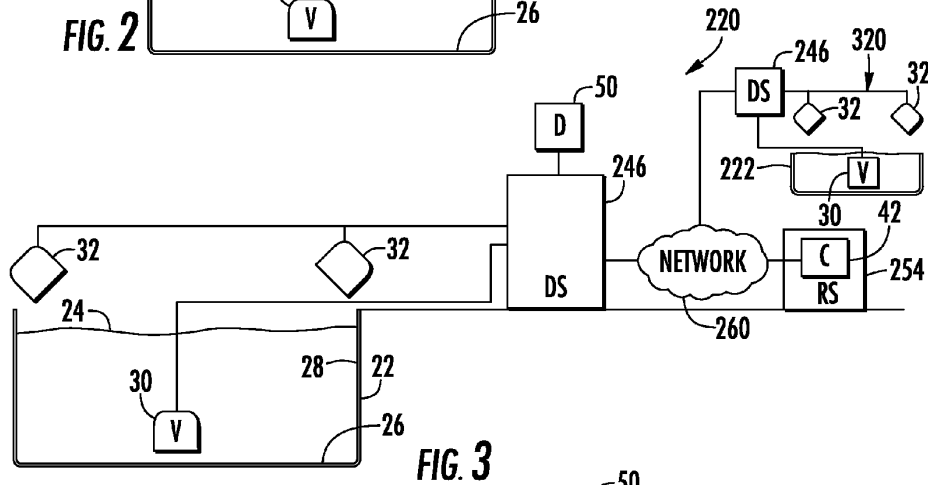
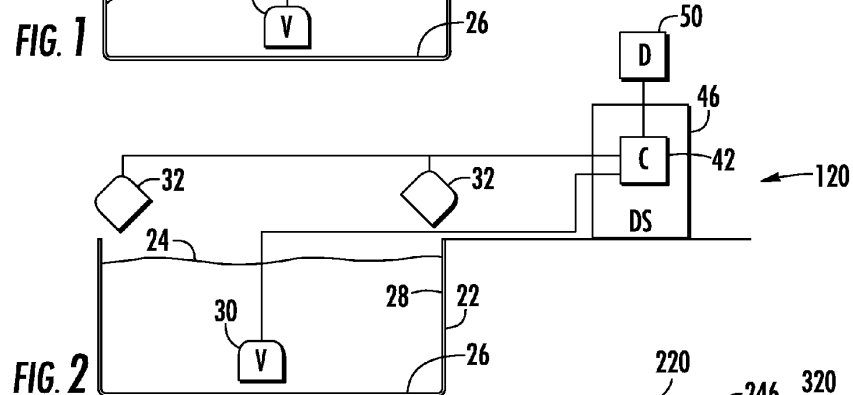
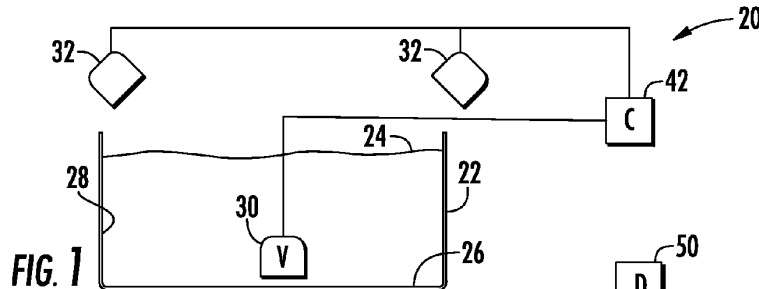
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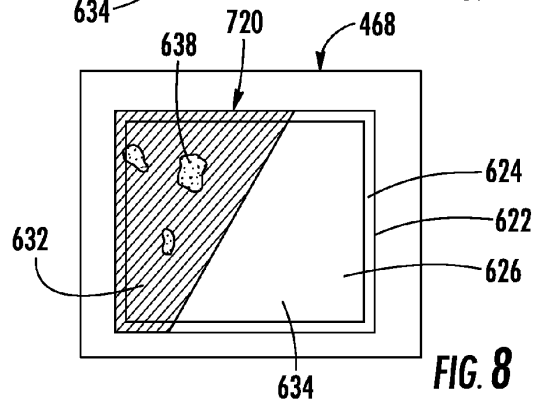
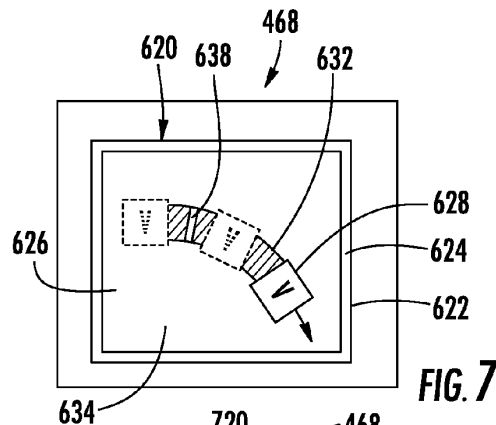
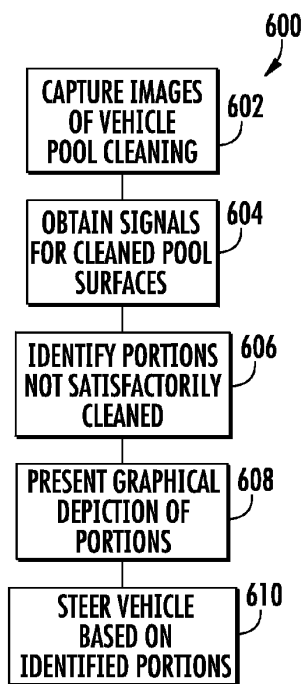
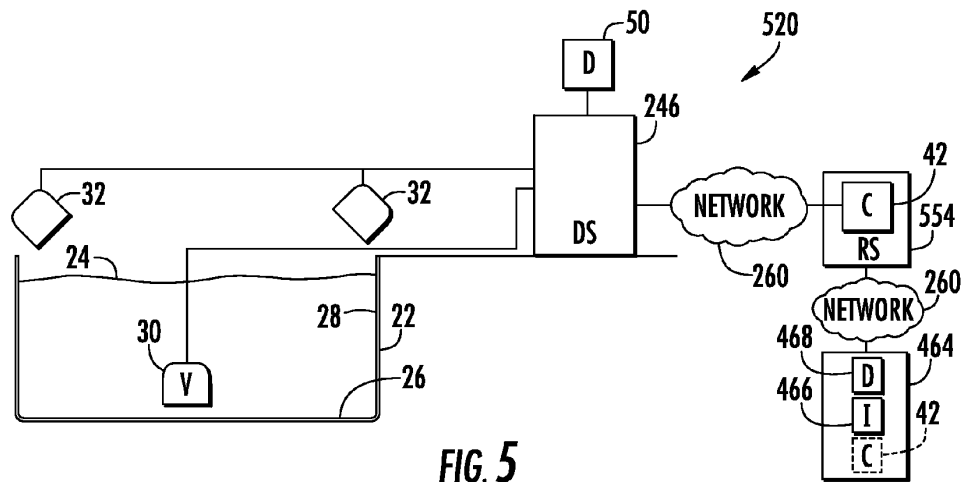
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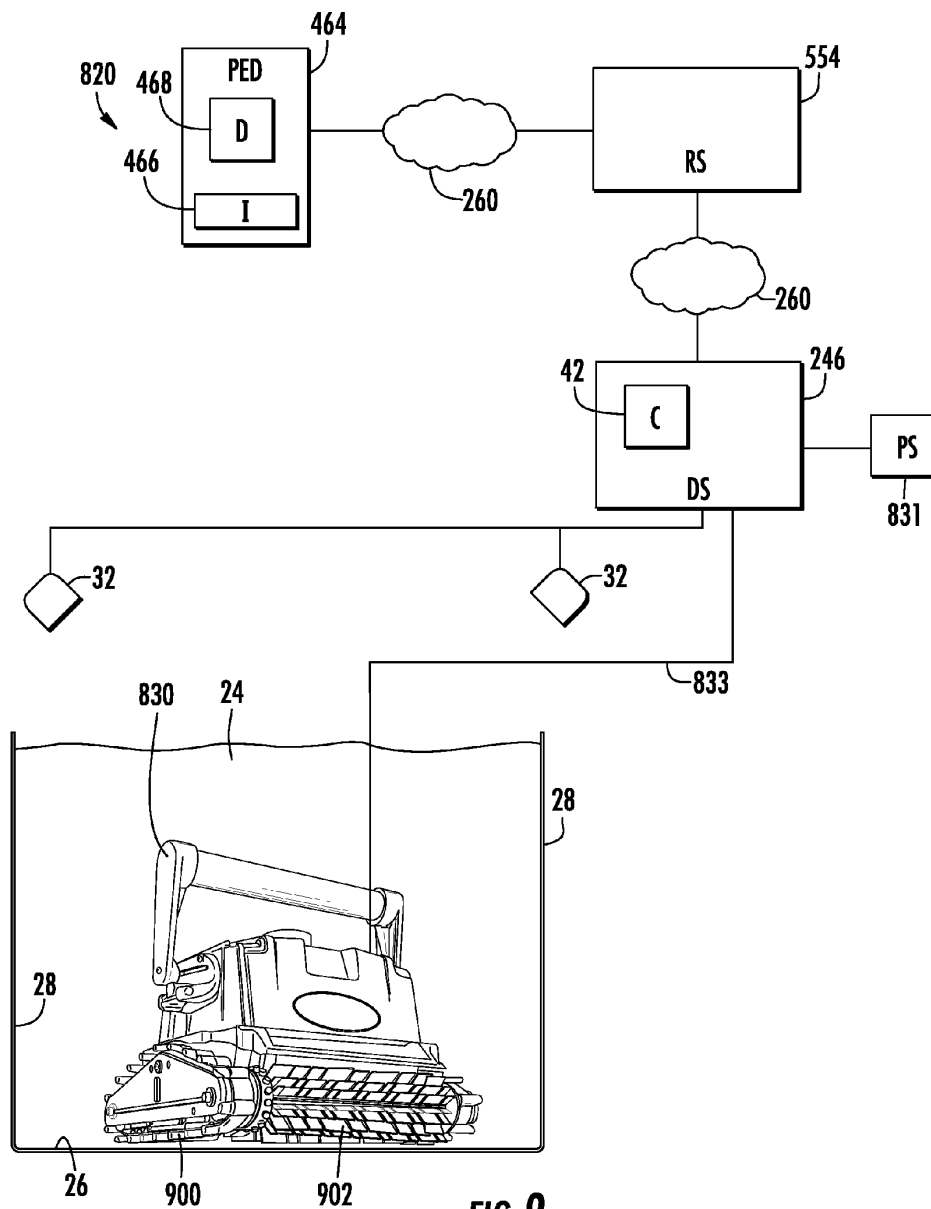


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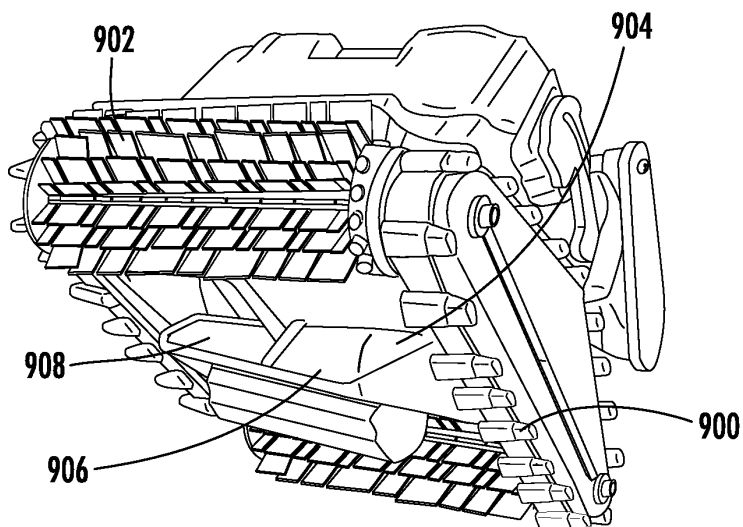


FIG. 10

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**POOL CLEANING SYSTEM AND METHOD
TO AUTOMATICALLY CLEAN SURFACES OF
A POOL USING IMAGES FROM A CAMERA**

BACKGROUND

Manually cleaning the floor and sides of a swimming pool may be a tedious and time-consuming task. As a result, automated robotic pool cleaners have been developed. However, controlling and monitoring such automated robotic pool cleaners to insure that all portions of the pool surfaces are satisfactorily cleaned remains a challenge.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a schematic illustration of an example pool cleaning system.

