

UNITED STATES PATENT AND TRADEMARK OFFICE

BEFORE THE PATENT TRIAL AND APPEAL BOARD

MOBILEYE GLOBAL, INC.,

Petitioner,

v.

MANDLI COMMUNICATIONS, INC.,

Patent Owner.

Case IPR2024-01111

Patent No. 9,671,328

**EXPERT DECLARATION OF CHARLES E. THORPE IN SUPPORT OF
PETITION FOR *INTER PARTES* REVIEW**

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- c. [9D]: “a computer processing system operably connected to the active light sensor and configured to detect objects of interest within the field of view and for each object of interest:”51
- d. [9E]: “determine whether the object of interest includes at least one light intensity value associated with a reflective surface of a road marker in the field of view; and”53
- e. [9F]: “analyze the at least one light intensity value to determine an assessment of a discrete location of the road marker within the field of view.”54
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6. Claim 11: “The automated system of claim 9, wherein the computer processing system is configured to operate in a mode selected from post-processing or on-the-fly.”58
7. Claim 12: “The automated system of claim 9, wherein the light source is selected from the set consisting of a laser scanning device, a strobe light, or a vehicle headlight lamp.”58
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- a. [1P]: “An automated system that detects and determines reflective surfaces of interest in a scene of non-retroreflective surfaces along a roadway that is being traversed by a vehicle, the automated system comprising:”64
 - b. [1A]: “an image capture system that captures images within a field of view along the roadway;”65
 - c. [1B]: “an active light sensor including:” [1C]: “a light source that illuminates an area along the roadway; and” [1D]: “a light sensor that measures light intensity values within at least a portion of the area illuminated by the light source; and”70
 - d. [1E]: “a computer processing system operably connected to the image capture system, and the active light sensor and configured to detect objects of interest within the field of view and for each object of interest:”70
 - e. [1F]: “determine whether the object of interest includes a reflective surface based on the light intensity values;”71
 - f. [1G]: “determine whether the reflective surface is a road marker based on an assessment of the reflective surface; and”72
 - g. [1H]: “determine a location of the road marker.”73
- 12. Claim 2: “The automated system of claim 1, wherein the road marker is an object of interest selected from the set consisting of a road sign or a pavement marker.”73
 - 13. Claim 3: “The automated system of claim 1, wherein the computer processing system is configured to operate in a mode selected from post-processing or on-the-fly.”74
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6. Claim 6: “The automated system of claim 5, wherein the light source angle characterization is a look-up-table that relates an angular displacement from a normal vector for the light source to a light intensity for the light vector associated with the reflective surface.”106

7. Claim 7: “The automated system of claim 5, further comprising a global positioning satellite (GPS) unit that determines a location of the vehicle operably coupled to the computer processing system, wherein the location of the vehicle is used in determining the location of the road marker.”107

I. INTRODUCTION AND SUMMARY OF OPINIONS

1. I, Charles E. Thorpe, have been retained as an independent expert by Mobileye Global, Inc. (“Petitioner” or “Mobileye”) in connection with an *inter partes* review of U.S. Patent No. 9,671,328 (the “’328 patent”) (Ex. 1001). I have prepared this declaration in connection with Petitioner’s Petition for *Inter Partes* Review. I believe the statements contained in this declaration to be true and correct to the best of my knowledge.

2. I have been asked by Petitioner to provide my opinion on the technology claimed in claims 1-22 of the ’328 patent (the “Challenged Claims”) and whether the Challenged Claims would have been obvious to a person of ordinary skill in the art (“POSITA”) at the time of the earliest claimed priority date of the ’328 patent, which I have been asked to assume is August 12, 2000. This declaration sets forth the opinions I have formed, the conclusions I have reached, and the bases for these opinions and conclusions. Based on my experience, and knowledge of the art at the time of the earliest claimed priority date, it is my opinion that claims 1-22 of the ’328 patent would have been obvious based on the asserted grounds discussed below. A POSITA would have found it obvious to combine the prior art references I cite and would have been motivated to do so before the priority date. I was not asked to provide any opinions that are not expressed herein.

II. BACKGROUND AND QUALIFICATIONS

3. I believe that I am well qualified to serve as a technical expert in this matter based upon my educational background, career history, publications, and other relevant qualifications, which I summarize below. I understand that my curriculum vitae, which includes a more detailed summary of my background, experience, patents, and publications, is attached as Exhibit 1004.

4. I have been working with vision-guided vehicles for over 40 years.

5. My undergraduate degree is in Natural Science from North Park College, now University, in Chicago IL. I then received a Ph.D. in Computer Science from Carnegie Mellon University, where I studied artificial intelligence under Professor Herb Simon, who had recently received the Nobel Prize for his work on artificial intelligence, and under Professor Allen Newell, both of whom are widely credited for being two of the founding fathers of artificial intelligence. My thesis committee included my advisor Professor Raj Reddy, founder of The Robotics Institute, a member of the National Academy of Engineering, a Turing Award winner, and past co-chair of the President's Information Technology Advisory Committee, and Professor Takeo Kanade, arguably the most-decorated roboticist, member of the National Academies, and recipient of numerous awards for his contributions to robotics and computer vision.

6. My Ph.D. thesis project, titled *Vision and Navigation for a Mobile Robot*, built a binocular vision system for a robot. By finding the same object in the left image and right image, and using triangulation, the robot determined the distance to those objects—a simple form of depth perception. By tracking those objects as the robot moved, it was able to update its own estimate of its motion—an early form of SLAM, or Simultaneous Localization and Mapping. The robot succeeded in crossing our lab under autonomous vision control and was used for simple outdoor demonstrations. This work was sponsored by the Office of Naval Research.

7. As I was finishing my Ph.D. thesis, the Advanced Research Projects Agency of the Department of Defense (“ARPA,” since renamed “DARPA”) was becoming interested in using the supercomputers it was developing to solve problems of interest to the military. The Strategic Computing initiative had an effort for the Air Force (Pilot’s Associate, including speech understanding for a pilot to communicate with an intelligent assistant) and an effort for the Navy (involving task force scheduling). For the Army, the application selected was an autonomous scout, called the Autonomous Land Vehicle. I helped write two proposals that were funded: Road Following, involving perception for unmanned vehicles to travel on roads; and a systems integration project that built software to allow vision systems to talk to planners, to talk to controllers, and to manage all the

details of real-time planning and travel. My team had our own testbed vehicle, called Navlab I (for Navigation Laboratory).

8. I was a co-investigator and then lead investigator of the Navlab group. The Navlab group built several systems for road following: one based on color classification for finding and following paved paths that may not have lane markings; one based on finding painted markings, potentially of different colors and running at different angles; and a neural network that automatically learned what the most salient features were and used them to steer the vehicle. We received one of the first scanning laser rangefinders. This used a laser to measure distance to objects and a pair of mirrors to scan the beam left and right and up and down so a complete depth image was obtained every $\frac{1}{2}$ second. We used the laser rangefinder to detect obstacles and to find landmarks and update our position. The rangefinder also had a channel where it measured the amount of light reflected back from the points being scanned. We trained the neural net to use the reflectance image to autonomously steer the vehicle. We built maps, planning systems, and control mechanisms. A video showing some of the components in Navlab I as of 1990 is Navlab 90 Neighborhood Navigation, found at <https://www.youtube.com/watch?v=0GXuqw3cgwU>. An edited collection of papers produced by the Navlab group is in the book Vision and Navigation: the Carnegie Mellon Navlab, published by Kluwer Academic Publishers, 1990.

9. The DARPA work with the Autonomous Land Vehicle, funded from the mid 1980s to 1999, led to two different directions for successor projects. The military side transferred directly to the Army Research Labs, with their Demo II and Demo III projects. We built two automated High Mobility Multipurpose Wheeled Vehicles (“HMMWVs,” also commonly known as Humvees), so we could continue our on-road work and do more off-road driving.

10. The Department of Transportation also became interested in our work. The National Highway Transportation Safety Administration had an Office of Crash Avoidance Research, with the charter to reduce road collisions. They had separate efforts to address rear-end collisions, lane-change collisions, and collisions at intersections. In the 1990s, we won the contract to work on Run Off Road Collision Countermeasures. Crashes where the vehicle departs the roadway are not as common as the other types but are much more likely to cause a fatality—hitting a tree is a larger impact than side-swiping an adjacent car. The vast majority of those collisions are caused by driver error, ranging from simple inattention to poor judgment to driving too fast for the visibility conditions. We approached the problem from a number of angles: how do these collisions actually occur; how long in advance would you have to warn a driver in order to avoid a crash; and, of course, how do you build a computer vision system that sees what the road is doing ahead so you can generate an appropriate intervention.

11. At the same time that NHTSA was working on collision avoidance, Federal Highways was starting a much larger project: fully automated driving. Our Navlab group at CMU Robotics was a part of the winning consortium for the National Automated Highways System Consortium (“NAHSC”). General Motors was the lead; Bechtel and Parsons-Brinkerhoff worked on roadways; Delco and Lockheed Martin (including some of our old colleagues from the Autonomous Land Vehicle and Army Demo II projects) did systems engineering; CALTRANS provided roadways and an operator’s insight. Berkeley, through the California PATH consortium, and our Navlab group were the autonomous vehicle providers. The Berkeley system relied on magnets buried in the pavement and low-latency communications among cooperative cars to show how tightly packed the autonomous systems could be. Our approach, in contrast, emphasized intelligent vehicles surrounded by sensors, so the autonomous system could be mixed in with other human-controlled vehicles. We had video cameras, radars looking forward, sideways, and rearwards; we experimented with sonars and built our own phased array radar; we used infrared cameras and high-accuracy GPS units.

12. The culmination of the NAHSC project was a showcase on the HOV lanes of I-15 in San Diego in 1997. We built two computer-controlled Pontiac sedans, a computer-controlled Oldsmobile minivan, and two full-sized city buses: Navlabs 6 through 10. The 1997 Automated Highway Demo was a success. We

carried over 1000 passengers, including the U.S. Secretary of Transportation, all under automated control.

13. In 2000, I became Director of The Robotics Institute at Carnegie Mellon. As Director, I had an overview of all of the work going on across more than 40 active faculty. During my whole time at The Robotics Institute, my work concentrated on perception for wheeled vehicles but also included work for underwater autonomous systems, flying robots, and walking robots for planetary exploration.

14. In 2004, I was asked to become the founding Dean of Carnegie Mellon's branch campus in Qatar. I along with two of my PhD students that came with me continued active research from Qatar. We received one of the inaugural grants from the Qatar National Research Fund and were the first to complete a project and submit our final report.

15. When I returned from Qatar, I worked in the Office of Science and Technology Policy, Executive Office of the President from 2011-2012. My immediate boss, Aneesh Chopra, was the Chief Technology Officer of the United States. The head of OSTP was Dr. John Holdren, the President's Science Advisor. My title was Assistant Director for Advanced Manufacturing and Robotics. In the Advanced Manufacturing side, four of us served as the staff to help the President's Committee on Advanced Manufacturing set up the Advanced Manufacturing

Institutes. On the Robotics side, one of my activities was hosting a workshop on the difficulties of robotics response to the Fukushima nuclear reactor disaster. As a result of that workshop, DARPA initiated the Robotics Challenge, creating robots that can cross rubble fields, climb stairs, open doors, and do a series of activities that simulate a response to a nuclear disaster.

16. I came to Clarkson University in 2012. I served a full 5-year term as Provost. When I finished that term and stepped down, I was asked to serve as Dean of Arts & Sciences until a new Provost arrived and selected her own Dean. I have been back in the classroom since then. My research includes projects on unmanned aerial vehicles and on teleoperation of ground vehicles with multiple sensors. I continue to serve on Ph.D. thesis committees dealing with perception systems.

17. Throughout, my research has been well received. I am a Fellow of the Association for the Advancement of Artificial Intelligence, and a Fellow of the Institute of Electrical and Electronic Engineers. My awards include:

- IEEE Intelligent Transportation Society “Institution Lead Award” to the Navlab group, 2009.
- C. Wang, C. Thorpe and S. Thrun. Best Paper Award for “Online Simultaneous Localization and Mapping with Detection and Tracking of Moving Objects: Theory and Results from a Ground Vehicle in Crowded

Urban Areas” in *Proceedings of the IEEE International Conference on Robotics and Automation*, May, 2003.

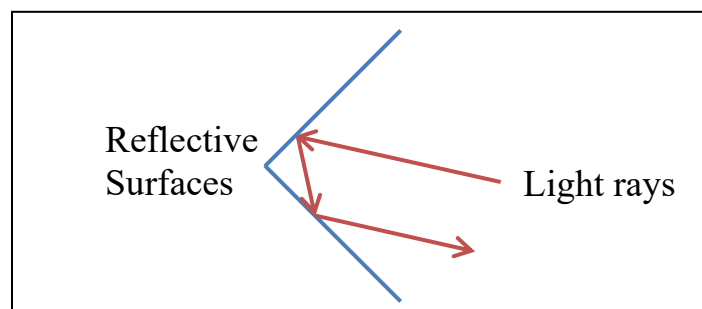
- Vectors of Pittsburgh, “Man of the Year” Technology Award, 2002.
- ROMAN 2001 Best Paper Award for “Multi-robot Driving with Collaborative Control.”
- Pennsylvania Quality Initiative Award, 1999, to the CMU Navlab group, for the 1998 Advanced Safety Bus Demonstration
- The National Automated Highway Systems Consortium, of which I was a part, received three awards at the 1998 ITS America Annual Meeting: Outstanding Achievement in Research, Development and Innovation; Outstanding Achievement in Intelligent Vehicles; and Most Effective ITS Promotion by a Public-Private Partnership.
- Newell Award for Research Excellence, 1997.
- Best Paper award. Single Leg Walking with Integrated Perception, Planning, and Control. E. Krotkov, R. Simmons and C. Thorpe. In Proceedings of IROS 90.