FIG. 2 is a schematic illustration of an implementation of the pool cleaning system of FIG. 1.

FIG. 2 is a schematic illustration of an implementation of the pool cleaning system of FIG. 1.

FIG. 3 is a schematic illustration of an implementation of the pool cleaning system of FIG. 1.

FIG. 4 is a schematic illustration of an implementation of the pool cleaning system of FIG. 1.

FIG. 5 is a schematic illustration of an implementation of the pool cleaning system of FIG. 1.

FIG. 6 is a flow diagram of an example method that may be carried out with the pool cleaning system of FIG. 2-5.

FIG. 7 is a plan view of an example display with an example graphical depiction.

FIG. 8 is a plan view of another example display with an example graphical depiction.

FIG. 9 is a schematic illustration of an implementation of the pool cleaning system of FIG. 1 with an example pool cleaning vehicle.

FIG. 10 is a bottom perspective view of the example pool cleaning vehicle of the system of FIG. 9.

**DETAILED DESCRIPTION OF THE EXAMPLE
EMBODIMENTS**

FIG. 1 schematically illustrates an example pool cleaning system 20. As schematically shown by FIG. 1, pool cleaning system 20 is adapted to clean submerged surfaces of a pool 22 containing a liquid 24. In particular, pool cleaning system 20 is adapted to clean at least a bottom or floor surface 26 of the pool 22 and possibly to additionally clean surfaces 28 of pool 22. As will be described hereafter, pool cleaning system facilitates the control and monitoring of a robotic pool cleaner to better assure that all portions of pool 22 are satisfactorily cleaned.

Pool cleaning system 20 comprises vehicle 30, cameras 32 and controller 42. Vehicle 30 comprises an automated powered device configured to travel adjacent to submerged or water containing surfaces of pool 20 (such as floor 26 and/or side surfaces 28) while cleaning such surfaces. In one implementation, vehicle 30 may include vacuum or suction devices, a liquid circulation system and a filter to draw debris, such as bacterial growth or plant growth, from such pool surfaces, wherein the drawn liquid containing such residue or foreign matter is filtered to collect the debris. In other implementations, vehicle 30 may not collect such debris, wherein vehicle 30 merely loosens such debris on the pool surfaces such that the loosened or separated debris may be subsequently removed using the existing liquid filtering system of pool 22.

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To assist in the loosening of debris, in one implementation, vehicle 30 may additionally include a chemical dispenser to closely apply pool cleaning chemicals to the pool surfaces as the vehicle 30 traverses such surfaces. In one implementation, vehicle 30 may additionally or alternatively include one or more scrubbing members, such as active (driven) or passive (undriven or idling) brushes, to assist in the removal of residue or foreign matter from such pool surfaces. In yet another implementation, vehicle 30 may additionally or alternatively include liquid jets to assist in the loosening of debris.

To move along the submerged surfaces of pool 22, vehicle 30 includes one or more propulsion mechanisms. In one implementation, vehicle 30 is propelled along the submerged pool surfaces using wheels, rollers, tracks or other surface contacting members powered by a motor and the like. Such wheels, rollers or tracks may themselves include the scrubbing members used to clean the surfaces. In one implementation vehicle 30 may also alternatively be propelled by means of the vacuum or liquid jets. The vacuum or liquid jets used for such propulsion nozzle facilitate loosening of debris for collection by vehicle 30. In other implementations, vehicle 30 may include other propulsion mechanisms.

Cameras 32 comprise devices configured to capture video or time lapse images of pool 22. In the example illustrated, cameras 32 are mounted on structures external to pool 22. In other words, cameras 32 are not submerged. In other implementations, cameras 32 may alternatively be mounted to vehicle 30. In the example illustrated, cameras 32 capture movement of vehicle 30 while vehicle 30 is submerged within pool 22. In other implementations, cameras 32 merely capture images of submerged surfaces 26, 28 of pool 22.

In the example illustrated, cameras 32 comprise cameras serving as part of a home or pool security system, wherein such cameras detect the presence of a person at pool 22 satisfying a predefined characteristic and wherein an alert is output upon the person's detected presence. For example, in one implementation, cameras 32 are utilized as part of a security system that detects when a person below a predefined age, such as a child, is present at pool 22 without a detected presence of a recognized adult. In another implementation, cameras 32 may detect the presence of an unauthorized person or intruder at pool 22. Identification of the person may be achieved by an off-site human or computerized monitoring system, wherein signals from cameras 32 are transmitted across a wide area network or may be achieved with software of controller 42 which includes facial recognition or other identification programming.

Because pool cleaning system 20 utilizes pre-existing cameras 32 provided as part of a security system or shares the use of cameras 32 with such a home or pool security system, pool cleaning system 20 is easier to set up, less complex and less expensive. In other implementations, pool cleaning system 20 may utilize dedicated cameras 22 independent of any cameras associated with a home, facility or pool security system. In such an alternative system, cameras 32 may be more precisely focused upon pool 22 and surfaces 26, 28 while also including appropriate lenses or modifications to account for glare, refraction and the like to better facilitate the capture of surfaces and vehicle 30 which are submerged.

Controller 42 comprises one or more processing units in communication with vehicle 30 and cameras 32. For purposes of this application, the term "processing unit" shall mean a presently developed or future developed processing unit that executes sequences of instructions contained in a memory. Execution of the sequences of instructions causes the processing unit to perform steps such as generating control signals. The instructions may be loaded in a random access

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memory (RAM) for execution by the processing unit from a read only memory (ROM), a mass storage device, or some other persistent storage. In other embodiments, hard wired circuitry may be used in place of or in combination with software instructions to implement the functions described. For example, controller 42 may be embodied as part of one or more application-specific integrated circuits (ASICs). Unless otherwise specifically noted, the controller is not limited to any specific combination of hardware circuitry and software, nor to any particular source for the instructions executed by the processing unit.

In one implementation, controller 42 communicates with vehicle 30 and cameras 32 entirely across a wired connection. In another implementation, controller 42 communicates with vehicle 30 and cameras 32 across a wireless connection, such as cross a local area network (LAN) or a wide area network (WAN) such as the Internet. One of limitation, controller 42 may communicate with vehicle 30 and cameras 32 using a combination of both wired and wireless communication connections.

Controller 42 is configured to generate control signals for steering vehicle 30 based upon signals received from cameras 32. In one implementation, controller 42 provides the sole steering directions for vehicle 30 using signals from cameras 32. Because vehicle 30 is precisely steered under the control of controller 42, rather than traveling in a random manner, entire summer surfaces of pool 22 may be more quickly and efficiently covered and cleaned. Because controller 42 provides the only steering instructions for vehicle 30 and utilizes signals from cameras 32, complex steering algorithms or codes in either vehicle 30 or controller 42 may be omitted to reduce complexity and cost of system 20.

In another implementation, vehicle 30 may cover or travel across surfaces of pool 22 in either a random fashion or according to an automated pool coverage algorithm or pool coverage pattern stored in a memory associated with vehicle 30 or controller 42. In such an implementation, controller 42 utilizes signals from cameras 32 to verify that all of the surfaces of pool 22 have been cleaned, that no spots have been missed. Upon identifying a missed spot, controller 42 utilizes signals from camera 32 to steer vehicle 32 cover such missed portions of surfaces 26, 28. According to one example, controller 42 not only uses signals from camera 32 to determine whether any portions of surfaces 26, 28 have been missed entirely, but to also determine whether any portions of surfaces 26, 28 have been cleaned, but not to a satisfactory degree or extent. In such circumstances, controller 42 uses signals from cameras 32 to steer vehicle 34 such areas to re-clean such portions until such portions have been satisfactorily cleaned such that the portions have a cleanliness characteristic satisfying a predefined threshold.

FIG. 2 schematically illustrates pool cleaning system 120, the particular example of pool cleaning system 20 described above. Pool cleaning system 120 is similar to pool cleaning system 20 except that pool cleaning system 120 additionally comprises dry station 46 and display 50. Those remaining components of pool cleaning system 120 which correspond to components of pool cleaning system 20 are numbered similarly.

Dry station 46 comprise a station in communication with vehicle 30 and cameras 32 outside of pool 22. Dry station 46 incorporates controller 42. In one implementation, dry station 46 communicates with vehicle 30 in a wired fashion. In such an implementation, dry station 46 further provides electrical power to vehicle 30 in a wired fashion. Dry station 46 communicates with cameras 32 and either a wired or wireless fashion.

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Display 50 comprises a device to present a graphical images and text on a display screen. In one implementation, display 58 may be incorporated as part of dry station 46. In another implementation, display 50 may be provided on a portable electronic device, a computer, a television and the like. Display 50 is utilized by pool cleaning system 120 to present information regarding the cleaning of pool 22 to facilitate control of vehicle 30 by controller 42. In one implementation, display 50 is utilized by pool cleaning system 120 and a controller 42 to present a graphical depiction of those portions of surfaces 26, 28 of pool 22 have not been satisfactorily cleaned so as to satisfy a predefined cleanliness characteristic threshold. Such portions may comprise portions that have been completely missed by vehicle 30 as well as those portions that have been covered by vehicle 30 but have not been satisfactorily cleaned with the given number of passes of vehicle 30 or the existing cleaning settings of vehicle 30. The graphical depiction presented on display 50 enables a person view the quality of the prior cleaning session and to input commands causing controller 42 to generate control signals using signals from camera 32 to steer vehicle 30 back to such identified portions where such portions may be cleaned at the same or elevated cleaning aggressiveness settings.

Another implementation, display 50 may be further utilized by controller 42 to depict the progress of vehicle 30 in cleaning pool 22. Such a display 50 allows a person to visually determine how much of the pool has been currently cleaned and to estimate the remaining time before the pool cleaning task is completed. In certain circumstances, using display 50, a person may adjust a setting of vehicle 30 to accelerate a rate at which surfaces 26, 20 of pool 22 are cleaned to meet an earlier desired completion time for such pool cleaning.

FIG. 3 schematically illustrates pool cleaning system 220, another example implementation of pool cleaning system 20. Pool cleaning system 220 is similar to pool cleaning system 20 except that pool cleaning system 220 additionally comprises dry station 246, display 50, and remote server 254. Those remaining components of pool cleaning system 220 which correspond to components of pool cleaning system 20 or pool cleaning system 120 are numbered similarly.