18. I have served on many advisory committees. For 12 years, I was on the Scientific Advisory Committee for CO-ME, the Swiss national research consortium on medical robotics. I was a member of the DARPA Defense Science Research Council. I chaired the IEEE-USA Research and Development Policy

Committee. Most significantly, I have served on 7 committees for the National Academies. In the most recent of those (2023-24), I chaired the review of Military Information Systems for Army research, both in-house and extramural, as part of the Technical Advisory Board for the Army Research labs.

III. BACKGROUND OF THE TECHNOLOGY

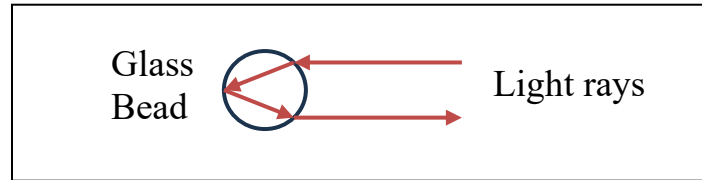
19. Making sure that road signs and other road markers are visible has long been an important factor in their design and maintenance. As road signs wear, they become harder to see, particularly at night, and need to be replaced. One key to making road signs visible at night is retroreflectivity. The sign material is designed so that a large fraction of the light from headlights is reflected back in the direction of the driver, making the signs brighter and easier to read. One common way this is accomplished is by “corner cube” shapes (sometimes called cube-corner shapes) embedded in the sign. In a 2-D drawing, if two reflective surfaces are placed at a 90 degree angle, any ray of light hitting one surface will bounce off of that surface, then the second surface, and will return on a parallel path towards the light source. This concept is depicted in the diagram below.



20. In three dimensions, the same end result can be accomplished by adding a third reflective surface perpendicular to the first two—the surface looks like the inside corner of a box, hence the name “corner cube.” The sign material can have many of these tiny corner cubes covering the entire area of the sign. Note that small imperfections in the returned angle are good: if the corner cubes were perfectly retroreflective, all the light from a headlight would be reflected back to the headlight, and not to the eyes of the driver. This kind of material is well-known and is described in several references published long before the priority date of the ’328 patent. *E.g.*, K. L. Black et al., *NCHRP Report No. 346: Implementation Strategies for Sign Retroreflectivity Standards*, Transportation Research Board (April 1992) (Ex. 1012); Joseph T. Fitzpatrick, *Unified Reflective Sign, Pavement and Delineation Treatments for Night Traffic Guidance*, Highway Research Board Bulletin, Issue No. 255 (1960) (Ex. 1017).

21. A different way to create a retroreflective surface is to use glass beads embedded in the surface. The same effect is accomplished: light coming into the glass bead is refracted (bent) as it enters the bead, reflects off of the back of the bead, and is refracted again as it emerges from the front of the bead, returning on a more-or-less parallel path. This is shown in the diagram below. Since the reflection at the back of the bead is on the border between the glass and whatever substrate is behind the glass, the reflected light can pick up the color of the substrate. Glass

beads are typically used in retroreflective lane markings, as it is easier to apply them to a painted line than it would be to create corner cube shapes on the paint.



22. Both of these methods of creating retroreflectivity can deteriorate over time. Corner cubes can become worn or filled with dirt or the layer of the sign containing the corner cubes can become delaminated from the sign backing, for example. Glass beads can be worn away by traffic, weather, or snow plows, for example. Accordingly, it is important to do periodic inspection to ensure that the signs and lane markings are bright enough to meet the minimum standards required for visibility.

23. The most accurate measurement of retroreflectivity would require a calibrated light source, no other external lighting, an accurately measured distance, and a calibrated photosensor to measure the returned light. The raw materials for signs can be measured in this fashion in a lab. Doing the same measurements in the field, on an installed sign or line, is more challenging. One known method uses a hand-held device that can be held to touch the sign: the distance is then set by the size of the instrument, and external light is blocked by the instrument's shape. This method is slow and potentially dangerous to the workers doing the inspection, and

is not viable for inspecting painted lines and raised pavement markings without closing down roads.

24. Another known method approximated the ideal conditions by taking measurements from a moving vehicle at night with known headlights or another known light source and corresponding photosensor. Taking measurements at night reduced the external illumination compared to the daytime. Alternatively, other known methods pulsed a very bright strobe light and timed the photosensor's data collection to match the timing of the light pulse, which allowed measurements from a moving vehicle during daytime by illuminating the reflective object at a much greater intensity than the ambient illumination. Both types of mobile systems typically either included a measurement device to tell how far away the reflective object was or approximated the distance by directing the light source at a fixed angle towards the pavement with a shallow field of view.

25. Additionally, if the photosensor collected two readings, one with the pulse on and one with it off, and subtracted the two readings, the result would be just the active illumination with the background subtracted. This same technique also works with a constant light source by subtracting a reading from just the road without a reflective object (the background) from the reading with the reflective object. My group used this technique in building a light-stripe sensor to detect

curbs and potholes near the vehicle, in full sun, without any special retroreflective properties of the surfaces.

IV. MATERIALS CONSIDERED

26. In forming my opinions, I have analyzed the following exhibits, including the '328 patent, its prosecution history, and the prior art cited in my analysis of the Petition Grounds, as well as the other materials cited in this declaration.

Exhibit	Description
Ex. 1001	U.S. Patent No. 9,671,328 (“the ’328 patent”)
Ex. 1002	Prosecution History of the ’328 patent
Ex. 1005	U.S. Patent Application Publication No. 2002/0063638 to Gallagher (“Gallagher”)
Ex. 1006	U.S. Patent No. 5,796,094 to Schofield et al. (“Schofield”)
Ex. 1007	U.S. Patent No. 5,202,742 to Frank et al. (“Frank”)
Ex. 1008	American Society for Testing and Materials D4383–96, Standard Specification for Plowable, Raised Retroreflective Pavement Markers (July 1996) (“ASTM”)
Ex. 1009	U.S. Patent No. 5,313,262 to Leonard (“Leonard”)
Ex. 1010	International Publication No. WO 96/17258 to Popovich (“Popovich”)
Ex. 1011	U.S. Patent No. 9,335,255 (“the ’255 patent”)
Ex. 1012	K.L. Black et al., <i>NCHRP Report No. 346: Implementation Strategies for Sign Retroreflectivity Standards</i> , Transportation Research Board (April 1992) (“Black”)

Exhibit	Description
Ex. 1013	U.S. Patent No. 6,359,274 to Nixon et al. (“Nixon”)
Ex. 1014	John J. Lumia, <i>A Mobile System for Measuring Retroreflectance of Traffic Signs</i> , Optics, Illumination, and Image Sensing for Machine Vision V, Donald J. Svetkoff, Editor, Proc. SPIE 1385, pp. 15-26 (1991) (“Lumia”)
Ex. 1015	Kenneth D. Uding, <i>Exact Road Geometry Output Program for Retroreflective Road Sign Performance</i> , Transportation Research Record 1421 (1993) (“Uding”)
Ex. 1016	V.J. Pezoldt, <i>Raised Pavement Marker Reflectivity</i> , Report No. TX-90/1151-1F, Texas Transportation Institute (Nov. 1990)
Ex. 1017	Joseph T. Fitzpatrick, <i>Unified Reflective Sign, Pavement and Delineation Treatments for Night Traffic Guidance</i> , Highway Research Board, Bulletin 255 (1960) (“Fitzpatrick”)
Ex. 1020	U.S. Patent No. 4,721,389 to Dejaiffe (“Dejaiffe”)

27. My opinions are based on my experience, knowledge of the relevant art, the documents identified above, and the documents discussed in this declaration.

V. LEGAL STANDARDS

28. I am not a lawyer. My understanding of the legal standards to apply in reaching the conclusions in this declaration is based on discussions with counsel for Petitioner, my experience applying similar standards in other patent-related matters, and my reading of the documents submitted in this proceeding. In preparing this declaration, I sought to faithfully apply these legal standards to the Challenged Claims.

A. Claim Construction

29. I have been instructed that the terms appearing in the '328 patent should be interpreted in view of the claim language itself, the specification, the prosecution history of the patent, and any relevant extrinsic evidence. The words of a claim are generally given their ordinary and customary meaning, which is the meaning that the term would have to a person of ordinary skill in the art at the time of the invention, which I am assuming here is August 12, 2000. While claim limitations cannot be read in from the specification, the specification is the single best guide to the meaning of a disputed term. I have followed these principles in reviewing the claims of the '328 patent and forming the opinions set forth in this declaration.

B. Level of Ordinary Skill

30. I understand a person of ordinary skill in the art is determined by looking at (i) the type of problems encountered in the art; (ii) the prior art solutions to those problems; (iii) the rapidity with which innovations are made; (iv) the sophistication of the technology; and (v) the educational level of active workers in the field.

31. In my opinion, based on these factors, a person of ordinary skill in the art ("POSITA") would have had at least a bachelor's degree in mechanical engineering, electrical engineering, computer science, physics, or related

discipline, and four years of experience in research, design, or development in computer vision systems. Higher levels of education may offset less experience and extensive experience can substitute for formal education.

32. I was at least a POSITA as of August 12, 2000, and supervised others who were at least a POSITA.

C. Obviousness

33. I have been told that under 35 U.S.C. § 103, a patent claim may be obvious if the differences between the subject matter sought to be patented and the prior art are such that the subject matter as a whole would have been obvious at the time the invention was made to a person having ordinary skill in the art to which said subject matter pertains.

34. I have been told that a proper obviousness analysis requires the following:

- a. Determining the scope and content of the prior art;
- b. Ascertaining the differences between the prior art and the claims at issue;
- c. Resolving the level of ordinary skill in the pertinent art; and
- d. Considering evidence of secondary indicia of non-obviousness (if available).

35. I have been told that the relevant time for considering whether a claim would have been obvious to a person of ordinary skill in the art is the time of invention. For purposes of my analysis, I assumed that the date of invention for the Challenged Claims is August 12, 2000.

36. I have been told that a reference may be modified or combined with other references or with the person of ordinary skill's own knowledge, if the person would have found the modification or combination obvious. I have also been told that a person of ordinary skill in the art is presumed to know all the relevant prior art, and the obviousness analysis may take into account the inferences and creative steps that a person of ordinary skill in the art would employ.

37. I have been told that whether a prior art reference renders a patent claim obvious is determined from the perspective of a person of ordinary skill in the art. I have also been told that, while there is no requirement that the prior art contain an express suggestion to combine known elements to achieve the claimed invention, and while a suggestion to combine known elements to achieve the claimed invention may come from the prior art as a whole or individually and may consider the inferences and creative steps a person of ordinary skill in the art would employ, as filtered through the knowledge of one skilled in the art, obviousness grounds cannot be sustained by mere conclusory statements and must

include some articulated reasoning with some rational underpinning to support the legal conclusion of obviousness.

38. I have been told that there is no rigid rule that a reference or combination of references must contain a “teaching, suggestion, or motivation” to combine references. But I also have been told that the “teaching, suggestion, or motivation” test can be used in establishing a rationale for combining elements of the prior art. I have also been told to be aware of distortions caused by hindsight bias, and that reading into the prior art the teachings of the invention at issue is improper.

39. I am aware that a claim may be obvious where the claim represents nothing more than a combination of prior art elements according to understood methods that yields predictable results. I am further aware that a claim may be obvious where it merely involves the simple substitution of one known element for another to achieve predictable results. I am additionally aware that it may be obvious to try a particular combination of claim features if selecting them requires merely choosing from a finite number of identified, predictable solutions, with a reasonable expectation of success.

40. I have been informed that, in an obviousness analysis, prior art must be analogous art to the patent being considered. I have been informed that a prior art reference is considered to be analogous, or in the same field of art, if the

reference is either (1) in the same field of endeavor as the challenged patent, regardless of the problems the challenged patent and the prior art address, or (2) reasonably pertinent to the particular problem being solved by the challenged patent.

VI. THE '328 PATENT

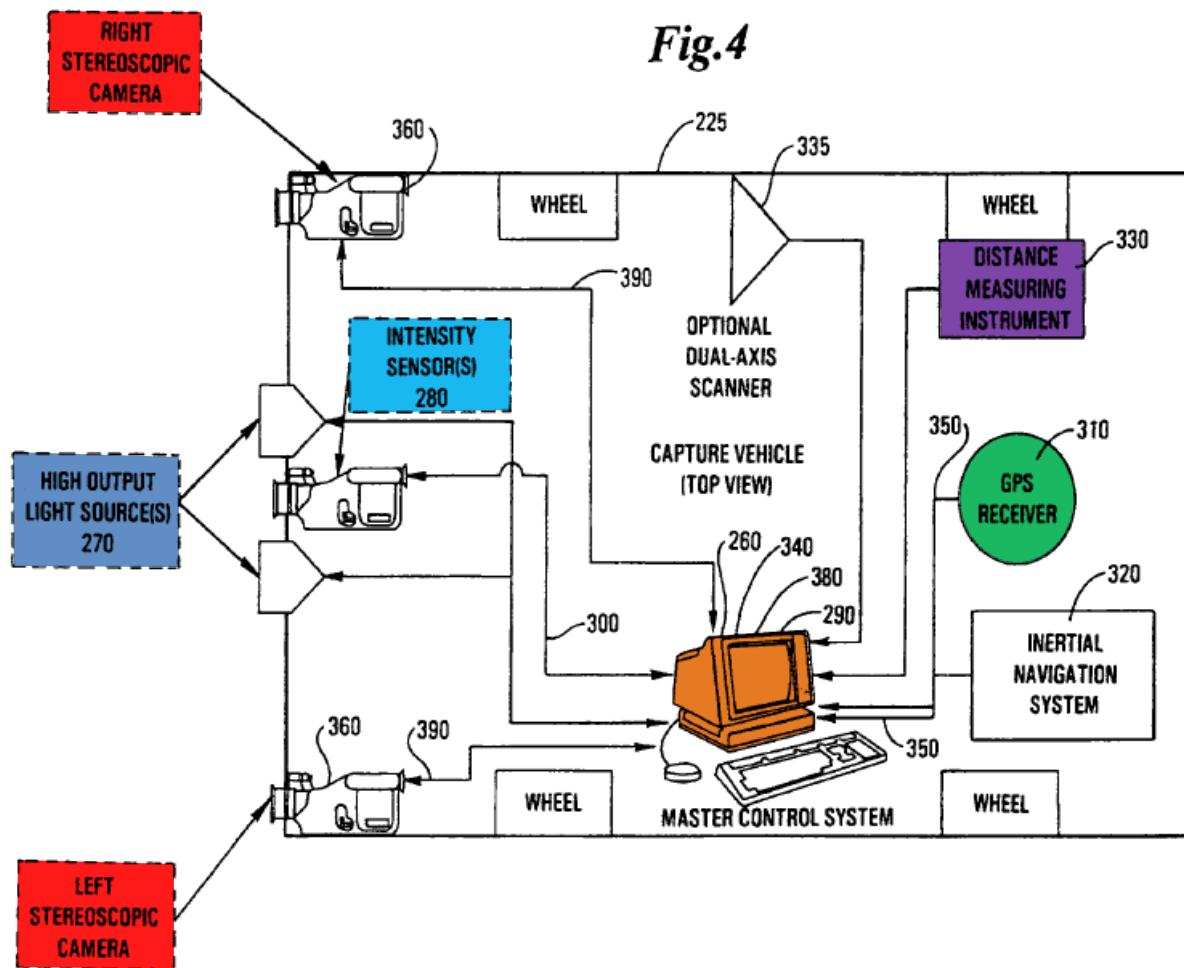
A. Specification

41. The '328 patent discloses a system for determining reflective objects of interest along a roadway. Ex. 1001, Abstract. The '328 patent admits that “using an automated image identification system to recognize road signs and traffic signs [was] well known,” but asserts that proposed systems used less accurate “template matching of shape and color.” Ex. 1001, 1:39-46. The '328 patent states that those inaccuracies are due to “the wide variations in lighting and conditions.” Ex. 1001, 1:46-47.

42. Like the known prior art, the '328 patent's system determines “retroreflectivity values for reflective surfaces disposed along a roadway” using “subsystems located on/in a capture vehicle 225.” Ex. 1001, 3:66-4:4, 7:65-8:18. As was well known by a POSITA, retroreflectivity is the ability of an object to reflect light back to its source. *E.g.*, Ex. 1012 (“Retroreflection occurs when light rays strike a surface and are redirected back to the source of light.”); Ex. 1014, 15-16 (“A retroreflector is a device which turns light back toward its source,

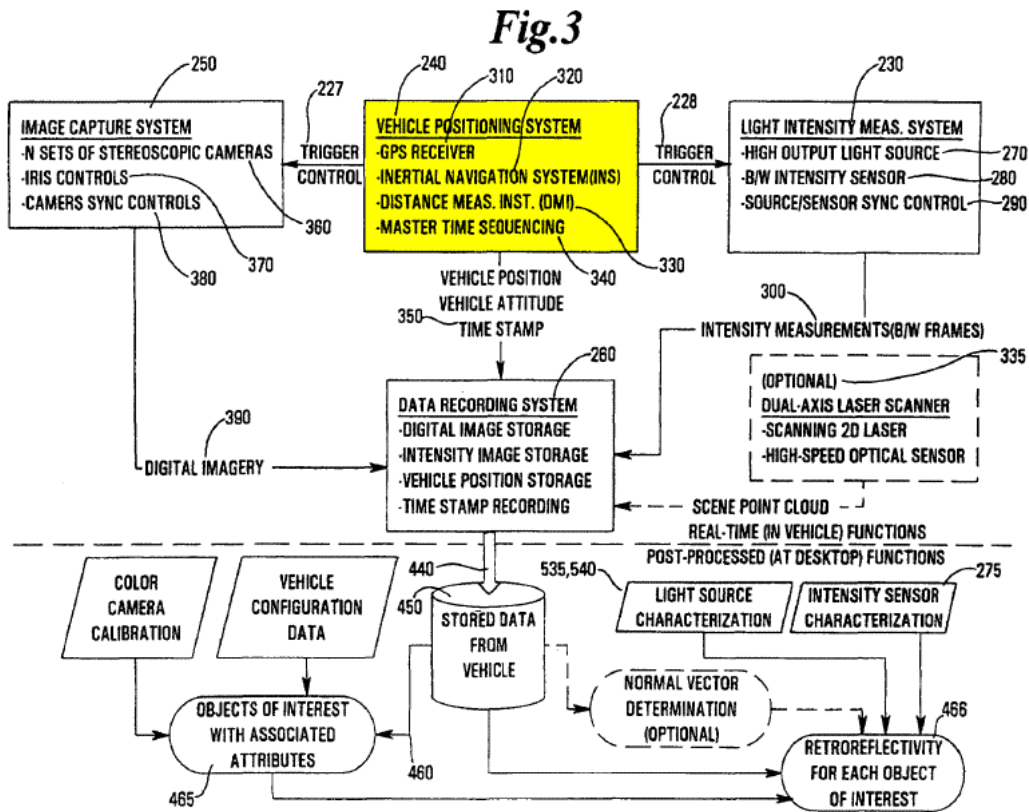
usually over a wide range of input angles.”); Ex. 1016 (“Retroreflection is the ability of a device to return light in directions close to that from which it came.”).

Figure 4, annotated below, depicts “a *typical* configuration within a capture vehicle” that can produce “data and imagery to create digital representations of objects of interest” and their retroreflectivity. Ex. 1001, 10:18-21 (emphasis added).



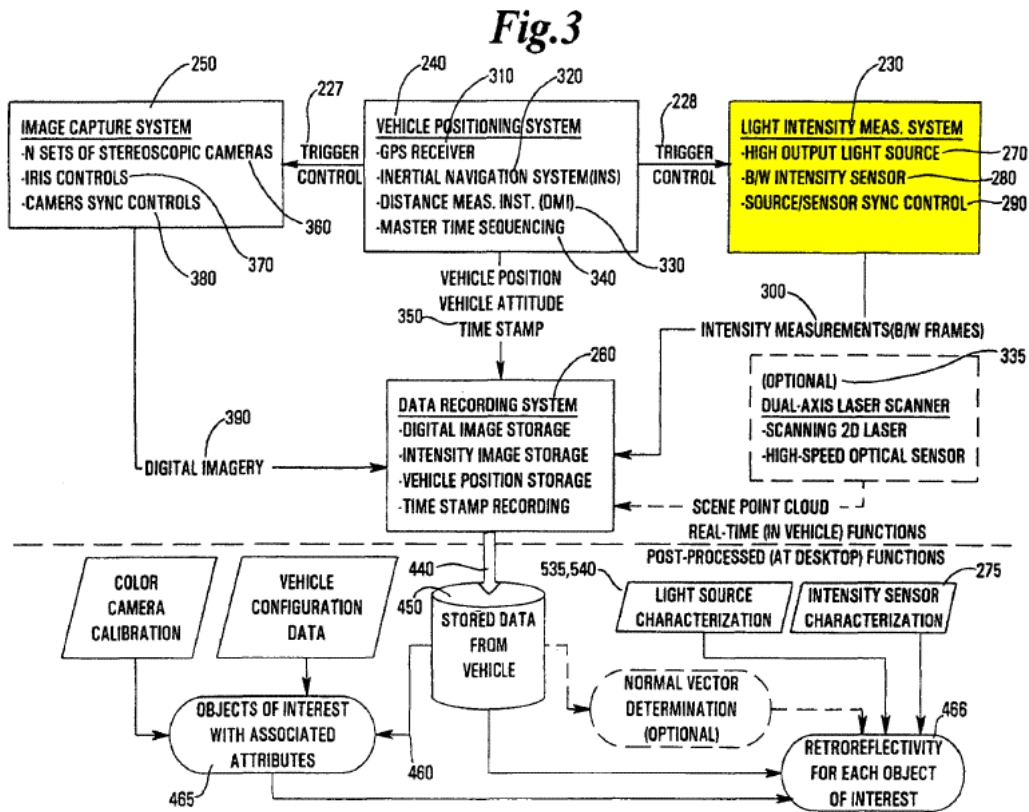
Ex. 1001, Fig. 4 (annotated).

43. A distance measuring instrument 330 and GPS receiver 310 form part of a vehicle positioning system 240 (highlighted in Figure 3, below) that generates position measurements (e.g., position of the vehicle and distance from the vehicle to a road marker). Ex. 1001, 8:9-14, 10:21-27, Fig. 3. A digital imagery system 390, which includes the stereoscopic cameras 360 in the embodiment above, “allows for the creation of objects of interest 460 and their associated attributes 465 during post-processing.” Ex. 1001, 10:35-38. The ’328 patent acknowledges that “[t]here are many methods for creating objects of interest 460 from digital imagery” and assumes that a POSITA would have been aware of other such methods, as it states that only “a few of [the methods] are discussed in” the ’328 patent. Ex. 1001, 10:14-17.



Ex. 1001, Fig. 3 (annotated).

44. “The **high output light source(s) 270** and **light intensity sensor(s) 280** constitute the light intensity measurement system 230.” Ex. 1001, 8:3-6, 10:28-30. Light intensity measurement system 230 (highlighted in Figure 3, below) generates intensity measurements “in response to the repeated strobing of the **high output light source 270**,” which makes it possible to collect the data needed to compute retroreflectivity. Ex. 1001, 8:6-9, 10:28-34. The number of intensity values in each intensity measurement can correspond to “the number of pixels in the light intensity sensor’s 280 array.” Ex. 1001, 11:39-45.



Ex. 1001, Fig. 3 (annotated).

45. The master control system (unlabeled) monitors the other onboard systems and records the data for post-processing by “desktop systems” to identify objects of interest and their retroreflectivity. Ex. 1001, 8:14-56, 9:13-10:17, Fig. 3.

46. The '328 patent discloses that intensity is “determined from the gray value of the corresponding pixels” in the image of the light intensity sensor 280. Ex. 1001, 11:36-39. “Intensity values will vary according to the color of the reflected light, since not all colors of incoming light excite the light intensity sensor 280 pixels in the same way.” Ex. 1001, 11:53-55. “By knowing the background or foreground color of the object of interest” and the intensity sensor’s

profile for a particular color, “the intensity value 300 for a particular color can be converted into a luminance value.” Ex. 1001, 11:55-60. With a “uniform light source,” knowing the luminance and the distance to the object of interest allows the retroreflectivity to be approximated. Ex. 1001, 12:7-22.

47. The '328 patent discloses using its system for determining retroreflectivity “to detect and determine a retroreflective surface of interest disposed in a scene of non-retroreflective surfaces.” Ex. 1001, 9:1-11. Through incorporation by reference of its parent application, the '328 patent discloses that “pavement markings” include reflective surfaces whose retroreflectivity may be measured. Ex. 1001, 1:7-27; Ex. 1011, 17:26-18:30; *see* Ex. 1001, 17:54-56 (reciting that “the road marker is an object of interest selected from the set consisting of a road sign or a pavement marker”).

48. Notably, none of the '328 patent's techniques for determining reflectivity laid out in its “Summary of the Invention,” reproduced below, are recited in the claims.

SUMMARY OF THE INVENTION

The present invention is a system for classifying different types of sheeting materials of road signs depicted in a videostream. Once a road sign has been identified in the videostream, the frames associated with that road sign are analyzed to determine each of a plurality of colors present on the road sign. An estimated retroreflectivity for each of the plurality of colors present on the road sign is then determined. By comparing the estimated retroreflectivity for each of the plurality of colors against known minimum retroreflectivity values for the corresponding color for different types of sheeting materials, an accurate determination of the classification of the sheeting material of the road sign is established. Preferably, certain conditions of gross failure of the sheeting material are filtered out before classification of the sheeting material is determined.

In a preferred embodiment, a system for the automated determination of retroreflectivity values for reflective sur-

faces disposed along a roadway is utilized to establish the retroreflectivity values for both foreground and background colors of a road sign for the purpose of classifying the sheeting material of that sign. An area along the roadway that includes at least one reflective surface is repeatedly illuminated by a light source and multiple light intensity values are measured over a field of view which includes at least a portion of the area illuminated by the light source. A computer processing system is used to identify a portion of the light intensity values associated with a reflective surface and analyze the portion of the light intensity values to determine at least one retroreflectivity value for that reflective surface. Color images of the area and locational information are also generated by the system and are used together with a characterization profile of the light source to enhance the accuracy of the determination of retroreflectivity values.

In contrast to the existing techniques for determining retroreflectivity that require an operator to target individual signs from a known distance, a preferred embodiment of the present invention can determine retroreflectivity without targeting individual signs and can automatically determine sheeting classification as a result. To overcome the limitations imposed by the existing techniques, the preferred embodiment employs several enhancements that are designed to improve the accuracy of evaluating intensity measurements made over a view where the reflective surfaces are not individually targeted and therefore neither the distance to the reflective surface or the normal vector to the reflective surface are known.

B. Prosecution History

49. The '328 patent was filed as Application No. 15/148,722. Following a preliminary amendment canceling the original claims and adding new claims, the Examiner allowed the claims without rejection. Ex. 1002, 200-202, 275-277.

VII. CLAIM CONSTRUCTION

50. I am told that claim construction is not necessary where there is no controversy as to the meaning of the terms with respect to the prior art. In my opinion, the prior art asserted in the petition ground discloses an embodiment within the indisputable scope of the ordinary and customary meaning of the claims. Therefore, it is my opinion that no explicit claim constructions are needed to apply the prior art to the Challenged Claims.