Dry station 246 is similar to dry station 46, described above, except that dry station 246 serves as a local interface for communication with controller 42 across a network 260. In one implementation, network 260 may comprise a local area network. In another implementation, network 260 may comprise a wide area network, such as the Internet. For example, in one implementation, dry station 246 may incorporate a modem. In one implementation, dry station 246 may communicate across a local area network to controller 42. In another implementation, dry station 246 may communicate through a router, across a local area network, to a local modem which communicates across a network 260. The example illustrated, dry station 246 further provides part of vehicle 30 across a wired cable or wired connection. Display 50 is described above with respect to system 120.

Remote server 254 comprises a server remote from dry station 246 which is in communication with dry station 246 across network 260. Remote server 254 includes controller 42. During operation, signals from cameras 32 are transmitted across dry station 246 across network 260 to controller 42 of remote server 254. Based upon such signals from cameras 32, controller 42 generates control signals which are transmitted back across network 260 and through dry station 246 to vehicle 30 to steer vehicle 30.

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As shown by FIG. 3, remote server 254 and network 260 may be shared as part of other pool cleaning systems 320, wherein controller 42 generates control signals for steering the pool cleaning vehicle 30 of system 320 based upon signals from cameras 32 transmitted across dry station 246 of system 320. In such an implementation, the cost and complexity of pool cleaning system 220 is reduced since controller 42 is remotely provided at remote server 254 which services multiple pool cleaning systems 220, 320. Upgrades to controller 42 and its software are also more easily achieved for all pool cleaning systems to 20, 320 and their pools 22, 222 being serviced. In one implementation, the supervised cleaning, inspection and possible re-cleaning facilitated by the use of cameras 32 may be provided as part of a subscription to users of vehicle 30. In such an implementation, a pool 22 having security cameras 32 may be upgraded with appropriate software or an appropriate software module added to dry station 246 to make a network connection with controller 42 which directs the security cameras 32 to capture vehicle 3020 utilizes such signals for steering vehicle 30.

FIG. 4 schematically illustrates pool cleaning system 420, another particular implementation of pool cleaning system 20. Pool cleaning system 420 is similar to pool cleaning system 120 except that pool cleaning system 420 additionally comprises a portable electronic device 464. Those remaining components of pool cleaning system 420 which correspond to components of pool cleaning system 120 are numbered similarly.

Portable electronic device 464 comprises a portable handheld electronic device in communication with controller 42 and/or dry station 46 across network 260. Examples of such a portable electronic device (PED) 300 include, but are not limited to, a smart phone, a personal data assistant (PDA), laptop, notebook computer, tablet computer (e.g. IPAD) and MP3 player (e.g., IPOD TOUCH). In the example illustrated, PED 464 comprises input 466 and display 468.

Input 466 serves as a user interface for PED 464 by which inputs are made to PED 464. Input 466 facilitates entry of inputs or commands by a person to cause controller 42 to generate control signals varying the control of vehicle 30. In one implementation, input 466 comprise a keyboard. In other implementations, input 466 may comprise a touchpad, a stylus, a microphone with associated speech recognition software or programming, a touch screen, buttons, switches and the like. In some implementations, input 466 may comprise a touch screen incorporated as part of display 468.

Display 468 comprises a user interface by which graphical or textual data is presented to a user. Display 468 may present the same or similar information as presented at dry station 246 by display 50 as described above. In one implementation, display 468 comprises a liquid crystal display. In other implementations, display 468 may comprise other types of display technology such as a light emitting diode display, an organic light emitting diode display (OLED), an electronic ink (e-ink) display or other types of display technology in present use or developed in the future. Although system 420 is illustrated as including controller 422 is part of dry station 46, in some implementations, controller 42 may alternatively be located as part of PED 464.

PED 464 enables a person located remote from pool 22 to monitor the progress of the cleaning of pool 22 by vehicle 30 of system 420. PED 464 provides a person with a graphical presentation (described above with respect to display 50) indicating those portions of surfaces 26, 28 of pool 22 that have been completed as well as those portions 26, 20 and that remain to be cleaned. The person may also be provided with a graphical indication of what portions need to be re-cleaned

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to meet predetermined cleanliness thresholds. In the example illustrated, input 466 enables a person to enter commands or selections which are transmitted across network 260 to controller 42 to adjust operation of vehicle 30. For example, the path or route of vehicle 30 may be changed, the aggressiveness of the cleaning chemicals or mechanical cleaning devices may be adjusted, the speed at which vehicle 30 traverses surfaces 26, 28 may be adjusted. In response to such adjustment signals from PED 464, controller 42 may utilize signals from cameras 32 to adjust the steering of vehicle 30.

FIG. 5 schematically illustrates pool cleaning system 520, another example implementation of pool cleaning system 20. Pool cleaning system 520 is similar to pool cleaning system 420 except that pool cleaning system 520 additionally comprises a remote server 554. Those remaining components of pool cleaning system 520 which correspond to components of pool cleaning system 420 are numbered similarly.

Remote server 554 is similar to remote server 254 described above with respect to system 220. Remote server 554 comprises a server remote from dry station 246 which is in communication with dry station 246 across network 260. Remote server 254 includes controller 42. During operation, signals from cameras 32 are transmitted across dry station 246 across network 260 to controller 42 of remote server 254. Based upon such signals from cameras 32, controller 42 generates control signals which are transmitted back across network 260 and through dry station 246 to vehicle 30 to steer vehicle 30. Controller 42 further relays either the raw signals from camera 32 or image signals generated based upon signals from cameras 32 to PED 464, wherein such images (described above) are presented on display 468. As noted above, PED may further receive commands through input 466, wherein such commands are transmitted to controller 42 which generates control signals that are ultimately transmitted to vehicle 30 for steering vehicle 30.

As with remote server 254, remote server 554 and network 260 may be shared as part of other pool cleaning systems 320 (shown in FIG. 3), wherein controller 42 generates control signals for steering the pool cleaning vehicle 30 of system 320 based upon signals from cameras 32 transmitted across dry station 246 of system 320. In such implementations, controller 42 of remote server 554 may interact with other PEDs 464. In such an implementation, the cost and complexity of pool cleaning system 220 is reduced since controller 42 is remotely provided at remote server 254 which services multiple pool cleaning systems 220, 320. Upgrades to controller 42 and its software are also more easily achieved for all pool cleaning systems to 20, 320 and their pools 22, 222 being serviced. In one implementation, the supervised cleaning, inspection and possible re-cleaning facilitated by the use of cameras 32 may be provided as part of a subscription to users of vehicle 30. In such an implementation, a pool 22 having security cameras 32 may be upgraded with appropriate software or an appropriate software module added to dry station 246 to make a network connection with controller 42 which directs the security cameras 32 to capture vehicle 3020 utilizes such signals for steering vehicle 30. As indicated by broken lines, in other implementations, the controller 42 for generating control signals steering vehicle 30 based upon signals from cameras 32 may alternatively be relocated in PED 464.

FIG. 6 is a flow diagram illustrating an example method 600 that may be carried out by any of systems 120-520. As indicated by step 602, cameras 32 capture images of pool cleaning by vehicle 30. As indicated by step 604, controller 42 obtain such signals from cameras 32 for the surfaces of pool 22 that have been cleaned. As indicated by step 606, control-

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ler 42 uses information gathered from the signals from cameras 32 to identify those portions of surfaces 26, 28 not satisfactorily cleaned—not satisfying a predefined cleanliness characteristic or measurement threshold. One example of a cleanliness characteristic measurement a threshold may be how well the color of a surface matches a predetermined desirable color for the pool surface (such as original color of the tile or surface). A surface that has been missed entirely by vehicle 30 during a pool cleaning session may be automatically deemed to not satisfy a predetermined cleanliness characteristic.

As indicated by step 608, based upon such determinations, controller 42 generates control signals resulting in the presentation of a graphical depiction of those portions of pool 22 that has not been satisfactorily cleaned. Such graphical representations or depictions may be presented on display 50 or display 468. FIGS. 7 and 8 illustrate examples of graphical depictions that may be presented.

FIG. 7 illustrates display 468 presenting graphical depiction 620. Graphical depiction 620 comprises a first graphic 622 having a first portion 624 representing sides or walls 28 of pool 22 and a second portion 626 representing the floor 26 of pool 22. Graphical depiction 620 further comprises a moving icon 628 representing the current positioning of vehicle 30. In one implementation, the path of vehicle 30 may additionally be depicted by icon 628 shown in broken lines. As shown by FIG. 7, those portions 632 of surfaces 26, 28 of pool 22 (shown in FIG. 1) over which of vehicle 30 has moved are identified by graphical depiction 620 either by color, markings or other various distinctive attributes. Likewise, those portions 634 of surfaces 26, 28 of pool 22 that have not been covered by vehicle 30 are identified by a distinct color color marking or distinctive attribute of depiction 620. As a result, a person may view the current position of vehicle 30, the extent to which pool 22 has been cleaned or covered by vehicle 30 and the extent of pool 22 that remains to be cleaned. In the example illustrated, depiction 620 further identifies those portions 638 of surfaces 26, 28 that have been cleaned, but which have not been cleaned to a satisfactory degree or extent. In one implementation, portions 638 may be identified by colors, brightnesses, markings or other visually distinctive attributes that are visually distinct from both portions 632 and portions 634. In other implementations, portions 638 may have the same characteristic of portions 634. In yet other implementations, different portions 638 may have different visual attributes depending upon a degree to which such clean portions have failed to satisfy the predefined cleanliness characteristic threshold. In some implementations, different portions 638 may have different visual attributes depending upon different cleaning strategies that may be recommended for the different portions 638. For example, controller 42 may determine and recommend a first cleaning strategy (a first chemical solution jetted at a first rate and scrubbed at a first rate) with respect to a first portion 638 and may recommend a second different cleaning strategy (a second chemical solution jetted at a second rate is about a second rate) with respect to a second portion 638, wherein the different cleaning strategies are represented by different visual attributes presented in depiction 620.

FIG. 8 illustrates display 468 presenting a graphical depiction 720. Graphical depiction 720 comprises a first graphic 622 having a first portion 624 representing sides or walls 28 of pool 22 and a second portion 626 representing the floor 26 of pool 22 (shown in FIG. 1). Graphical depiction 720 is similar to graphical depiction 620 except that graphical depiction 720 omits icon 628 presenting vehicle 30. Like depiction 620, depiction 720 graphically depicts those portions 632 of sur-

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faces 26, 28 over which vehicle 30 has traveled while in a cleaning mode. Depiction 720 also visually depicts those portions 634 that have not been covered by vehicle 30 in the cleaning mode and those portions 638 over which vehicle 30 has traveled while in the cleaning mode, but which have not been cleaned to a satisfactory degree. As illustrated in FIG. 8, different portions 638 may be visibly distinguished from one another through color, text or markings indicating either differences in the cleanliness of such portions 638 or indicating different recommended cleaning strategies or approaches that may be selected by a person using input 466 when vehicle 30 is steered back to such portions 638 for re-cleaning using signals from camera 32.

As indicated by step 610 of FIG. 6, controller 42 generates control signals steering vehicle 30 to re-clean portions of pool 22, such as portions 638. Such steering may be facilitated by using signals from cameras 32. As noted above, in some implementations, a person may be allowed choose a cleaning approach for a particular portion 638 using input 466. The selection may be facilitated by visual inspection of the different visual attributes for the particular portion 638 provided by depiction 720 (or depiction 620). In some implementations, input 466 may additionally be utilized by a person to prioritize an order in which portions 638 are re-cleaned.