VIII. ANALYSIS OF PETITION GROUNDS

51. In my opinion, the Challenged Claims of the '328 patent would have been obvious over the following grounds.

1	Gallagher and Schofield render obvious claims 1-4, 8-13, and 17-18
2	Gallagher, Schofield, and Frank render obvious claims 15-16, 19, and 21-22
3	Gallagher, Schofield, Frank, and ASTM render obvious claims 14 and 20
4	Gallagher, Schofield, Leonard, and Popovich render obvious claims 5-7

A. Ground 1: Gallagher and Schofield Render Obvious Claims 1-4, 8-13, and 17-18

1. Gallagher (Ex. 1005)

52. Gallagher, like the '328 patent, discloses a “reflectivity measuring apparatus” used on a moving vehicle. Gallagher, [0001], [0031]-[0033]. Gallagher

discloses that “[l]ight reflective road markings and markers are extensively used to demarcate vehicle lanes and supply vital information to drivers about sections of road” and “function by reflecting or retroreflecting light rays entering the reflective material of the road marking back to a driver.” Gallagher, [0002]. Gallagher’s apparatus tests “road markings and road markers such as, for example, road signs and posts, reflective painted lines whether continuous or broken, and ... raised pavement markers” “to ensure they continue to meet minimum standards of reflectivity/retroreflectivity.” Gallagher, [0003], [0006], [0031]-[0033]. It overcomes the disadvantages of then-conventional test methods that relied on subjective “night time drivebys using headlights” or a labor-intensive “portable hand held measuring instrument.” Gallagher, [0003]-[0006].

53. Gallagher’s apparatus “is mounted on ... a vehicle 3” and “can obtain reflectivity measurements, inter alia, with the vehicle 3 travelling at speeds of up to about 100 kph.” Gallagher, [0032]. “For simplicity,” Gallagher describes an embodiment that measures “raised pavement markers 2,” referred to as “markers,” but it can also “be adapted to measure other types of reflective markings on or adjacent the road.” Gallagher, [0033]. Gallagher’s apparatus includes “a light source 4 in the form of a standard vehicle headlight” with a “relatively constant and even intensity.” Gallagher, [0035]. “A reflected light results from the beam illuminating” a surface of marker 2, and “[a] light sensor 6 detects the reflected

light.” Gallagher, [0036], [0038], [0046]. Gallagher, [0038]. Sensor arrays containing multiple sensors, each “arranged to detect reflected light from a relatively small viewing angle,” “are advantageously aligned in an encased module 6a to increase the field of view of the apparatus 1.” Gallagher, [0038], [0040]. The sensors may be “photodiodes mounted precisely on the module 6a at a height and angle to properly detect reflected light” and may be configured to “indicate the [color] of a road marking being tested.” Gallagher, [0039]. The light source 4 and light sensor module 6a are mounted in close proximity “to reduce the observation angle to almost zero.” Gallagher, [0041]. This apparatus is depicted in Figure 1, below from Gallagher’s patent.

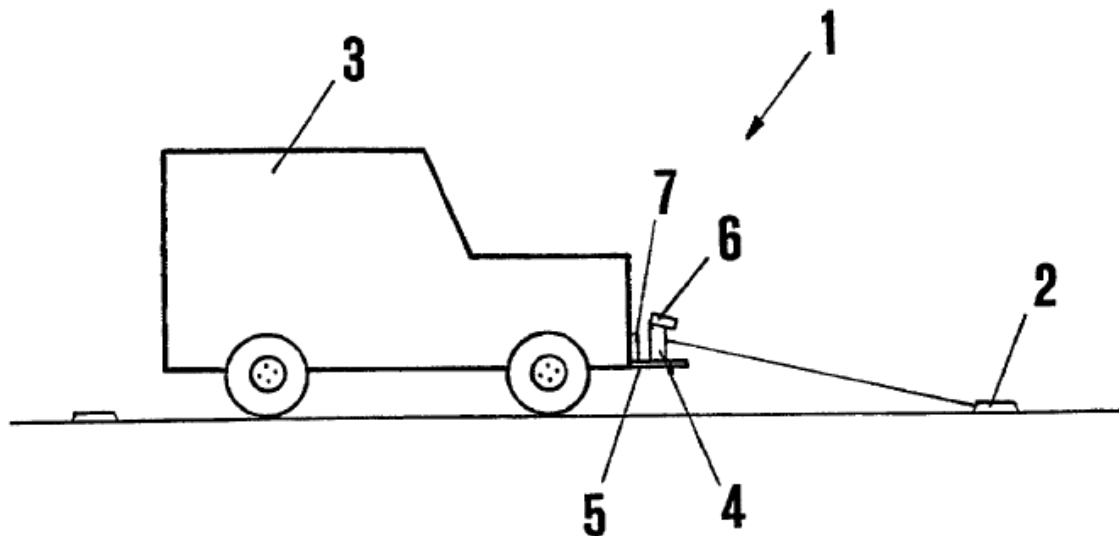
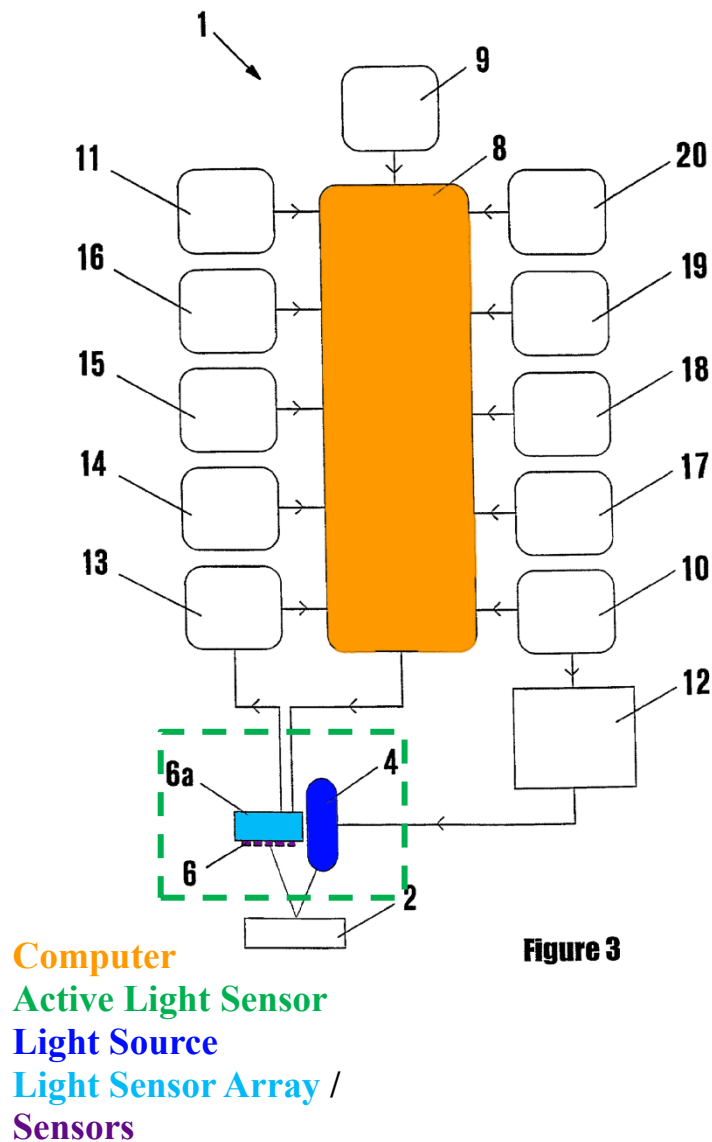


Figure 1

Gallagher, Fig. 1.

54. The apparatus also includes “a computer 8 ... to carry out a method of testing the integrity of road markings.” Gallagher, [0045]. Computer 8’s processing includes “getting the data ... on the reflected light detected by the light sensors 6,” “calculating the average reflectance level from a set of sampled data from each sensor,” “calibrating the data by multiplying the data with a predetermined calibration factor to calibrate for different positions in the light sensor module 6a,” “determining the distance travelled from the start position of the road marking test so as to determine the location of each road marking,” “determining the background reflectance level on the road and establishing non-marker reflectance levels,” “selecting ... which reflectance levels indicate a road marker,” “determining the reflectance level of the road marker in a value of millicandela per Lux (CIL),” and “tagging ... a road marker if it is determined as measuring a reflectivity less than the predetermined minimum acceptable reflectance level.” Gallagher, [0055]-[0068]. “The data obtained on the reflectance level and location of each road marking tested can be stored and later used in a rerun of a stretch of road tested earlier.” Gallagher, [0073]. Gallagher’s apparatus also provides “an audio and/or visual indicator” of the vehicle’s position on the road to the driver to help the driver “maintain the vehicle 3 in a proper position on the road to allow the apparatus 1 to obtain reflectivity measurements.” Gallagher, [0060]-[0062].

55. Gallagher's Figure 3, below, highlights the reflectivity measuring apparatus' active light sensor, which includes the light source 4 and the array 6a of light sensors 6, and its computer 8. Gallagher, [0035]-[0050], Fig. 3.



Gallagher, Fig. 3 (annotated).

2. Schofield (Ex. 1006)

56. Schofield discloses a system that “identifies particular light sources” by “separating each light source” in a forward scene of a vehicle and “analyzing that source to determine its characteristics,” including its spectral characteristics and spatial layout. Schofield, 1:56-67, 2:6-14. Light sources include “[l]ane markers, signs, and other sources of reflected light.” Schofield, 10:43-45. Schofield discloses using its system to “identify particular traffic signs” and “detect lane markers,” among other light sources. Schofield, 12:1-4, 12:40-42.

57. Schofield’s system includes “an imaging sensor module 14 which senses light from a scene forward of vehicle 10” and “an imaging control circuit 13 which receives data from sensor 14.” Schofield, 3:36-44. “Imaging sensor module 14 includes an optical device 36, such as a lens, an array 38 of photon-accumulating light sensors, and a [filter array 40] for separating light from the scene forward of vehicle 10 into a plurality of spectral bands.” Schofield, 4:16-21. The “array 38 may be a charge couple device (CCD) array of the type commonly utilized in video camcorders and the like,” and may include an array of “light-sensing pixels, each made up of a photosensor element 42.” Schofield, 4:28-31, 8:38-40, Fig. 4.

58. The imaging control circuit 13 “responds to the plurality of sensors in order to determine if spatially adjacent regions of the field of view forward of the

vehicle include light of a particular spectral signature above a particular intensity level.” Schofield, 2:28-32, 4:47-5:12, 7:64-8:12. Analyzing the intensity values of each of the red, green, and blue pixels in the array both relative to each other and relative to a particular intensity range “helps to reduce false detection of light sources.” Schofield, 7:64-8:8. Schofield’s control circuit also uses “spatial filtering” and “[p]attern recognition” to further assist in identifying objects of interest. Schofield, 10:51-11:3. Spatial filtering refers to considering “whether a particular pixel, or pixel group, is detecting a light source having a particular spectral signature” and “what adjacent, or closely related, pixels or pixel groups, are detecting.” Schofield, 10:53-57. “Pattern recognition identifies objects of interest based upon their shape, reflectivity, luminance, and spectral characteristics.” Schofield, 11:1-3.

59. Schofield’s system is used to identify “point sources of light in any particular location within the scene viewed forward of the vehicle” and “at great distances.” Schofield, 9:24-26, 10:22-26. For example, Schofield discloses using its system “to identify particular traffic signs by their spectral signature as well as their geometric organization” (e.g., identifying red octagons as stop signs or yellow triangles as caution signs). Schofield, 12:1-4. Schofield attributes this ability to the “significant reduction in the amount of data to be processed because the image forward of the vehicle is captured in a manner which preselects data” using the

spatial and spectral light-source characteristics. Schofield, 12:5-11. Schofield also discloses using its system “to detect lane markers ... to either assist in steering the vehicle or provide a warning to the driver that a lane change is occurring.”

Schofield, 12:40-42.

3. Gallagher and Schofield Are Analogous Art

60. Gallagher and Schofield are analogous art to the '328 patent because they are in the same field of endeavor, namely, automated object recognition.

Ex. 1001, 1:31-32; Gallagher, [0007], [0066], [0078]; Schofield, 1:56-2:15, 9:24-

26. Gallagher and Schofield are also analogous art to the '328 patent because they

are reasonably pertinent to problems addressed by the '328 patent, including

automatically identifying road markers without relying solely on “template

matching of shape and color.” Ex. 1001, 1:39-47; Gallagher, [0066] (identifying

road markers based on “peak responses sensed” by light sensors); Schofield,

10:66-11:12 (using various characteristics, including “reflectivity,” for object

identification).

4. Independent Claim 9

a. [9P]: “An automated system for assessing reflective surfaces disposed along a roadway comprising:”

61. While I have been advised that a preamble is not always limiting, I have been asked to assume for the purposes of this Declaration that each of the

preambles in the independent claims of the '328 patent is limiting. Gallagher discloses [9P].

62. Gallagher discloses an automated system for assessing reflective surfaces disposed along a roadway using its reflectivity measuring apparatus. Gallagher, [0033]-[0035]. Gallagher's reflectivity measuring apparatus assesses reflective surfaces of road markers because it includes a light source that "illuminates a reflective surface of a" road marker disposed along a roadway, light sensors 6 that detect "the reflected light," and a computer 8 that obtains data "on the reflected light detected by" light sensors 6 and selects "which reflectance levels indicate a road marker." Gallagher, [0046], [0055]-[0066]. This system then tags any road markers determined to have "a reflectivity less than the predetermined minimum acceptable reflectance level." Gallagher, [0068]. This system is automated because, once a measurement process is initiated, measurements automatically are "made in real time" by the computer. Gallagher, [0046], [0071].