FIG. 9 illustrates pool cleaning system 820, an example implementation of pool cleaning system 20. Pool cleaning system 820 is similar to pool cleaning system 520 except the pool cleaning system 820 located controller 42 in dry station 246 and includes pool cleaning vehicle 830, a specific example of vehicle 30. As shown by FIG. 9, in addition to transmitting control signals generated by controller 42 to vehicle 830, dry station 246 further transmits power from power source 831 through a power line or power cable 833 to vehicle 830. In the example illustrated, data communication and communication of control signals, also occurs across wired connections within or alongside the same line 833. In the example illustrated, remote server 554 serves as a communication link by which upgrades to controller 42 may be implemented across a wide number of pool cleaning systems and by which information from controller 42 is conveyed to one or more portable electronic devices 464 across network 260.

Vehicle 830 comprises a robotic or automated pool cleaning device. Vehicle 830 comprises a self-contained onboard filtration system with drive and pump motors. Vehicle 830 utilizes an internal microprocessor guided drive motor to systematically clean surfaces of pool 22. As shown by FIGS. 9 and 10, vehicle 830 utilizes a toothed track drive 900 provide traction and propulsion for vehicle 30. Vehicle 830 comprises rotating brushes 902 to loosen waterline buildup and breakdown large debris while power washing jets 904 flush out dirt from pores, seams in corners where brushes 902 may not be able to reach. The loosened dirt and debris is vacuumed through off-center vacuum ports 906 which passes the vacuumed debris through internally house filter bag. In the example illustrated, vehicle 830 further comprises rollers 908 which inhibit vehicle 830 from becoming impeded or stuck on raised drains or pop-up heads. Although illustrated as being employed with system 820, vehicle 830 may also be utilized with any of systems 20, 120, 220, 320 and 420. In other implementations, other robotic or automated pool cleaning vehicles may be utilized.

Although the present disclosure has been described with reference to example embodiments, workers skilled in the art will recognize that changes may be made in form and detail without departing from the spirit and scope of the claimed subject matter. For example, although different example

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embodiments may have been described as including one or more features providing one or more benefits, it is contemplated that the described features may be interchanged with one another or alternatively be combined with one another in the described example embodiments or in other alternative 5 embodiments. Because the technology of the present disclosure is relatively complex, not all changes in the technology are foreseeable. The present disclosure described with reference to the example embodiments and set forth in the following claims is manifestly intended to be as broad as possible. 10 For example, unless specifically otherwise noted, the claims reciting a single particular element also encompass a plurality of such particular elements.

What is claimed is:

1. A pool cleaning system comprising:
a powered robotic surface cleaning vehicle to travel on and clean adjacent water containing surfaces of a pool while submerged within the pool;
a camera configured to capture movement of the vehicle while the vehicle is submerged within the pool;
a controller in electronic communication with the camera to generate control signals to steer the vehicle based on the signals from the camera; and
sensors, in electronic communication with the controller and carried by the vehicle, to sense the water containing surfaces of the pool after the water containing surfaces of the pool have been cleaned by the vehicle during a pass of the vehicle under control of a pool coverage algorithm, wherein the control signals steer the vehicle so as to reclean the water containing surfaces having a cleanliness characteristic that is sensed by the sensors and fails to satisfy a predefined threshold.
2. The system of claim 1 further comprising a station remote from the vehicle and in communication with the vehicle, wherein the station includes the controller.
3. The system of claim 1 further comprising a station remote from the vehicle and in communication with the vehicle, wherein the controller is located remote from the vehicle and the station.
4. The system of claim 1, wherein the camera is mounted to the vehicle.
5. The system of claim 1 further comprising a portable electronic device having a display, wherein the portable electronic device is configured to present a graphic on the display, the graphic depicting water containing surfaces of the pool and those portions of the water containing surfaces that remain uncleaned as a vehicle traverses the water containing surfaces.
6. The system of claim 5, wherein the portable electronic device depicts movement of the vehicle on the display.
7. The system of claim 1, wherein the controller generates second control signals for steering the vehicle based on a coverage algorithm independent of signals from the camera, and wherein the control signals based on the captured coverage steer the vehicle to clean portions of the water containing surfaces missed by the vehicle while being steered according to the second control signals.
8. The system of claim 1, wherein the camera is mounted remotely from the vehicle.
9. The system of claim 1 further comprising a portable electronic device having a display and in electronic communications with the vehicle.
10. The system of claim 1, wherein the controller is located at a server remote from the camera and the vehicle.
11. An apparatus comprising:
a non-transitory computer-readable medium comprising code configured to cause a processor to:

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- generate first control signals for moving a robotic pool cleaning vehicle so as to clean water containing surfaces of a pool;
obtain signals from a camera representing the water containing surfaces of the pool and movement of a robotic pool cleaning vehicle adjacent to and along the water containing surfaces of the pool;
identify portions of the water containing surfaces of the pool that have not been cleaned by the pool cleaning vehicle to satisfy a predefined threshold; and
automatically generate second control signals to steer the robotic pool cleaning vehicle to reclean the identified portions of the water containing surfaces based upon the signals from the camera.
12. The apparatus of claim 11, wherein the code is further configured to present a graphical depiction of the identified portions.
13. The apparatus of claim 12 further comprising a portable electronic device comprising:
a processing unit;
a display to present the graphical depiction; and
the non-transitory computer readable medium.
14. A method comprising:
moving a robotic pool cleaning vehicle so as to clean water containing surfaces of a pool;
capturing images of a pool being cleaned with a robotic pool cleaning vehicle operating according to a steering algorithm;
obtaining signals from a camera representing the water containing surfaces of the pool and movement of a robotic pool cleaning vehicle adjacent to and along the water containing surfaces of the pool;
identifying portions of the water containing surfaces of the pool that have not been cleaned by the pool cleaning vehicle to satisfy a predefined threshold; and
steering the robotic pool cleaning vehicle based upon signals from the camera to reclean the identified portions.
15. The method of claim 14 further comprising presenting a graphical depiction of the identified portions.
16. A pool cleaning system comprising:
a powered robotic pool cleaning vehicle to travel adjacent to water containing surfaces of a pool while submerged within the pool;
a camera configured to capture movement of the vehicle while the vehicle is submerged within the pool and identify debris located on the water containing surfaces;
a controller in electronic communication with the camera to generate control signals to steer the vehicle, wherein the controller automatically steers the robotic pool cleaning vehicle to reclean identified portions of the water containing surfaces still having debris based on the signals from the camera; and
a dry station remote from the pool and in communication with the vehicle.
17. The system of claim 16, further comprising:
one or more processing units;
at least one non-transitory computer-readable medium comprising code configured to direct the one or more processing units to cause a portable electronic device to display coverage of the water containing surfaces of the pool by the vehicle.
18. The system of claim 16 further comprising sensors, in electronic communication with the controller and carried by the vehicle, to sense the water containing surfaces of the pool after the water containing surfaces of the pool have been cleaned by the vehicle during a pass of the vehicle under control of a pool coverage algorithm, wherein the control

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signals steer the vehicle so as to reclean the water containing surfaces having a cleanliness characteristic that is sensed by the sensors and fails to satisfy a predefined threshold.

19. The system of claim 18, wherein the camera comprises a pool security camera and wherein the at least one non-transitory computer-readable medium causes a portable electronic device to output an alert based on signals from the camera indicating presence of a person at pool satisfying a predefined characteristic. 5

20. The system of claim 16, wherein the camera is mounted remotely from the vehicle. 10

21. The system of claim 16, further comprising a server in communication with the dry station across a wide area network.

22. The system of claim 21, further comprising a portable electronic device in communication with the server. 15

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EXHIBIT H

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(12) **United States Patent**
Michelon et al.(10) **Patent No.:** **US 11,828,082 B2**(45) **Date of Patent:** **Nov. 28, 2023**(54) **POOL CLEANING APPARATUS WITH OPTIMIZED CONTROL**(71) Applicant: **ZODIAC POOL CARE EUROPE**,
Bron (FR)(72) Inventors: **Thierry Michelin**, Toulouse (FR);
Philippe Pichon, Villeneuve de Riviere (FR)(73) Assignee: **ZODIAC POOL CARE EUROPE**,
Belberaud (FR)

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 352 days.

(21) Appl. No.: **17/188,056**(22) Filed: **Mar. 1, 2021**(65) **Prior Publication Data**

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Related U.S. Application Data

(62) Division of application No. 15/572,293, filed as application No. PCT/FR2016/051060 on May 4, 2016, now Pat. No. 10,961,738.

(30) **Foreign Application Priority Data**

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(51) **Int. Cl.**
E04H 4/16 (2006.01)
G06T 7/44 (2017.01)(52) **U.S. Cl.**
CPC **E04H 4/1654** (2013.01); **G06T 7/44** (2017.01); **E04H 4/1636** (2013.01)(58) **Field of Classification Search**CPC E04H 4/16; E04H 4/1654
See application file for complete search history.(56) **References Cited**

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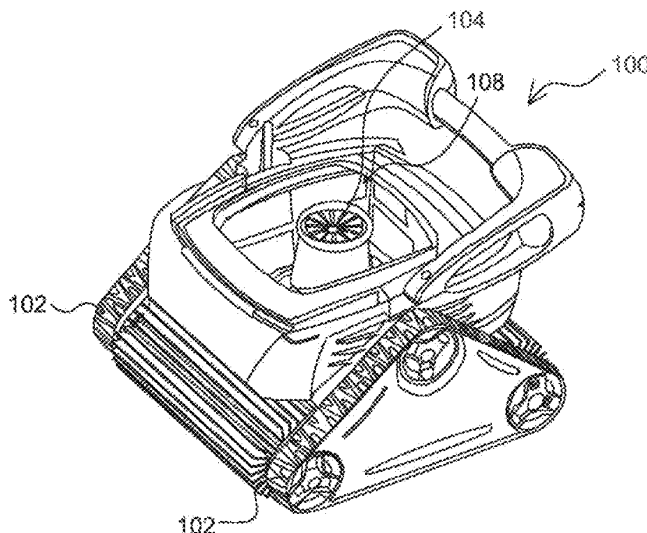
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Primary Examiner — Michael D Jennings(74) *Attorney, Agent, or Firm* — Kilpatrick Townsend &
Stockton LLP(57) **ABSTRACT**

The invention relates to a pool cleaning apparatus including: a cleaning unit (100), at least one hydraulic system for circulating a liquid between at least one liquid inlet (103) and at least one liquid outlet (104) and through a filtration device of the cleaning unit (100), a pump suitable for forcing the circulation of water between the liquid inlet (103) and the liquid outlet (104) and through the filtration device, drive and guide means for moving the cleaning unit, and means for controlling said drive and guide means. The pool cleaning apparatus includes at least one debris detection means placed in the hydraulic system of the cleaning unit (100).