- b. **[9A]: “an active light sensor that is traversed along a roadway that includes at least one reflective surface on a road marker, the road marker having a reflective characteristic, the active light sensor including: [9B] a light source to illuminate an area that includes the at least one reflective surface; and [9C] a light sensor that measures a plurality of light intensity values within a field of view which includes at least a portion of the area illuminated by the light source; and”**

63. Gallagher discloses or suggests [9A] and its sub-elements [9B] and [9C].

64. Gallagher’s reflectivity measuring apparatus includes an active light sensor including “a light source 4” and an array of light sensors 6 “aligned in an encased module 6a.” Gallagher, [0035]-[0039]. As discussed below, Gallagher’s active light sensor includes all of the corresponding claim elements for [9B], the light source, and [9C], the light sensor.

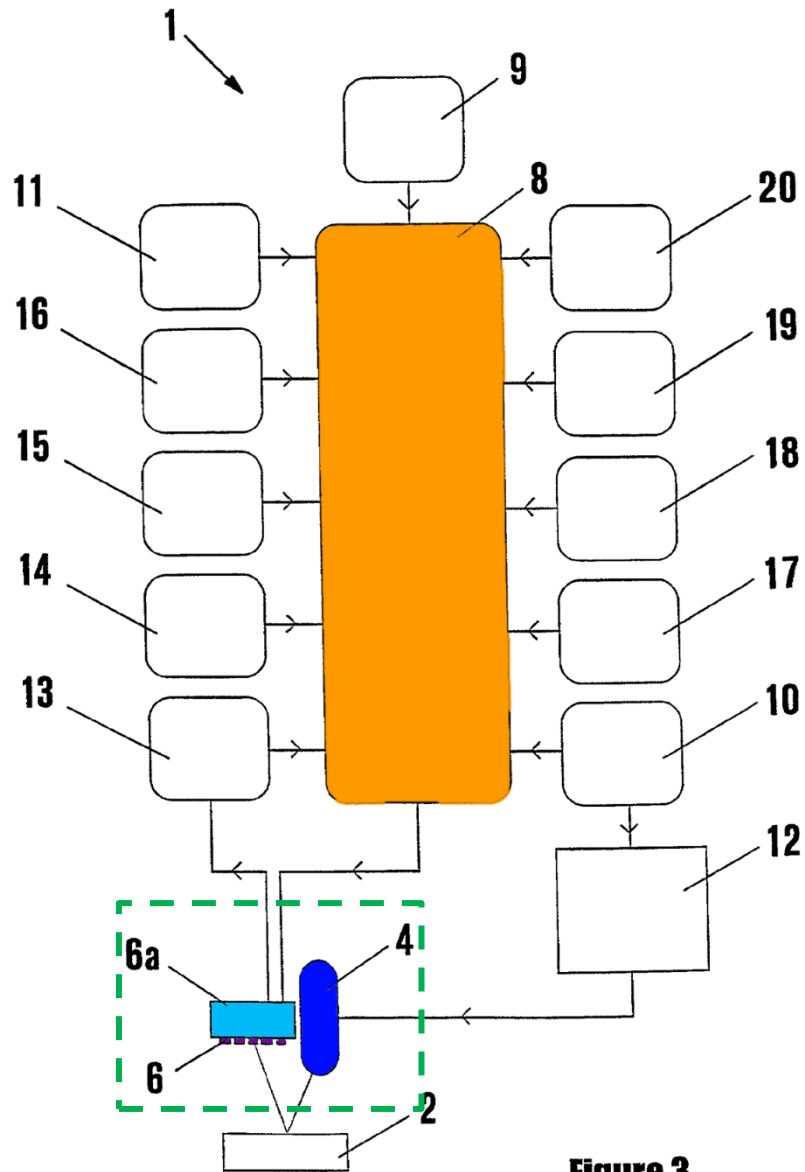


Figure 3

Computer
Active Light Sensor
Light Source
Light Sensor Array / Sensors

Gallagher, Fig. 3 (annotated).

65. Gallagher's active light sensor is traversed along a roadway because it is "mounted on ... a vehicle 3" and measures reflectivity while the vehicle travels

“at speeds of up to about 100 kph” (traverses) “on a road” (along a roadway).

Gallagher, [0031]-[0032], Fig. 2 (below). The roadway includes raised pavement markings, for example, that “have two highly reflective surfaces” (at least one reflective surface on a road marker). Gallagher, [0005], [0034]. The apparatus measures the level of reflectivity (a reflective characteristic) of the “road markers.” Gallagher, [0032]-[0033], [0066]-[0068]. Gallagher’s active light sensor can also “be adapted to measure other types of reflective markings on or adjacent the road.” Schofield, [0033].

66. For [9B], Gallagher’s active light sensor includes “a light source to illuminate an area that includes the at least one reflective surface” because it discloses “a light source 4 in the form of a standard vehicle headlight” that, when activated, “illuminates” a “test area A” along the roadway that includes “a reflective surface of a marker 2.” Gallagher, [0035]-[0037], [0046]. For example, a wide-beam light source illuminates an area along the roadway in front of the vehicle “to cover a 3 [meter] by 0.5 [meter] area.” Gallagher, [0035]. The area along the roadway illuminated by the light source 4 is highlighted below, with the area A including at least one reflective surface on marker 2.

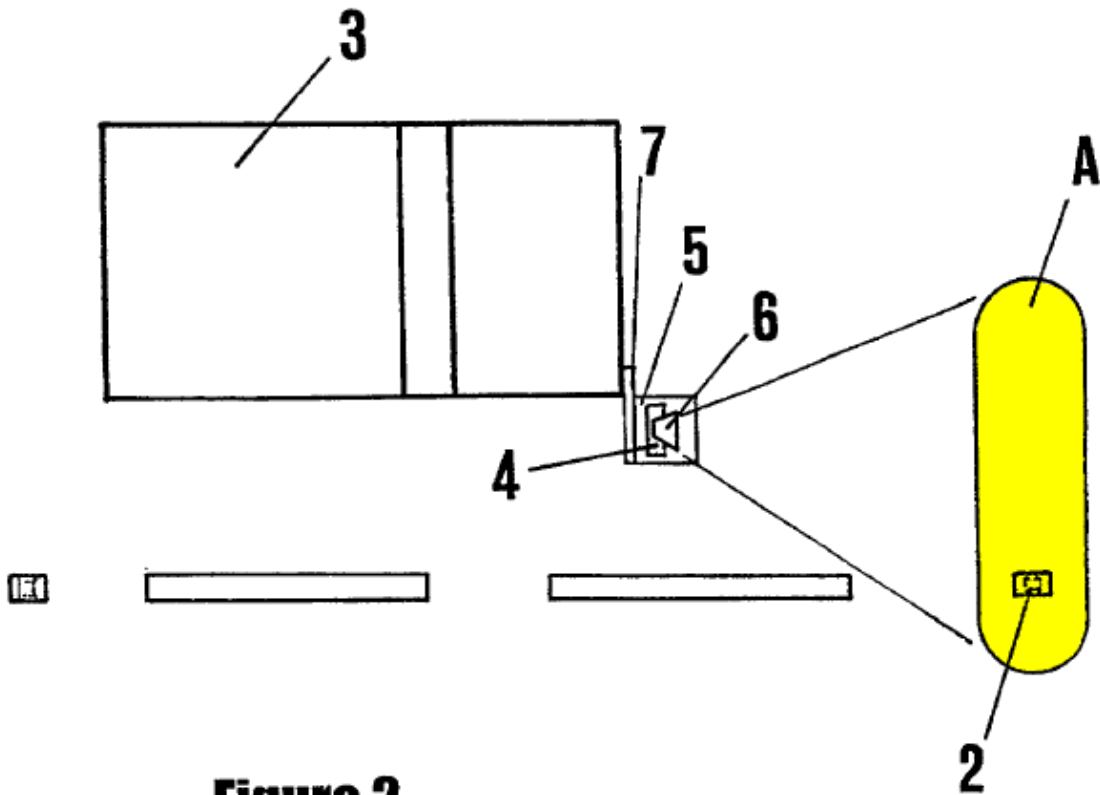


Figure 2

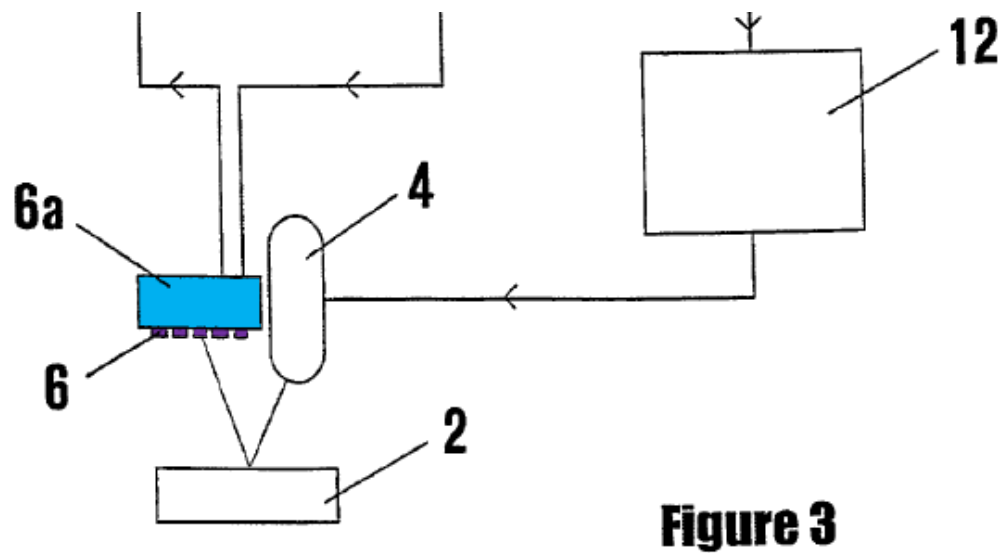
Gallagher, Fig. 2 (annotated).

67. For [9C], Gallagher's active light sensor also includes or at least suggests "a light sensor that measures a plurality of light intensity values within a field of view which includes at least a portion of the area illuminated by the light source" because it includes a "light sensor module 6a" (light sensor) with an array of "light sensors 6," one or more of which detects "reflected light" from "a reflective surface of a marker 2." Gallagher, [0038], [0040]-[0041], [0046]. The array of light sensors "cover[s] a wide field of view," with each light sensor covering "a section of the area A" that is illuminated by light source 4 (a field of

view which includes at least a portion of the area illuminated by the light source)

and “arranged to detect reflected light from a relatively small viewing angle.”

Gallagher, [0009], [0035], [0040], [0060], Fig. 2. The cropped and annotated version of Figure 3, below, depicts an array of light sensors 6 aligned in a light sensor module 6a. Gallagher, [0038], [0040], Fig. 3.



Gallagher, Fig. 3 (cropped, annotated).

68. A POSITA would have understood that Gallagher’s light sensor module 6a measures a plurality of light intensity values within the area A (its field of view) via its light sensors 6. For example, Gallagher discloses sampling “at frequent intervals” (e.g., 10 kHz) the data output by the light sensors in the light sensor module 6a. Gallagher, [0046]-[0047]. Gallagher uses inconsistent terminology when referring to the data output by the light sensors. Gallagher, [0009] (“a data signal ... representing the reflectivity of each said area of road”),

[0016] (“data on the reflectance levels”), [0047] (“road marking reflectance level data”), [0056] (“data ... on the reflected light”), [0060] (“data ... showing the reflectance levels”). But a POSITA would have understood from Gallagher and the data output by each light sensor corresponds to a measure of a light intensity value within the area A.

69. Gallagher discloses that its computer “get[s] the data ... on the reflected light detected by the light sensors 6”; “determine[es] the background reflectance level on the road and establish[es] non-marker reflectance levels”; selects, from the data “on the reflected light detected by the light sensors 6,” “which reflectance levels indicate a road marker”; and then “determin[es] the reflectance level of the road marker in a value of millicandela per Lux (CIL).” Gallagher, [0055]-[0056], [0066]-[0067]. CIL, also known as the “coefficient of luminous intensity,” was a well-known way to express “the ratio of luminous intensity of [the] reflector in the direction of the observation to the illumination at the retroreflector on a plane perpendicular to the light.” Ex. 1012, 4 (“The International Commission of Illumination (CIE) uses the term coefficient of luminous intensity that is defined as the ratio of luminous intensity of reflector in the direction of the observation to the illumination at the retroreflector on a plane perpendicular to the light.” Like Gallagher’s CIL value, the coefficient of luminous intensity “is expressed as candelas, cd ([equivalent to 1000 millicandelas]), per lux,

lx.”). A POSITA would have understood that data output by each of the light sensors 6 is indicative of the measured luminous intensity values (a plurality of light intensity values) within the area A. *See* Ex. 1013, 1:18-19 (“A light sensor generates an output signal indicating the intensity of light incident upon the light sensor.”). A POSITA would have understood that the selected luminous intensity value gives Gallagher’s computer the “millicandela” (luminous intensity) portion of the determined “reflectance level of the road marker in a value of millicandela per Lux (CIL).” Gallagher, [0067].

- c. **[9D]: “a computer processing system operably connected to the active light sensor and configured to detect objects of interest within the field of view and for each object of interest:”**

70. Gallagher discloses [9D].

71. Gallagher’s apparatus includes “a computer 8” (computer processing system) that “get[s] the data ... on the reflected light detected by the light sensors 6” (operably connected to the active light sensor). Gallagher, [0033], [0045], [0047], [0055]-[0066]. These light sensors provide computer 8 with light intensity values from the area A (field of view). *Supra* Section VIII.A.4.b ([9C]). As shown in the figure below, the computer 8 is operatively connected to the active light sensor.