4 Claims, 2 Drawing Sheets

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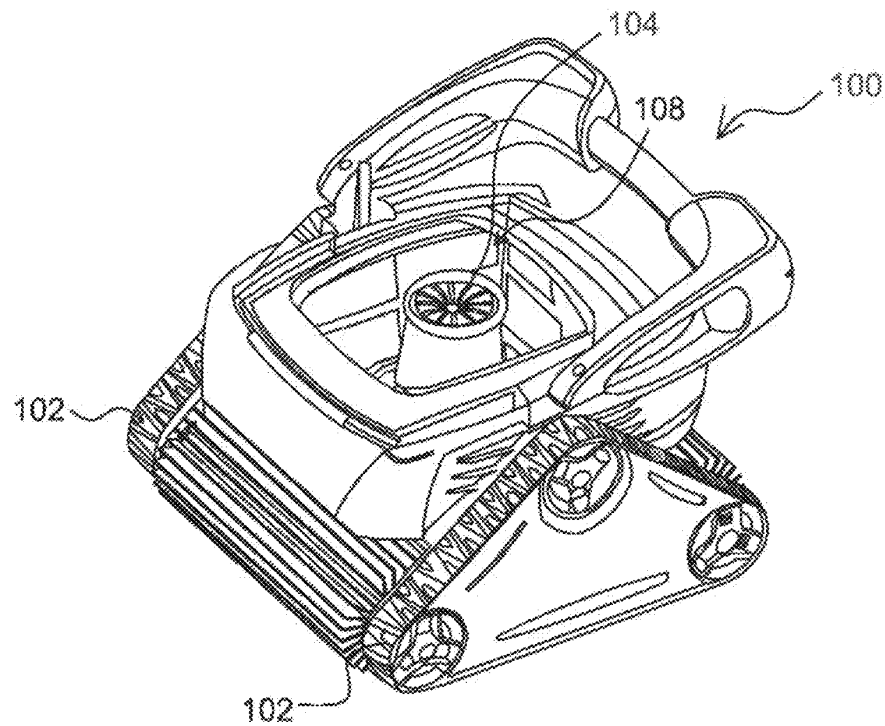


Fig. 1

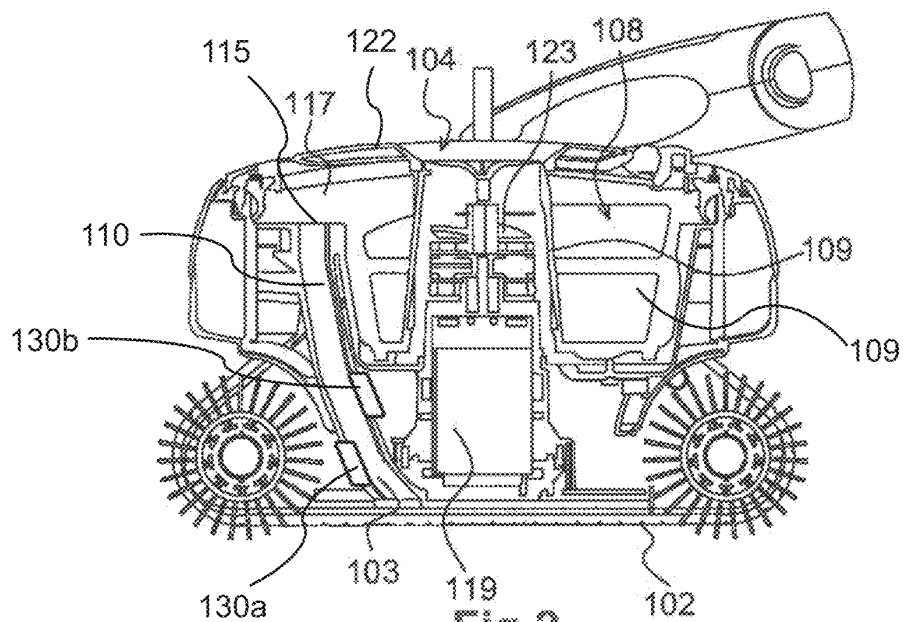


Fig. 2

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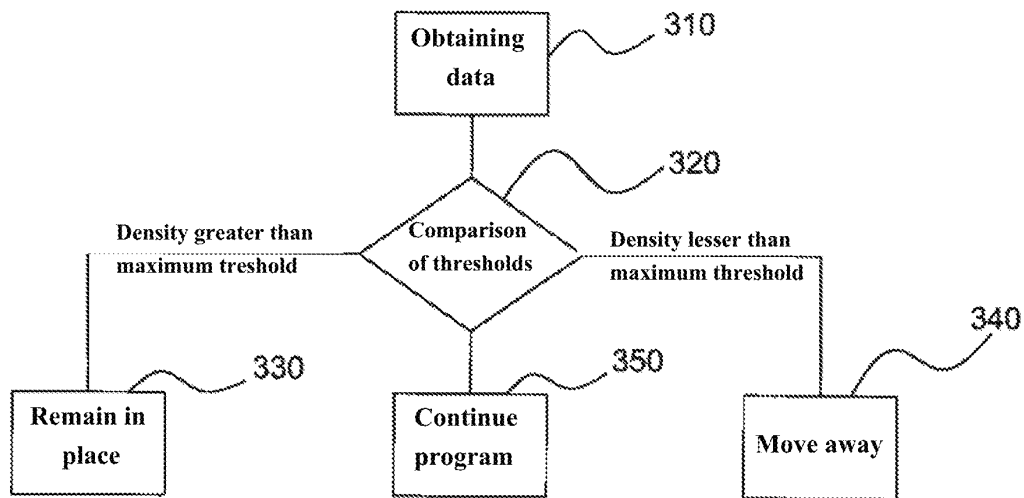


Fig.3

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**POOL CLEANING APPARATUS WITH
OPTIMIZED CONTROL**

**CROSS REFERENCE TO RELATED
APPLICATIONS**

This application is a division of U.S. patent application Ser. No. 15/572,293, filed on Feb. 13, 2018, which is a U.S. national phase under 35 U.S.C. § 371 of International Patent Application No. PCT/FR2016/051060, filed on May 4, 2016, which claims priority to French Patent Application No. 1554125 filed on May 7, 2015, the entire contents of each of which are incorporated herein by reference.

The present invention relates to the field of equipment for swimming pools. It relates more specifically to a swimming pool cleaning apparatus including means for optimizing control so as to improve the cleaning of the pool.

PREAMBLE AND PRIOR ART

The invention relates to an apparatus for cleaning a surface submerged in a liquid, such as a surface formed by the walls of a pool, in particular of a swimming pool. It is in particular a mobile swimming pool cleaning robot. Such a cleaning robot carries out said cleaning by travelling over the bottom and the walls of the swimming pool, brushing these walls and aspirating, into a filter, the debris that is present in the water or has been deposited on the walls. Debris is understood to be any particles that are present within the pool, such as fragments of leaves, micro-algae, etc., this debris normally being deposited on the bottom of the pool or stuck to the side walls thereof.

Most commonly, the robot is supplied with power through an electric cable that connects the robot to an external control and power supply unit.

Known in this field are, for example, the applicant's patents FR 2 925 557 and FR 2 925 551, which relate to a submerged-surface cleaning apparatus having a removable filter device. Such devices comprise a body, members for driving said body over the submerged surface, and a filtration chamber which is provided within the body and comprises a liquid inlet, a liquid outlet, a hydraulic circuit for liquid circulation between the inlet and the outlet, through a filter device. In these two patents, the filter device is removable in order to make it possible to empty the leaves and other debris without having to turn over the cleaning apparatus.

These apparatus have automatic programs for cleaning the bottom of the pool and optionally the side walls of the pool. Such a program, chosen by the user, determines cleaning of the swimming pool over a predetermined time, for example an hour and a half. The robot then travels through the swimming pool and has to be removed from the water by the user at regular intervals, when the filter is too full of particles (leaves, microparticles etc.). In recent models, the external control and power supply unit of the robot emits a signal when this filter cleaning operation has to be carried out.

It has been found that, on account, inter alia, of the geometry of the pool and of the position of the water inlets and skimmers in the pool, particles sometimes remain after a cleaning cycle. The same goes when the robot is held back by its cable and cannot travel freely over the entire surface of the swimming pool or when there is a region of the pool that has a shape conducive to significant agglomeration of debris (edge of diving well, for example).

Patent application EP 2607573, which is known from the prior art, targets the limitation of electrical consumption by

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a robot for cleaning a swimming pool by modulation of the aspiration power of the pump. The modulation is carried out depending on dirt identified by the processing of images captured upstream of the aspiration mouth of the robot. This apparatus requires the implementation of expensive image capturing means; in addition, the image processing quality is likely to be adversely affected by variations in luminosity.

The aim of the invention is in particular to alleviate some of these drawbacks.

The invention aims in particular to propose a swimming pool cleaning apparatus that carries out optimized cleaning of the swimming pool in terms of cleaning time or cleanness of the water and the walls of the swimming pool after an operating cycle of the robot.

SUMMARY OF THE INVENTION

According to a first aspect, the invention relates to a swimming pool cleaning apparatus comprising:

a cleaning unit intended to be submerged in the swimming pool,

at least one hydraulic circuit for liquid circulation between at least one liquid inlet and at least one liquid outlet, through a filtration device of the cleaning unit, able to retain the debris present in the water,

a pump designed to force water to circulate between at least one water inlet and at least one water outlet through the filtration device,

driving and guiding means for producing the movements of the cleaning unit,

control means for these driving and guiding means.

The cleaning apparatus comprises at least one means for detecting debris in the hydraulic circuit of the cleaning unit.

Debris is detected in particular by the density of said debris in the water being measured.

Density measurement is understood to mean both the measurement of the quantity of debris in suspension in the water, and/or the measurement of the size of this debris.

It is this debris that the cleaning apparatus is intended to extract from the pool, by detaching this debris from the walls or the bottom and then aspirating it and retaining it in the filter of the cleaning unit (also known as the cleaning robot).

It will be understood that this debris density measurement, for example at the inlet to the filtering hydraulic circuit, is representative of the local dirtiness of the pool. In this way, the control of the cleaning unit can include commands that take into account this local dirtiness of the pool, for example, by commanding the cleaning unit to remain for a longer time in the regions in which the measured debris density is high, and for less time in the regions of the pool in which the measured debris density is low.

In one particular embodiment, the means for measuring the density of debris are disposed at the water inlet into the filtering hydraulic circuit.

In this way, the measurement is carried out upstream of the filter and is thus not skewed by the filling level thereof.

In another embodiment, the apparatus also includes means for measuring the density of debris in the water at the water outlet of the filtering hydraulic circuit. In this way, it is possible to verify that the water at the outlet of the cleaning robot has been completely purified. If this is not the case, it is then possible either to command the cleaning unit to remain for a longer time at the same location, or to inform the user of the need to empty the filter.

In one particular embodiment of the means for measuring the density of debris, the latter include an optical sensor.

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Advantageously, the means for measuring the density of debris include a turbidity sensor. A turbidity sensor is understood to be an apparatus which measures the solid particles in suspension in the water by measuring the quantity of light transmitted through the water.

In one embodiment, the turbidity sensor includes a calibrated light source and an optical sensor. Advantageously, the light source and the optical sensor can be disposed facing one another.

In another embodiment, which is optionally used in conjunction with the preceding embodiment, the means for measuring the density of debris include a camera and image analysis means, making it possible to determine the size and the nature of the aspirated debris.

In yet another embodiment, which is optionally used in conjunction with one of the two preceding embodiments, the means for measuring the density of debris include means for measuring the local resistivity of the water.

In another embodiment, the measurement means include a turbidimeter, of the type used in particular in dishwashers. In this way, the equipment is inexpensive to produce and makes use of a tried and tested material.