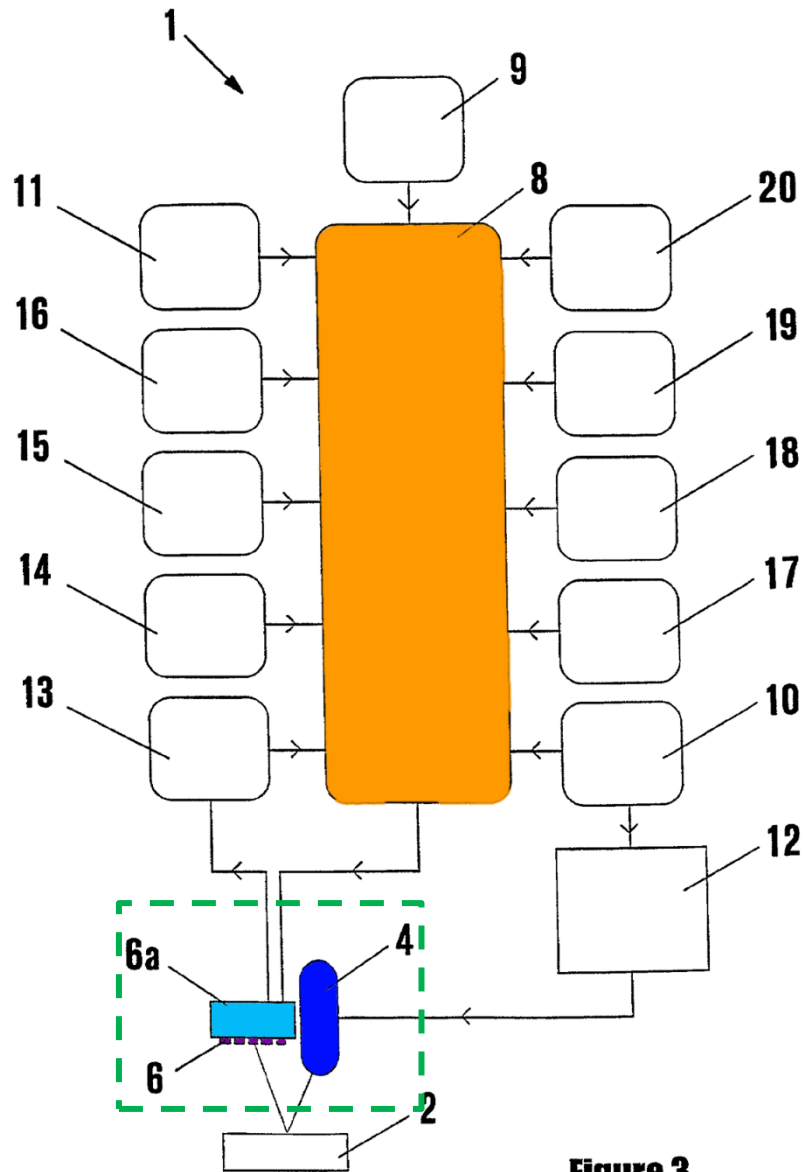


Figure 3

Computer
Active Light Sensor
Light Source
Light Sensor Array / Sensors

Gallagher, Fig. 3 (annotated).

72. Gallagher's computer 8 detects objects of interest (e.g., road markings and road markers) within the field of view because Gallagher discloses that

“background reflectance levels on non[-]road marking sections of the road are low” and the reflectance levels of the objects of interest are “relatively high,” allowing Gallagher’s computer 8 to detect objects of interest based on “which light sensor 6 is reading the highest reflectance reading.” Gallagher, [0033], [0060]. Gallagher’s computer 8 then “provide[s] the operator with that information” so that the driver can maintain the vehicle in a position that has “the most central of the light sensors 6 detecting the highest reflectance levels.” Gallagher, [0060]-[0062]. Gallagher’s computer 8 then “determine[s] the location of each road marking” (objects of interest), which “is used to tag or identify the road markers tested along a stretch of road.” Gallagher, [0063]-[0064].

d. [9E]: “determine whether the object of interest includes at least one light intensity value associated with a reflective surface of a road marker in the field of view; and”

73. Gallagher discloses or at least suggests [9E].

74. Gallagher discloses its computer 8 obtaining “the data ... on the reflected light detected by the light sensors 6,” “determining the background reflectance level on the road and establishing non-marker reflectance levels,” and “selecting, from data obtained ..., which reflectance levels indicate” a reflective surface of a road marker (e.g., painted lines and/or raised pavement marker) (determining whether the object of interest includes at least one light intensity value associated with a reflective surface of a road marker in the field of view).

Gallagher, [0033], [0055]-[0056], [0065]-[0066]. Because the reflectance level data from the light sensors indicate the light intensity values, *supra* Section VIII.A.4.b ([9C]), Gallagher uses the light intensity values from the light sensors to determine whether objects of interest (e.g., painted lines and/or raised pavement markers) include a reflective surface by distinguishing their reflectance levels from the “non-marker reflectance levels.” Gallagher, [0065]-[0066]. If the light intensity values do not indicate a reflective surface where one should be, Gallagher’s apparatus notes “the location of [the] missing road marker[.]” Gallagher, [0023].

e. [9F]: “analyze the at least one light intensity value to determine an assessment of a discrete location of the road marker within the field of view.”

75. Gallagher and Schofield render obvious [9F].

76. A POSITA would have found it obvious to implement Schofield’s determination of a light source’s location within a field of view to distinguish between different types of road markers. Schofield, 9:26-32. Schofield discloses that the sensors in its light-imaging array “divide the scene forward of the vehicle into spatially separated regions, and light sources are identified, at least in part, according to their spatial distribution across the regions.” Schofield, 2:36-41, 9:26-32.

77. A POSITA would have been motivated to implement Schofield’s determination of a light source’s location within a field of view because doing so

would have improved Gallagher's computer by allowing it to differentiate between road markers "that are spaced apart on the road." Gallagher, [0040], [0043]. For example, Gallagher discloses using its apparatus to measure the reflectivity of road markers that are "arranged side by side on either side of a cent[er]line," where "[r]eflected light from these markers can be detected simultaneously by" separate light sensors in the array. Gallagher, [0040]. Gallagher discloses that it is desirable to select a light source with a wider beam when "testing markers 2 that are spaced apart on the road." Gallagher, [0043]. In this situation, a POSITA would have seen Schofield's determination of a light source's location within the field of view as advantageous because it would have allowed Gallagher's computer to associate the measured reflectance level with the appropriate road marker. Doing so would have improved Gallagher's system because it would have allowed more specificity in indicating which road markers (e.g., left or right at a particular location) were "determined as measuring a reflectivity less than the predetermined minimum acceptable reflectance level." Gallagher, [0068].

78. Moreover, a POSITA would have been motivated to implement Schofield's determination of a light source's location within a field of view because Schofield discloses that doing so would improve the identification of objects of interest through spatial filtering and pattern recognition. Schofield, 10:51-11:12. For example, Schofield discloses that, when objects of interest

“usually occur in pairs,” this fact “could be used to assist in qualifying or disqualifying objects as” objects of interest. Schofield, 11:3-6. A POSITA would have been motivated to apply this pattern recognition to improve the identification of markers that “are arranged side by side on either side of a cent[er]line.” Gallagher, [0040].

79. A POSITA would have had a reasonable expectation of success in determining an assessment of a discrete location of the road marker within the field of view based on the at least one light intensity value because Schofield discloses that this technique can be implemented using a photosensing array of “photo diodes,” and Gallagher similarly discloses that the light sensors 6 in its light sensor array 6a are photodiodes. Schofield, 2:36-41, 8:38-45, 9:26-32, 10:51-11:12; Gallagher, [0039], [0041]. Accordingly, implementing this determination would have required a POSITA to implement only conventional techniques of image processing (identifying a location of a particular pixel within an array), which was well known by a POSITA, to predictably yield the result of the location within a field of view indicating an intensity value associated with a road marker. Given that Schofield and Gallagher disclose similar types of arrays, this combination would have merely required the use of Schofield’s known technique to improve Gallagher’s similar device in the same way.

80. To the extent Patent Owner contends or the Board finds that “a discrete location of the road marker within the field of view” refers to a location in 3-D space, this also would have been obvious because Gallagher discloses “determin[ing] the location of each road marking” using either the vehicle’s “gearbox revolution sensor 14” or a “GPS interface 15” “as measurements are being taken.” Gallagher, [0048], [0063]. This location corresponds to a discrete location that is within the 3-D space covered by the sensor array’s field of view. Gallagher, [0009], [0038], [0048], [0063]

5. Claim 10: “The automated system of claim 9, wherein the road marker is selected from a set consisting of pavement markings and road signs.”

81. Gallagher discloses the additional limitation of claim 10.¹

82. As discussed in connection with [9E], the road marker is reflective painted lines on a road and/or raised pavement markers (pavement markings). Gallagher, [0033], [0066]; *supra* Section VIII.A.4.d. Additionally, Gallagher

¹ I have been informed that this format of claiming is referred to as a Markush group and that demonstrating unpatentability of a Markush group claim only requires demonstrating that one element of the group is anticipated or obvious.

discloses adapting its reflectivity measuring apparatus to measure the reflectivity of “road signs.” Gallagher, [0033].

6. Claim 11: “The automated system of claim 9, wherein the computer processing system is configured to operate in a mode selected from post-processing or on-the-fly.”

83. Gallagher discloses the additional limitation of claim 11.

84. Gallagher discloses that measurements are “made in real time” (on-the-fly), allowing the computer to tag any “faulty or unacceptable marker 2” “as the vehicle 3 is passing” them. Gallagher, [0051], [0072].

7. Claim 12: “The automated system of claim 9, wherein the light source is selected from the set consisting of a laser scanning device, a strobe light, or a vehicle headlight lamp.”

85. Gallagher discloses the additional limitation of claim 12.

86. As discussed in connection with [9B], light source 4 is “in the form of a standard vehicle headlight” (vehicle headlight lamp). Gallagher [0035]; *supra* Section VIII.A.4.b.

8. Claim 13: “The automated system of claim 9, wherein the computer processing system is further configured to associate at least one color with the reflective characteristic of the road marker to confirm the assessment that what is positioned at the discrete location within the field of view is a road marker, wherein the at least one color is selected from a set of colors consisting of yellow, green, red and white.”

87. Gallagher and Schofield render obvious the additional limitations of claim 13.

88. Gallagher discloses one embodiment where the light sensors in the light sensor module are “photodiodes mounted precisely ... at a height and angle to properly detect reflected light.” Gallagher, [0039]. But Gallagher also discloses that “[a] variety of light sensors” are “suitable” in its apparatus. Gallagher, [0039]. In particular, when “sensing [colored] markers, light sensors with different spectral responses or similar light sensors with different filters can be used” such that “[t]he data signals detected by the sensors ... indicate the [color] of a road marking being tested.” Gallagher, [0039]. When using Gallagher’s reflectivity measuring apparatus “to test different [colored] road markings simultaneously,” a POSITA would have found it obvious to implement in Gallagher’s computer processing system Schofield’s use of color to confirm the identification of objects of interest, associating at least one color (e.g., yellow, red, and/or white) with the reflective characteristic of the road marker (e.g., its reflectance levels) to thereby confirm the assessment that what is positioned at the discrete location within the field of view is a road marker. Gallagher, [0039].

89. Schofield discloses using color to assist in identifying objects of interest because Schofield discloses identifying the “spectral signature” of a light source—its color—to “warn the driver that a light has changed from green to yellow to red,” to identify “red octagons ... as stop signs,” or to identify “yellow triangles as caution signs,” for example. Schofield, 11:60-64, 12:1-4. Schofield

also teaches that “[l]ane markers ... may be readily identified by spectral signature.” Schofield, 10:43-45.

90. A POSITA would have been motivated to implement Schofield’s use of color to confirm the identification of objects of interest because Gallagher suggests such a combination, as Gallagher discloses using its reflectivity measuring apparatus to sense “[colored] markers” and “to test different [colored] road markings simultaneously.” Gallagher, [0039]. This would have suggested to a POSITA to use Schofield’s identification of objects of interest using spectral signature to assist in assessing the type of road marker with which an identified reflective surface is associated.

91. Road markers were well known to be a variety of colors, including yellow, green, red, and white, each of which indicates different information to the driver. ASTM, 452-453 (disclosing white, yellow, red, blue, and green raised retroreflective pavement markers). For example, as was well known and set by roadway standards, white markers may be on the lane line between the two lanes of the same direction and yellow markers may be by the median edge line. Each color of road marker required a different reflectance level. ASTM, 452-453 (Table 1). A POSITA would have been motivated to implement Schofield’s use of color to confirm that the color of the detected object corresponded to a color of a road marker being tested, such as yellow, green, white, or red. This would have

beneficially allowed Gallagher's computer to associate the required reflectance level for those colors with the reflective characteristic (e.g., its reflectance level in terms of the CIL value) of the road marker and determine whether it meets the corresponding "predetermined minimum acceptable reflectance level" associated with each colored road marker. Gallagher, [0068].

92. A POSITA would have had a reasonable expectation of success because Schofield teaches different techniques for associating yellow, white, and red with other characteristics of a particular object of interest (e.g., associating pairs of white light sources with oncoming headlights, yellow triangles with caution signs, and red octagons with stop signs) that a POSITA would have reasonably expected to work with Gallagher's array of "light sensors with different spectral responses or similar light sensors with different filters." Schofield, 10:35-50, 11:1-6, 12:1-8; Gallagher, [0039]. Schofield also discloses that "reflectivity" and "spectral characteristics" may be used together to identify objects of interest. Schofield, 11:1-3. Accordingly, combining Gallagher and Schofield to associate yellow, white, or red with a reflective characteristic of the road marker to confirm the assessment that the reflective surface is a road marker would have required a POSITA to apply only conventional techniques of associating a color with reflectivity to yield the predictable result of confirming the assessment of the reflective surface.