In one particular embodiment, the swimming pool cleaning apparatus also includes means for modifying the cleaning strategy of the cleaning unit in response to the detection of debris.

In this case, in various embodiments that are optionally used in conjunction, the means for modifying the cleaning strategy comprise:

- means for controlling the movements of the cleaning unit within the pool in response to the detection of debris,
- means for modifying the power of the pump in response to the detection of debris,
- means for transmitting information to a remote user in response to the detection of debris,
- means for transmitting the results of the detection of debris in the water to an external unit for controlling the apparatus.

According to a second aspect, the invention relates to a method for controlling a swimming pool cleaning apparatus as described above, this method including the following steps in a cyclical manner:

- data relating to the density of debris in the water at the inlet to the hydraulic circuit are obtained,
- these data are compared with a predetermined threshold, the cleaning strategy of the cleaning unit is modified if and as long as the estimated density of debris becomes greater than a maximum value chosen beforehand.

In one embodiment, the modification in the cleaning strategy includes at least one of the following operations:

- the movements of the cleaning unit within the pool are controlled in response to the detection of debris, in order to move the cleaning unit around in the vicinity of its current location in the swimming pool.

In this way, the cleaning unit will, for example, spend more time in the regions where the density of debris is greater than a predetermined threshold, or will increase its aspiration power in this region.

In one particular embodiment, which is optionally used in conjunction with the preceding embodiment, the method includes the following steps in a cyclical manner

- data relating to the density of debris in the water at the inlet to the filtering hydraulic circuit are obtained,
- the dirt density data are compared with at least one second predetermined threshold,
- the commands for moving the cleaning unit are modified if and as long as the estimated density of debris

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becomes less than a minimum value chosen beforehand, in order to move the cleaning unit away from its current location in the swimming pool.

In this way, the cleaning unit will spend less time in the regions where the density of debris is less than a predetermined threshold.

In one particular embodiment, the method also includes an initial step in which the cleaning unit travels rapidly through the swimming pool while acquiring density measurements, and at least one threshold is determined depending on the values measured during the rapid travel through the pool.

In this way, the method includes a phase of learning the normal level of debris in the pool during cleaning, and can adapt its top and bottom values depending on the average dirtiness measured. Specifically, a pool is usually much dirtier at the end of winter than during the normal season of use. The cleaning cycle can then take this situation into account.

All of the embodiments mentioned above can of course be combined in any technically feasible manner.

The invention also relates to a kit for modifying an assembly comprising a cleaning apparatus as described, and a control unit, said kit comprising an apparatus for detecting debris in the water, said apparatus being designed to be installed within the cleaning apparatus.

It optionally includes a program for controlling the apparatus, designed to be installed in the control unit and to implement a control method.

It is then possible to modify an existing piece of equipment so as to give it a control mode designed to emphasize cleaning in the dirtiest regions, and by contrast to spend less time in the cleanest regions. The installation of a sensor for measuring the density of debris in the filtering hydraulic circuit of the cleaning unit should be carried out by a professional, as should the updating of the control software within the control unit.

The invention also relates to a cleaning apparatus as described, including means for transmitting the results of the detection of debris in the water to an external unit for controlling the apparatus.

According to another aspect, the invention then relates more particularly to a cleaning set including a cleaning apparatus as described above and an external unit for controlling the apparatus, said cleaning set including means for transmitting the results of the detection of debris in the water to a control system for controlling the items of equipment of the swimming pool, and means for modifying the control thereof depending on the results of the detection of debris in the water.

PRESENTATION OF THE FIGURES

The features and advantages of the invention will be better appreciated by virtue of the following description, which describes the features of the invention by way of a nonlimiting example of application.

The description is based on the appended figures, in which:

FIG. 1 illustrates a perspective view of a swimming pool apparatus implementing a filtration system as described,

FIG. 2 illustrates a sectional side view of the same apparatus,

FIG. 3 illustrates a flowchart of the method for controlling the cleaning unit.

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DETAILED DESCRIPTION OF ONE EMBODIMENT OF THE INVENTION

The invention finds its application in a swimming pool technical environment, for example a family-type swimming pool set into the ground.

A submerged-surface cleaning apparatus is shown, according to an embodiment that is given in this case by way of nonlimiting example, in FIGS. 1 and 2. It includes a cleaning unit, referred to as swimming pool cleaning robot below, and a power supply and control unit for said swimming pool cleaning robot, said unit being situated outside the pool.

The swimming pool cleaning robot **100** comprises a body and a driving and guiding device comprising members **102** for driving and guiding the body over a submerged surface. In the present nonlimiting example, these driving and guiding means **102** are formed by wheels or caterpillar tracks disposed laterally on the body (see FIG. 1).

The swimming pool cleaning robot **100** also comprises a motor that drives said driving and guiding members **102**, said motor being supplied with power via a cable. In one variant, the wheels or caterpillar tracks **102** are controllable independently of one another so as to be able to freely orient the cleaning robot on the walls of the swimming pool, in forward-running or reverse-running mode.

The swimming pool cleaning robot **100** has a hydraulic circuit including at least one liquid inlet **103** and a liquid outlet **104**. The liquid inlet **103** is, in the present nonlimiting example, situated at the base of the body (in other words under the latter, when the swimming pool cleaning robot is placed in its normal operating position at the bottom of the swimming pool), that is to say immediately next to a submerged surface over which the apparatus **100** moves in order to be able to aspirate the debris accumulated on said submerged surface. The liquid outlet **104** is situated on the top of the swimming pool cleaning robot **100**. In the present exemplary embodiment, the liquid outlet **104** is made in a direction substantially perpendicular to the guiding plane, that is to say vertically if the cleaning apparatus is resting on the bottom of the swimming pool.

The hydraulic circuit connects the liquid inlet **103** to the liquid outlet **104**. The hydraulic circuit is designed to be able to allow the liquid to circulate from the liquid inlet **103** towards the liquid outlet **104**. To this end, the apparatus comprises a pump comprising a motor **119** and an axial flow impeller **123** (see FIG. 2), said motor **119** driving the axial flow impeller **123** in rotation, said axial flow impeller **123** being disposed in the hydraulic circuit.

In the present exemplary embodiment, the axial flow impeller **123** is disposed downstream of the filter—that is to say just upstream of the liquid outlet **104**.

The electric motor **119** drives the axial flow impeller **123** of the circulation pump and, optionally, the driving and guiding device.

The swimming pool cleaning robot **100** comprises a filtration chamber **108** that is interposed, in the hydraulic circuit, between the liquid inlet **103** and the liquid outlet **104**.

In the present exemplary embodiment, illustrated in particular in FIG. 1, the filtration chamber **108** comprises a filtration basket **117** and a cover **122** forming the upper wall of the filtration chamber **108**.

The filtration basket **117** forms the bottom and the external and internal peripheral walls of the filtration chamber **108**.

The bottom and the external and internal peripheral walls of the filtration chamber **108** comprise at least one filtering

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wall **109**, the liquid contained in the filtration chamber **108** being evacuated towards the liquid outlet **104** through said central filtering wall **109**.

A pipe **110**, situated between the liquid inlet **103** into the hydraulic circuit and the liquid inlet **115** into the filtration chamber **108**, carries the water loaded with debris into the upper part of the filtration basket **117**.

In other exemplary embodiments, the pipe can be very short or even non-existent. In this case, the liquid inlet **103** of the hydraulic circuit is coincident with the liquid inlet **115** of the filtration chamber **108**.

The swimming pool cleaning robot **100** is supplied with power and with operating commands by means of a flexible cable. In the present example, this flexible cable is attached to the body of the swimming pool cleaning robot **100** in its upper part. This flexible cable is connected, at its other end, to the power supply and control unit (not illustrated in FIG. 1) disposed outside the pool, this power supply and control unit being itself connected to the electrical mains supply.

The cleaning robot may also emit data to and receive data from the power supply and control unit. In the present example, the cleaning robot includes in particular means for detecting whether the fouling of the filter has exceeded a predetermined threshold, and for transmitting the data to the power supply and control unit in order to emit an alert to a user. In one exemplary embodiment, the swimming pool cleaning robot **100** includes a processor that is able to execute a predetermined algorithm that generates commands for moving the robot and for operating the filtration circuit.

This power supply and control unit also includes a control interface so that a user of the cleaning robot can choose, for example, a type of cleaning cycle, or can interrupt the operation of the robot.

In a variant embodiment, the power supply and control unit includes a processor that is able to execute a predetermined algorithm that generates commands for moving the swimming pool cleaning robot **100** and for operating the filtration circuit.

In this case, the swimming pool cleaning robot **100** includes at least one device **130a**, **130b** for detecting debris in the water (known as turbidimeter in the rest of the description). In the present exemplary embodiment, a turbidimeter **130** is disposed inside the hydraulic circuit, downstream of the water inlet **103** in position **130a** or in the conduit **110** at position **130b**.

In other embodiments, a plurality of turbidimeters are present, for example in the two locations **130a**, **130b** described above.

It is for example an optical sensor, associated with a computing means that detects variations in the opacity of the water. Such a device is then optionally associated with a calibrated light source. It is also possible, alternatively, to use a device based on resistivity measurements, or any other device known to a person skilled in the art that is designed to provide a measurement of the density of debris floating in the water at the inlet of the hydraulic circuit.

The turbidimeter can also be installed on the external surface of the robot body, or within a second water pipe that does not include a filter.

The turbidimeter sends measurement data continuously or at regular intervals (for example every few seconds) to the means for controlling the pumping, driving and guiding means.

Mode of Operation

As can be seen in FIG. 3, which illustrates, in a nonlimiting manner, a flowchart of a method for controlling the

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cleaning apparatus as described above, such a method includes for example the following steps:

310. Data relating to the density of debris in the water at the inlet to the hydraulic circuit are obtained,

320. These data are compared with at least one predetermined threshold,

330. The commands for moving the cleaning unit are modified if and as long as the estimated density of debris is greater than a maximum value chosen beforehand, in order to move the cleaning unit around in the vicinity of its current location in the swimming pool,

340. The commands for moving the cleaning unit are modified if and as long as the estimated density of debris is less than a minimum value chosen beforehand, in order to move the cleaning unit away from its current location in the swimming pool,

350. The previous control mode is maintained if and as long as the estimated density of debris is between the minimum and maximum values.

The commanded movements of the cleaning unit about its current position can consist of circles or of a spiral about this position, or even of movements of a fractal nature.

Similarly, the movement away can consist of a straight-line movement for a predetermined time, for example a few seconds, this corresponding to a distance of a few metres, typically six seconds corresponding to a movement away of around one metre.

In the absence of data received from the turbidimeter or of data departing from a predetermined range of values, the control method no longer takes into account the turbidimeter data, and returns to the usual control mode for a cleaning unit, such a control method being known to a person skilled in the art and departing as such from the scope of the present invention.

Variants

In another variant, the turbidimeter is installed a posteriori on a pre-existing cleaning unit, in the form of an upgrade kit. In this variant, the logic operation executed by the power supply and control unit is also modified to take into account the control modifications to be commanded according to the data received from the turbidimeter.

If a detection of particles at the outlet of the water circuit is observed, it is possible to send a message to the control

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unit, which can inform the user of an adaptation to the operation of the water filtration and treatment system.

If the control box of the robot can exchange data with the water filtration and treatment control boxes, the adjustment can be made automatically.