9. Independent Claim 17

- a. [17P]: “An automated method for assessing reflective surfaces disposed along a roadway comprising:”**

93. Gallagher discloses [17P] for the reasons discussed in connection with [9P]. *Supra* Section VIII.A.4.a.

- b. [17A]: “activating a light source as the light source is traversed along a roadway to illuminate an area that includes at least one reflective surface on a road marker, the road marker having a reflective characteristic;”**

94. Gallagher discloses a light source to illuminate an area that includes the at least one reflective surface on a road marker for the reasons discussed in connection with [9B]. *Supra* Section VIII.A.4.b. Gallagher discloses that, as the vehicle—and thus the light source—traverses along a roadway, an operator in the vehicle activates the light source “by sending a signal via the computer 8 to activate the light control relay 10,” which “switches power from the power supply 12 to the light source 4.” Gallagher, [0046]. This causes light source 4 to “illuminate[] a reflective surface of a marker 2.” Gallagher, [0046]. The apparatus measures the level of reflectivity (a reflective characteristic) of the “road markers.” Gallagher, [0032]-[0033], [0066]-[0068].

- c. **[17B]: “determining a plurality of light intensity values with at least one intensity sensor directed to cover a field of view which includes at least a portion of the area illuminated by the light source; and”**

95. [17B] is substantively identical to [9C]. Thus, Gallagher discloses or suggests [17B] for the reasons discussed in connection with [9C]. *Supra* Section VIII.A.4.b. Because the light sensors measure a plurality of light intensity values, a POSITA would have understood Gallagher’s light sensor module to disclose at least one intensity sensor. *Supra* Section VIII.A.4.b.

- d. **[17C]: “using a computer processing system configured to: identify at least one light intensity value of the plurality of light intensity values associated with one of the at least one reflective surface of the road marker in the field of view; and”**

96. [17C] is substantively identical to [9D]-[9E]. Thus, Gallagher discloses or Gallagher and Schofield render obvious [17C] for the reasons discussed in connection with [9D]-[9E]. *Supra* Sections VIII.A.4.c-VIII.A.4.d.

- e. **[17D]: “analyze the at least one light intensity value of the plurality of light intensity values to determine an assessment of a discrete location of the road marker within the field of view.”**

97. [17D] is substantively identical to [9F]. Thus, Gallagher and Schofield render obvious [17D] for the reasons discussed in connection with [9F]. *Supra* Section VIII.A.4.e.

- 10. Claim 18: “The automated method of claim 17, wherein the computer processing system is further configured to associate at least one color with the reflective characteristic of the road marker to confirm the road marker at the discrete location within the field of view, wherein the at least one color is selected from a set of colors consisting of yellow, green, red and white.”**

98. The additional limitations of claim 18 are substantively identical to those in claim 13. Thus, Gallagher and Schofield render obvious the additional limitations of claim 18 for the reasons discussed for claim 13. *Supra* Section VIII.A.8.

11. Independent Claim 1

- a. [1P]: “An automated system that detects and determines reflective surfaces of interest in a scene of non-retroreflective surfaces along a roadway that is being traversed by a vehicle, the automated system comprising:”**

99. Gallagher discloses [1P].

100. Gallagher discloses an automated system that detects and determines reflective surfaces of interest in a scene of non-retroreflective surfaces along a roadway that is being traversed by a vehicle using its reflectivity measuring apparatus. Gallagher, [0033]-[0035]. Gallagher’s reflectivity measuring apparatus detects and determines reflective surfaces of interest along a roadway that is being traversed by a vehicle because it is mounted on a moving vehicle and includes a light source that “illuminates a reflective surface of a” road marker disposed along a roadway, light sensors 6 that detect “the reflected light,” and a computer 8 that

obtains data “on the reflected light detected by” light sensors 6; selects “which reflectance levels indicate a road marker”; “determin[es] the reflectance level of the road marker in a value of millicandela per Lux (CIL)”; and stores “the location and CIL levels of each road marker” tested. Gallagher, [0032], [0046], [0055]-[0069]. This system tags any road markers determined to have “a reflectivity less than the predetermined minimum acceptable reflectance level.” Gallagher, [0068]. This detecting and determining occurs in a scene of non-reflective surfaces because Gallagher discloses that “background reflectance levels on non[-]road marking sections of the road are low.” Gallagher, [0060]. This system is automated because, once a measurement process is initiated, measurements automatically are “made in real time” by the computer. Gallagher, [0046], [0071].

b. [1A]: “an image capture system that captures images within a field of view along the roadway;”

101. Gallagher and Schofield render obvious [1A].

102. Schofield discloses [1A] because it discloses “an imaging sensor module 14.” Schofield, 3:36-44. Schofield discloses mounting “imaging sensor module 14” “to, or near, the vehicle’s windshield” to “sense[] light from a scene forward of [a] vehicle.” Schofield, 3:64-66, 3:36-44. The imaging sensor module captures images “forward of the vehicle” (images within a field of view along the roadway) using “an optical device 36, such as a lens,” and “a charge couple device (CCD) array of the type commonly utilized in video camcorders and the like.”

Schofield, 4:16-21, 8:38-40, 11:44-47, 12:8-11. One such image within a field of view along a roadway is depicted in Figure 11a, below. Schofield, 3:29-30, Fig. 11a. Schofield's imaging sensor module captures "frames" (images), which may be used to enhance its object recognition "by comparing identified objects over successive frames." Schofield, 11:8-12.

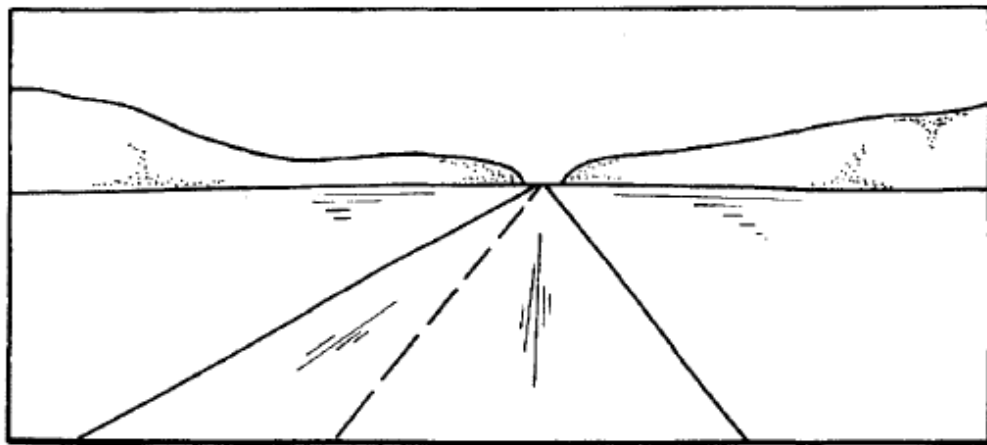


FIG. 11a

Schofield, Fig. 11a.

103. A POSITA would have found it obvious to incorporate Schofield's imaging sensor module 14 into Gallagher's reflectivity measuring apparatus. A POSITA would have been motivated to do so to improve the apparatus' ability to identify objects of interest along the roadway. Schofield, 9:24-26, 10:18-11:12, 11:58-12:46. For example, Schofield discloses applying "[p]attern recognition" to "assist in the detection of ... objects of interest," where this pattern recognition "identifies objects of interest based upon their shape, reflectivity, luminance, and

spectral characteristics” (e.g., color). Schofield, 10:66-11:12. Accordingly, a POSITA would have seen Gallagher’s reflectivity measuring apparatus, which measures reflectivity, and Schofield’s imaging sensor module 14, which enables the identification of objects through things like their shape and spectral characteristics, as complementary systems that, through pattern recognition, would advantageously work together to improve the identification of objects of interest. Gallagher, [0055]-[0067]; Schofield, 9:24-26, 10:18-11:12, 11:58-12:46. A POSITA would have been motivated to incorporate the data from Schofield’s imaging sensor module into the processing performed by Gallagher’s “powerful” computer to improve the identification of objects of interest, like road markers. Gallagher, [0050]-[0072].

104. That a POSITA would have seen these teachings as complementary is further supported by the fact that Gallagher’s reflectivity measuring apparatus and Schofield’s imaging sensor module both identify road signs and road markers using different characteristics, suggesting to a POSITA that performing Schofield’s pattern recognition using Gallagher’s computer, based on data from Gallagher’s light sensor module and Schofield’s imaging sensor module, would further improve the identification of road signs and road markers. Gallagher, [0031]-[0033]; Schofield, 10:66-11:12, 12:1-4, 12:40-42. Accordingly, a POSITA would have seen incorporating Schofield’s imaging sensor module into Gallagher’s

reflectivity measuring apparatus as a combination of well-known prior-art elements according to known methods to predictably yield a system that better detects objects of interest. Indeed, a POSITA would have known that incorporating a separate video camera in a mobile system for measuring retroreflectivity of road markings, like Gallagher's, had several advantages, including simultaneously recording "the driver's view and numerical performance data." Ex. 1020, 4:16-43, 7:46-8:3, Fig. 10.

105. Moreover, Gallagher suggests that such a combination would have been desirable. Gallagher discloses "converting data to a format for presentation in either a graphical or numerical form, and be viewed in real time on a monitor," which is advantageous because it allows "an assessment ... as to whether the apparatus is measuring accurately or not." Gallagher, [0052], [0071]-[0072]. Likewise, a POSITA would have been motivated to display a video feed from Schofield's imaging sensor module to allow operators to assess whether the reflectivity measuring apparatus is working properly, for example, by allowing the operator to easily determine whether it is identifying all of the road markers and/or using the right "predetermined standard reflectance level" for the road marker when assessing its reflectivity. Gallagher, [0068]-[0072].

106. A POSITA would have had a reasonable expectation of success in combining Gallagher and Schofield. A POSITA would have seen Gallagher's

reflectivity measuring apparatus and Schofield's system as complementary because both are used to identify road markings like traffic signs and lane markers in real time from a moving vehicle. Gallagher, [0031]-[0033], [0072]; Schofield, 12:1-4, 12:40-42. Accordingly, a POSITA would have needed to apply only conventional techniques of incorporating Schofield's imaging sensor module into Gallagher's reflectivity measuring apparatus, which were within the skill of a POSITA because combining data from various systems was conventional, to predictably carry out Gallagher's testing of reflective road markings and road markers.

107. Moreover, Gallagher's reflectivity measuring apparatus uses "a standard computer" with processing speed "powerful enough to be capable of processing the incoming data." Gallagher, [0035], [0038]-[0039], [0050]. Given Gallagher's description of the computer as "powerful," a POSITA would have reasonably expected success with Gallagher's computer handling the processing of the incoming data from Schofield's imaging sensor module. Gallagher, [0050]. Indeed, Schofield describes performing the processing on data from its imaging sensor module using "a suitably programmed micro-processor with input and output buffers," further leading a POSITA to expect success from processing the necessary data using the processor in Gallagher's computer. Schofield, 5:46-49. Implementing Schofield's imaging sensor module into Gallagher's reflectivity measuring apparatus would have been a straightforward application of known,

conventional components and software operations (sending data from Schofield's imaging sensor module to Gallagher's "powerful" computer) used according to their known functions to yield predictable results (processing data from both Gallagher's light sensor module and Schofield's imaging sensor module to improve the identification of objects of interest).

- c. **[1B]: "an active light sensor including;" [1C]: "a light source that illuminates an area along the roadway; and" [1D]: "a light sensor that measures light intensity values within at least a portion of the area illuminated by the light source; and"**

108. Gallagher renders obvious [1B] and its sub-elements [1C] and [1D] for the reasons discussed in connection with [9A] and its sub-elements [9B] and [9C]. *Supra* Section VIII.A.4.b.

- d. **[1E]: "a computer processing system operably connected to the image capture system, and the active light sensor and configured to detect objects of interest within the field of view and for each object of interest:"**

109. Gallagher and Schofield render obvious [1E].

110. Gallagher discloses a computer processing system operably connected to the active light sensor and configured to detect objects of interest within the field of view for the reasons discussed for [9D]. *Supra* Section VIII.A.4.c. For the reasons discussed in connection with [1A], a POSITA would have found it obvious to operably connect Gallagher's computer processing system—a computer whose

“processing speed and technical specifications” is “powerful enough to be capable of processing the incoming data”—to Schofield’s imaging sensor module to further improve the detection of objects of interest (e.g., reflective painted lines and raised pavement markers) within the field of view. Gallagher, [0033], [0050]; *supra* Section VIII.A.11.b.

111. For example, Schofield discloses detecting objects of interest like “[l]ane markers, signs, and other sources of reflected light” within its field of view using their “spectral signature” and ignoring “non-relevant light sources” based on analyzing their “spectral signature[s].” Schofield, 10:20-29, 10:43-45. As discussed in connection with [1A], configuring Gallagher’s computer 8 to perform this object detection would have been advantageous because, when combined with Gallagher’s detection through reflectivity, it would “assist in the detection of ... objects of interest.” Schofield, 10:66-11:12; Gallagher, [0055]-[0066]; *supra* Section VIII.A.11.b.

- e. **[1F]: “determine whether the object of interest includes a reflective surface based on the light intensity values;”**

112. Gallagher discloses [1F].

113. Gallagher’s apparatus “can test the reflectivity” of various lane markers, including “painted lines whether continuous or broken” and “raised pavement markers 2” “fastened or secured along lanes.” Gallagher, [0033]-[0034].

Gallagher discloses its computer 8 obtaining “the data ... on the reflected light detected by the light sensors 6,” “determining the background reflectance level on the road and establishing non-marker reflectance levels,” and “selecting, from data obtained ..., which reflectance levels indicate” a reflective surface of a marker. Gallagher, [0055]-[0056], [0065]-[0066]. “For simplicity,” Gallagher only describes the details of this process for raised pavement markers, but Gallagher also discloses that this same process is used “to measure other types of reflective markings on ... the road,” like the reflective surfaces of painted lines. Gallagher, [0033]. Accordingly, Gallagher uses the light intensity values from the light sensors 6 to determine whether lane markers, including the painted lines of the lane and raised pavement markers fastened along the lane, include a reflective surface by distinguishing their reflectance levels from the “non-marker reflectance levels.” Gallagher, [0065]-[0066]. If the light intensity values do not indicate a reflective surface where one should be, Gallagher’s apparatus notes “the location of [the] missing road marker[.]” Gallagher, [0023].

f. [1G]: “determine whether the reflective surface is a road marker based on an assessment of the reflective surface; and”

114. Gallagher discloses [1G].

115. Gallagher discloses that, “[i]n the case of road markers[,], the peak responses sensed are determined as the highly reflective surfaces of a road

marker.” Gallagher, [0066]. Accordingly, Gallagher discloses determining that a reflective surface is a raised pavement marker (road marker) based on assessing whether the reflectivity of the reflective surface indicates a “peak response[.]” Gallagher, [0066].

g. [1H]: “determine a location of the road marker.”