The invention claimed is:

1. Method for controlling a swimming pool cleaning apparatus wherein the method includes the following steps in a cyclical manner:

obtaining data relating to a density of debris in water in a vicinity of a hydraulic circuit and estimating density of debris,

comparing the estimated density of debris with at least one predetermined threshold, and

modifying a cleaning strategy of the swimming pool cleaning apparatus if and as long as the estimated density of debris is greater than the at least one predetermined threshold.

2. Controlling method according to claim 1, wherein modifying the cleaning strategy includes at least one of the following operations:

controlling movements of the swimming pool cleaning apparatus within the swimming pool in response to a detection of debris, in order to move the swimming pool cleaning apparatus around in a vicinity of its current location in the swimming pool.

3. Controlling method according to claim 1, wherein the method includes the following steps in a cyclical manner:

obtaining inlet data relating to the density of debris in the water at an inlet to the hydraulic circuit and estimating inlet density of debris,

comparing the estimated density of debris with at least one second predetermined threshold, and

modifying commands for moving the cleaning unit if and as long as the estimated inlet density of debris is less than the at least one second predetermined threshold, in order to move the cleaning unit away from its current location in the swimming pool.

4. Controlling method according to claim 1, wherein the method also includes an initial step in which the cleaning unit travels rapidly through the swimming pool while acquiring density measurements, and the at least one predetermined threshold is determined depending on the density measurement values measured during the rapid travel through the pool.

* * * * *

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Patent Owner Zodiac Pool Systems LLC
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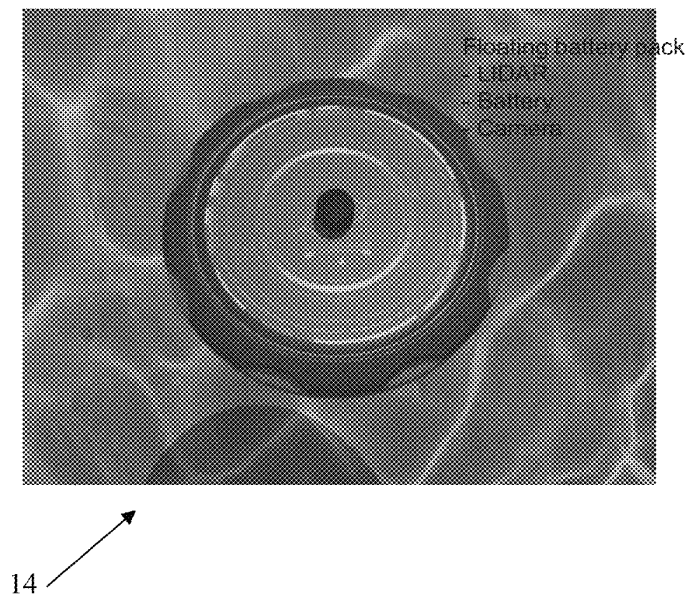


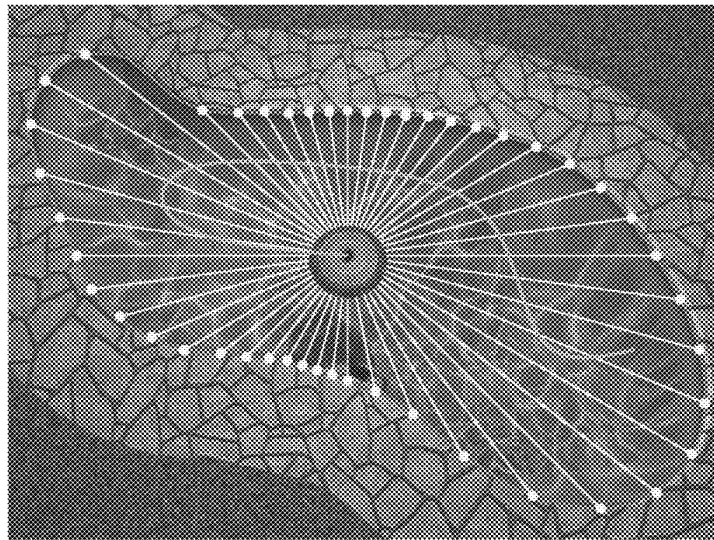
FIG. 1

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Path traced by floating LIDAR during SLAM in green

14

FIG. 2

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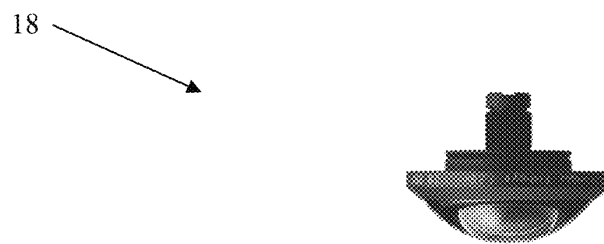


FIG. 3

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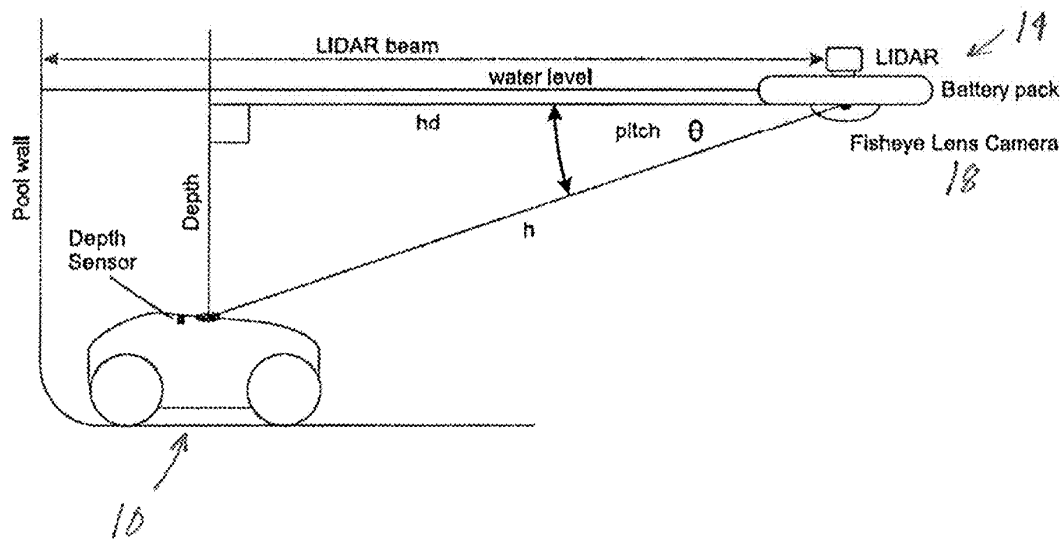


FIG. 5

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**MAPPING AND TRACKING METHODS AND
SYSTEMS PRINCIPALLY FOR USE IN
CONNECTION WITH SWIMMING POOLS
AND SPAS**

**CROSS-REFERENCE TO RELATED
APPLICATION**

This application claims the benefit of and priority to U.S. Provisional Patent Application Ser. No. 62/719,867, filed Aug. 20, 2018, and having the same title as appears above (the "Provisional Application"), the entire contents of which Provisional Application are hereby incorporated herein by this reference.

FIELD OF THE INVENTION

This invention relates to mapping and tracking systems and more particularly, although not necessarily exclusively, to systems for mapping characteristics of water-containing vessels such as swimming pools or spas and tracking positions of moveable equipment, such as an automatic pool cleaner ("APC"), within the vessels.

BACKGROUND OF THE INVENTION

European Patent Application No. 1122382 of Clementi (the "Clementi Application"), whose entire contents are incorporated herein by this reference, illustrates an APC capable of moving over to-be-cleaned surfaces of a swimming pool. Connected to the APC via a cable is a shuttle incorporating a battery, a microcontroller, and a signal transmitter and receiver. The shuttle, described in the Clementi Application as "a sort of floating 'island,'" floats on the surface of water within a swimming pool and is towed by the APC as the latter moves within the pool.

Absent from the shuttle of the Clementi Application is any capability of tracking location of the mobile APC within the pool. Similarly absent from the shuttle is any ability to track its own position within a pool or to determine any characteristics of the pool itself. Because all of this information is valuable in the context of efficiently and effectively cleaning vessels such as swimming pools and spas, it would be advantageous to develop methods and systems for obtaining some or all of it.

SUMMARY OF THE INVENTION

The present invention provides such methods and systems. In a general sense, the invention facilitates more efficient and cost-effective cleaning of swimming pools by mapping a pool environment in three dimensions, performing path planning for an APC, and assisting in navigating the APC along the planned paths. The APC may have an on-board power source for effecting autonomous movement within a pool as well as a pump to draw debris-laden pool water through a filter for cleaning, although components such as these alternatively may be located remote from the APC.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 illustrates an exemplary floating object configured to facilitate mapping and tracking in connection with the present invention.

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FIG. 2 schematically illustrates exemplary information which may be gleaned by a ranging sensor floating within a swimming pool.

FIG. 3 illustrates an exemplary camera that may be used in connection with the floating object of FIG. 1.

FIG. 4 schematically illustrates exemplary positions of an APC relative to the camera of FIG. 3.

FIG. 5 diagrammatically illustrates development of a three-dimension estimate of a position of an APC relative to the floating object of FIG. 1.

DETAILED DESCRIPTION

Tethered to the APC 10 (see, e.g., FIGS. 4-5) may be a floating object 14 configured to facilitate mapping and tracking. Advantageously, the tether may be or include a cable configured to convey electronic data between the APC 10 and the floating object 14. The cable additionally may, in some cases, convey electrical power to the APC 10 as well, as advantageously the floating object 14 includes an on-board battery or other source of power both for it and for the APC 10. One presently-preferred tether is a cable approximately 2.4 m in length, although persons skilled in the art will recognize that shorter or longer cables may be used instead. As the APC 10 moves within the pool, it tows the floating object along the water surface.

In some versions of the invention, the floating object 14 may include apparatus for light detection and ranging ("LIDAR"). As known to persons skilled in the relevant art, LIDAR constitutes methods of measuring distance to a target by illuminating the target with pulsed laser light and sensing the reflected pulses with a sensor. Presently preferred is that the LIDAR apparatus have a rotating time of flight ("ToF") ranging sensor projecting above the waterline of the pool (so as to send laser light through air, rather than water) that generally continuously collects data as it scans the walls forming the perimeter of a pool at and above the waterline. An exemplary such sensor rotates at approximately 5 Hz and collects approximately 500-1000 samples of ranging and angular data per cycle. The LIDAR apparatus thus may develop an accurate mapping of the pool perimeter as well as of its position within the perimeter of the pool.

FIG. 2 schematically illustrates exemplary distance and angle information which may be gleaned by rotating through 360° a ToF ranging sensor floating within a pool. Because rotation of the sensor through one revolution is materially faster than an APC 10 typically travels within a pool, linear movement of the tethered APC 10 either may be ignored or accounted for when obtaining distance and angle information for a particular cycle. In some versions of the invention, conventional techniques of simultaneous localization and mapping ("SLAM") may be employed in processing data obtained by the ToF ranging sensor of the LIDAR apparatus.

The floating object 14 additionally may include a camera 18 (see FIG. 3) configured to record images of the APC 10 to which the object 14 is tethered. Advantageously, the camera 18 may have a "fish-eye" type of lens whose fields of view ("FOV") both horizontally and vertically are 180° (or approximately so). Similarly advantageously, the camera 18 is integrated into or attached to the floating object 14 facing downward into the water of the pool. The camera 18 is configured to record the underwater scene with the APC 10 constantly in view, which is possible due to the relatively short length of the cable. Conventional techniques of visual simultaneous localization and mapping ("VSLAM") may be utilized to process its image data.

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In particular, the APC 10 may include any suitable marker (e.g., a red dot) on its body that the camera 18 may track continuously in its video frame. Preferably the marker is located on a top, central portion of the body, although it may be located elsewhere instead. The position of the marker as tracked through the camera 18 (by associated hardware or software, or both) may provide information as to the heading and pitch of the APC 10 relative to the LIDAR apparatus, samples of which are schematically depicted in FIG. 4. Collectively, the LIDAR apparatus and camera 18 supply information sufficient to determine various dimensions and contours of the pool in which the object 14 is floating as well as certain information respecting locations of the APC 10 (in "x" and "y" coordinates) and the floating object 14 itself.

In some embodiments of the invention, the APC 10 includes a depth sensor configured to supply additional information (a "z" coordinate) as to its position within a pool. By utilizing depth information together with information as to marker heading and pitch angle, a three-dimensional estimate of the APC's position relative to the LIDAR apparatus may be obtained (see FIG. 5). And because the position of the LIDAR apparatus within the pool relative to the pool walls is known via the ToF ranging sensor, an accurate determination of the location of the APC 10 within the pool may be made.

Yet additionally, the APC 10 may include an inertial measurement unit or other device configured to provide information as to how the APC 10 is tilted. Considered altogether, therefore, information gathered by the floating object 14 may supply accurate estimates of position and orientation of the APC 10 excluding its azimuth direction. Although the absolute direction the APC 10 is facing is not necessarily known if the APC 10 is stationary, such direction becomes apparent as soon as the APC 10 moves forward or backward from a particular position. Alternatively, azimuth direction could be set by use of a second marker located on the APC 10 at a distance from the other marker. Accordingly, at this point all relevant absolute position and orientation estimates may be obtained for the APC 10 relative to the pool, allowing precise pool mapping, path planning, and navigation. Any or all of this information, further, may be recorded and displayed in any suitable manner for evaluation by a pool user, pool equipment technician or manufacturer, or otherwise.

Moreover, the floating object 14 may perform some or all of the functions attributed to the shuttle of the Clementi Application. It thus may, if desired, include any or all of at least one battery, controller (including processing capabilities), and signal transmitter and receiver. The floating object 14 further could include components such as solar panels for charging the battery, for example.

Exemplary concepts or combinations of features of the invention may include:

- A. A method of mapping a pool using a device floating on water within the swimming pool.
- B. A method of mapping a swimming pool using a LIDAR apparatus.
- C. A method of cleaning a swimming pool comprising (i) obtaining information from a sensor of a LIDAR apparatus and a camera positioned within the pool, (ii) processing the obtained information, and (iii) conveying navigation information via a cable to an APC travelling along a surface of the pool.
- D. A cleaning system comprising: (i) a floating object comprising a LIDAR apparatus, (ii) an APC, and (iii) a cable connecting the LIDAR apparatus and the APC both mechanically and electronically.

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These examples are not intended to be mutually exclusive, exhaustive, or restrictive in any way, and the invention is not limited to these exemplary embodiments but rather encompasses all possible modifications and variations within the scope of any claims ultimately drafted and issued in connection with the invention (and their equivalents). For avoidance of doubt, any combination of features not physically impossible or expressly identified as non-combinable herein may be within the scope of the invention.

Included in connection with the figures of the Provisional Application was at least the following text:

FIG. 1: Floating battery pack

LIDAR

Battery

Camera

FIG. 2: Basic SLAM (simultaneous localization and mapping) is continuously performed to establish the position and rotation of the floating LIDAR at any time. The rotational reference of the LIDAR is known relative to the first data sample at each 360° scan. Thus if the LIDAR is rotated in the pool, the rotation of the LIDAR base is also known relative to its starting rotation as long as SLAM calculations are ongoing.

FIG. 3: Camera (180° FOV)

Attached to the floating LIDAR is a camera facing straight down which has a fish-eye lens with a horizontal and vertical field of view of 180°.

The camera records the underwater scene with the pool cleaner constantly in view. This is almost guaranteed because of its relatively short cable. There is a tracking marker on top and more or less on the center of the cleaner that is tracked continuously in the video frame. The position of the marker on the screen gives us the relative heading and pitch of the cleaner to the floating LIDAR.

FIG. 4: Image showing various cleaner positions relative to the camera providing heading and pitch relative to the screen center.

FIG. 5: The pool cleaner has a depth sensor. The depth information is applied to the marker heading and pitch angles which then gives us a 3 dimensional estimate relative to the floating LIDAR which in turn has an absolute reference to the pool outline (real world). This gives us an accurate estimate of where the pool cleaner is in the pool at any given point in time. Coupled to that the cleaner also has an IMU (inertial measurement unit) that provides tilt information. The above mentioned solution thus provides us with an accurate cleaner position and orientation estimation excluding its azimuth direction. The absolute direction that the pool cleaner is facing is not known if it is stationary but soon becomes apparent when it moves forward or backward from a previous position. Thus the solution finally provides an absolute position and orientation estimate relative to the pool. The above is sufficient for pool mapping, path planning and navigation.

Given a certain pitch angle θ and a depth one can determine h as well as hd horizontal distance from the LIDAR unit. Heading is also provided from the tracked marker in each camera frame.

Further, although applicant has described devices and techniques for use principally with swimming pools, persons skilled in the relevant field will recognize that the present invention may be employed in connection with other objects and in other manners. Variants of the invention, moreover, allow for use of one or more cameras on the top of the floating object in addition to (or instead of) the LIDAR apparatus to track fixed-location objects outside the pool as well as aid in mapping the pool perimeter. These fixed-

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location objects could then serve as reference points for assessing the location of the floating object.

Other variants contemplate use of a more complex range of markers or fiducials placed on the APC and which are visible to the camera to allow determination, through image processing, of such things as direction and bank, pitch and roll angles. Yet alternatively, a camera may be placed on the APC to capture images of the floating island, to whose bottom surface one or more markers or fiducials have been attached, again facilitating determination of the relative positions of the APC and floating object. Furthermore, the camera and LIDAR apparatus may, if desired, be mounted on a weighted gimbal for image stability by assuring a much better vertical axis. The floating buoy may encounter some ripples or waves which may otherwise cause errors in accuracy of the readings taken by both the camera and the LIDAR apparatus, hence benefitting from the weighted gimbal mounting. Finally, references to “pools” and “swimming pools” herein may also refer to spas or other water-containing vessels used for recreation or therapy and for which mapping or tracking is needed or desired.

What is claimed is:

1. A cleaning system comprising: (a) a floating object comprising a LIDAR apparatus, (b) an automatic pool cleaner, and (c) a tether connecting the LIDAR apparatus and the automatic pool cleaner.

2. The cleaning system according to claim 1 in which the tether comprises a cable connecting the LIDAR apparatus and the automatic pool cleaner both mechanically and electronically.

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3. The cleaning system according to claim 2 in which the floating object further comprises a camera.

4. The cleaning system according to claim 3 in which the LIDAR apparatus comprises a rotating ranging sensor projecting above a waterline of a swimming pool when the floating object is floating in the swimming pool.

5. The cleaning system according to claim 4 in which the camera faces downward into the swimming pool when the floating object is floating in the swimming pool.

6. The cleaning system according to claim 5 in which the automatic pool cleaner comprises a marker which the camera is configured to track.

7. The cleaning system according to claim 6 in which the automatic pool cleaner further comprises a depth sensor.

8. The cleaning system according to claim 7 in which the automatic pool cleaner further comprises a tilt sensor.

9. The cleaning system according to claim 8 in which the floating object further comprises a battery and a controller.

10. A method of cleaning a swimming pool comprising (a) obtaining information from a sensor of a LIDAR apparatus and a camera positioned within the swimming pool, (b) processing the obtained information, and (c) conveying navigation information via a cable to an automatic pool cleaner travelling along a surface of the swimming pool.

11. A method of mapping a swimming pool using a device floating on water within the swimming pool, wherein the device comprises a LIDAR sensor.

12. A method of mapping a swimming pool using a LIDAR apparatus.

* * * * *

EXHIBIT J

EXHIBIT J

Exemplary Infringement Claim Chart of U.S. Patent No. 11,800,207 by Beatbot Aquasense 2 Ultra

U.S. Patent No. 11,880,207	Beatbot Aquasense 2 UltraCordless Robotic Pool Cleaner
1. A self-propelled pool cleaning system for cleaning debris from a submerged surface of a swimming pool, comprising:	 https://beatbot.com/products/aquasense-2-ultra. “HybridSense AI Vision detects missed debris on the floor and tackles high platforms – delivering precision cleaning and full coverage for even complex multi-level pools.” https://beatbot.com/products/aquasense-2-ultra.

Exhibit J, p. 1

a. a vehicle body;



<https://beatbot.com/products/aquasense-2-ultra>.

Exhibit J, p. 2

b. means for moving the vehicle body within the swimming pool;	 means for moving the vehicle body within the swimming pool https://beatbot.com/products/aquasense-2-ultra.
c. a filter configured to retain debris collected from the submerged surface;	What size and types of debris can the AquaSense 2 Ultra clean? AquaSense 2 Ultra comes with a two-layer filter (150µm+250µm) that can effectively capture debris of all sizes, including leaves, hair, sand, insects, and more. It can filter particles as small as 150 micrometers (µm). https://beatbot.com/products/aquasense-2-ultra.

Exhibit J, p. 3

d. at least one camera for capturing an image of at least a first object within the swimming pool; and



<https://beatbot.com/products/aquasense-2-ultra>.

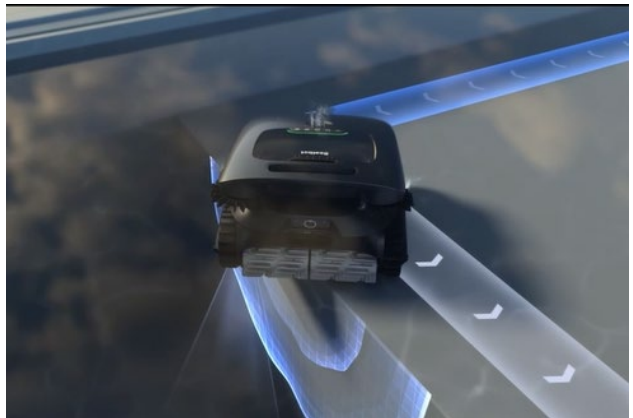
“Combining an industry-first blend of AI camera....” <https://beatbot.com/products/aquasense-2-ultra>.

“HybridSense AI Vision detects missed debris on the floor and tackles high platforms – delivering precision cleaning and full coverage for even complex multi-level pools.”
<https://beatbot.com/products/aquasense-2-ultra>.

e. a controller (i) in electronic communication with the at least one camera and (ii) configured to generate, in response to the captured image, at least one control signal to cause movement of the body within the swimming pool to, or away from, the first object.



<https://beatbot.com/products/aquasense-2-ultra>.



<https://beatbot.com/products/aquasense-2-ultra>.

“HybridSense AI Vision detects missed debris on the floor and tackles high platforms – delivering precision cleaning and full coverage for even complex multi-level pools. It currently recognizes various leaf types, with more debris types coming soon through OTA updates for even smarter, more effective cleaning.” <https://beatbot.com/products/aquasense-2-ultra>.

Exhibit J, p. 5