116. Gallagher discloses [1H].

117. Gallagher discloses using a GPS interface or “a vehicle gearbox revolution sensor” to “determin[e] the location of a road marking.” Gallagher, [0008], [0020], [0048]. Gallagher’s apparatus then “stores data measured on the ... location of each ... road marking tested.” Gallagher, [0012], [0022].

12. Claim 2: “The automated system of claim 1, wherein the road marker is an object of interest selected from the set consisting of a road sign or a pavement marker.”

118. Schofield and Gallagher render obvious the additional limitations of claim 2.

119. As discussed in connection with [1G] and [1H], the road marker is a raised pavement marker (pavement marker). Gallagher, [0033], [0063]-[0064], [0066]; *supra* Sections VIII.A.11.f, VIII.A.11.g.

13. Claim 3: “The automated system of claim 1, wherein the computer processing system is configured to operate in a mode selected from post-processing or on-the-fly.”

120. Gallagher discloses that the computer processing system is configured to operate in an on-the-fly mode for the reasons described in connection with claim 11. *Supra* Section VIII.A.6.

14. Claim 4: “The automated system of claim 1, wherein the light source is selected from the set consisting of a laser scanning device, a strobe light, or a vehicle headlight lamp.”

121. Gallagher discloses that the light source is a vehicle headlight lamp for the reasons described in connection with claim 12. *Supra* Section VIII.A.7.

15. Claim 8: “The automated system of claim 1, wherein the computer processing system is further configured to associate at least one color with the reflective characteristic of the road marker to confirm the assessment that the reflective surface is a road marker, wherein the at least one color is selected from a set of colors consisting of yellow, green, red and white.”

122. Gallagher and Schofield render obvious the additional limitations of claim 8.

123. When using Gallagher’s reflectivity measuring apparatus “to test different [colored] road markings simultaneously,” a POSITA would have found it obvious to implement Schofield’s use of color in Gallagher’s computer processing system to confirm the identification of objects of interest, associating at least one color (e.g., yellow, red, and/or white) with the reflective characteristic of the road

marker to confirm the assessment that an identified reflective surface is a road marker. Gallagher, [0039].

124. Schofield discloses using color to assist in identifying objects of interest because it discloses identifying the “spectral signature” of a light source—its color—to “warn the driver that a light has changed from green to yellow to red,” to identify “red octagons ... as stop signs,” or to identify “yellow triangles as caution signs,” for example. Schofield, 11:60-64, 12:1-4. Schofield also teaches that “[l]ane markers ... may be readily identified by spectral signature.” Schofield, 10:43-45.

125. As discussed in connection with claim 13, a POSITA would have been motivated to associate at least yellow, white, or red with the reflective characteristic of the road marker to confirm the assessment that a reflective surface is a road marker because doing so would have allowed the system to better determine the type of road marker and determine whether it meets the corresponding “predetermined minimum acceptable reflectance level” associated with each colored road marker. Gallagher, [0068]; *supra* Section VIII.A.8.

126. A POSITA would have had a reasonable expectation of success because Schofield teaches different techniques for associating yellow, white, and red with other characteristics of a particular object of interest (e.g., associating pairs of white light sources with oncoming headlights, yellow triangles with

caution signs, and red octagons with stop signs). Schofield, 10:35-50, 11:1-6, 12:1-8. Schofield also discloses that “reflectivity” and “spectral characteristics” may be used together to identify objects of interest. Schofield, 11:1-3. Accordingly, combining Gallagher and Schofield to associate yellow, white, or red, as determined from analysis of the data from Schofield’s imaging sensor module, with a reflective characteristic of the road marker, as determined from analysis of the data from Gallagher’s light sensor array, to confirm the assessment that the reflective surface is a road marker would have required a POSITA to apply only conventional techniques of associating a color with reflectivity to yield the predictable result of confirming the assessment of the reflective surface.

**B. Ground 2: Gallagher, Schofield, and Frank Render Obvious
Claims 15-16, 19, and 21-22**

1. Frank (Ex. 1007)

127. Frank discloses “a laser radar system capable of accurately measuring the distance and angle between a vehicle and a retroreflector located ahead at or near the road surface at some distance ahead of the vehicle.” Frank, 3:8-12. Frank’s apparatus “may be mounted in any location on the vehicle where the apparatus can be provided with a view of at least one retroreflector ahead of the vehicle.” Frank, 4:45-51. Frank’s apparatus “calculates the distance D between vehicle 101 to the retroreflector and the angle θ formed between axis 104 and an imaginary line drawn between vehicle 101 and a retroreflector, for example[,]”

retroreflector 114,” as depicted below. Frank, 4:37-42. “[T]he retroreflectors may be standard roadway reflectors embedded in the roadway” or “may be mounted at another location near the roadway,” such as “on posts.” Frank, 6:53-55, 7:13-18.

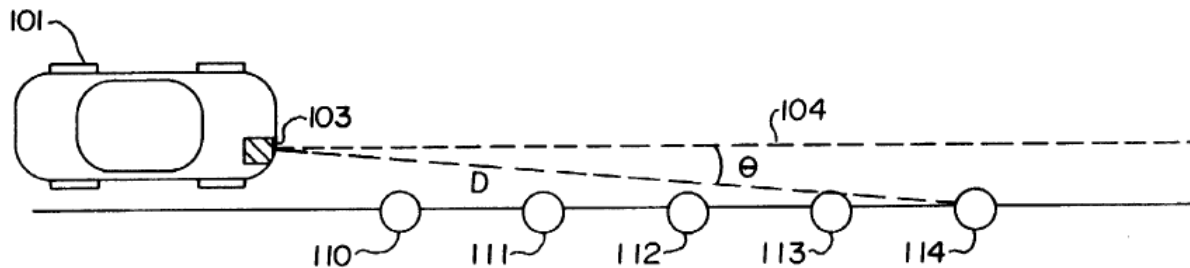


FIG. 2

Frank, Fig. 2.

128. Frank’s apparatus includes a laser 332 producing a light beam 336 that “passes through cylindrical lens 331 to produce fan beam 339,” which is “very thin but broadens at a predetermined angle forming a triangular or fan shaped beam.” Frank, 4:52-5:7. “Fan beam 339 is reflected from mirror surface 330 and is directed towards roadway 102” Frank, 5:7-9. The angle of mirror surface 330 oscillates through a range, causing “fan beam 339 to scan a particular area.” Frank, 5:12-21. Alternatively, Frank’s apparatus may instead output a pulse-modulated “floodlight beam 946” covering all of a predetermined area that is similar in size to that covered by fan beam 339. Frank, 10:54-62. Figures 1A and 2A, below, depict the scanned area 447, with a beam angle ω and scanning range α producing “a

beam that would scan the area from distance 121 in front of vehicle 101

(approximately 25 feet at the preferred two foot mounting height)” to an effective distance 122, approximately 130 feet, “due to the attenuation effects of the atmosphere” on the beam. Frank, 6:12-49.

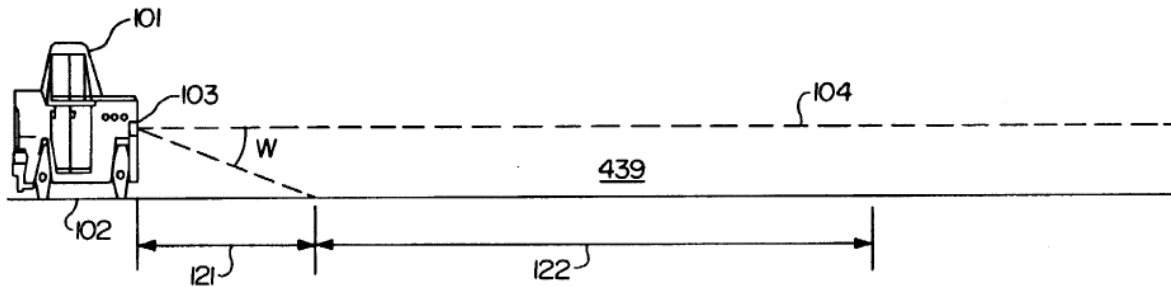


FIG. 1A

Frank, Fig. 1A.

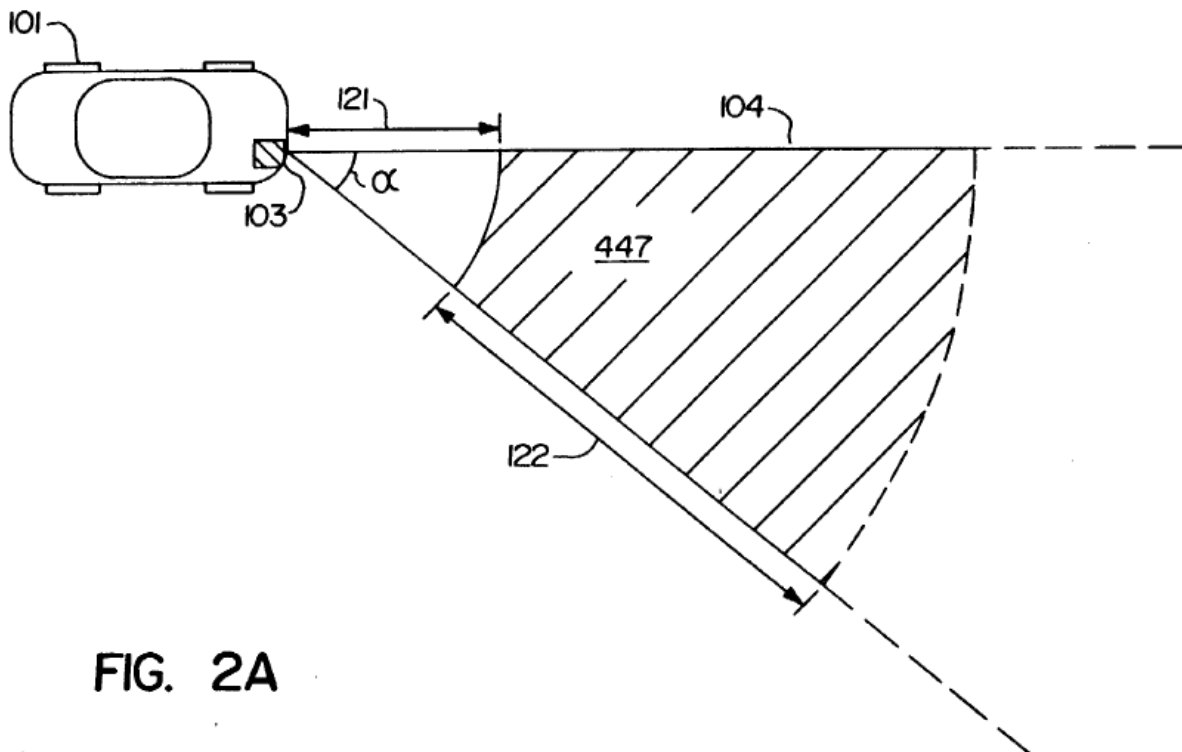


FIG. 2A

Frank, Fig. 2A.

129. Frank's apparatus includes a "receiving apparatus 465," including an optical receiver that "receives the reflected light beams from" all retroreflectors that "fall within a predetermined beam path" and "outputs a corresponding electrical signal to receiver electronics 443," which "determines distance D and angle θ for each retroreflector scanned." Frank, 6:4-7, 7:27-50. "If only reflectors located a certain distance or range from vehicle 103 are of interest, the controller may then subsequently sort such data and use only data of interest to the particular control algorithm." Frank, 6:7-11.

2. Frank Is Analogous Art

130. Frank is analogous art to the '328 patent because it is in the same field of endeavor, namely, automated object recognition. Ex. 1001, 1:31-32; Frank, 6:4-11. Frank is also analogous art to the '328 patent because it is reasonably pertinent to problems addressed by the '328 patent, including automatically identifying road markers without relying solely on "template matching of shape and color." Ex. 1001, 1:39-47; Frank, 7:27-50 (identifying retroreflectors using "reflected light ... transmitted back to [a] laser radar apparatus").

3. **Claim 15: “The automated system of claim 9, wherein the computer processing system is further configured to determine exemplary angular displacements of incident light for each light intensity measurement from a reference position relative to the field of view as part of the assessment of the discrete location of the road marker within the field of view.”**

131. Gallagher and Frank render obvious the additional limitations of claim 15.

132. Gallagher discloses taking multiple light intensity measurements, explaining that its reflectivity measuring apparatus “is capable of sampling road marking reflectance level data at frequent intervals” and smooths the sampled data “by calculating the average reflectance level from a set of sampled data from each sensor.” Gallagher, [0047], [0057]. Gallagher also discloses an observation angle (exemplary angular displacement of incident light) that “is the angle between the incident and reflected light.” Gallagher, [0041]. Gallagher discloses mounting its light sensor module 6a in a way “to reduce the observation angle to almost zero” and “to account for road[] authorities standards.” Gallagher, [0041]. Gallagher discloses that the observation angle “is generally about 0.2 degrees.” Gallagher, [0041].

133. A POSITA would have understood that the observation angle depends on the distance to the road marker. Ex. 1015, 67 (disclosing that the observation angle changes as the vehicle gets closer to the reflective surface). It was well

known that the observation angle changes as the position of the vehicle relative to the road marker (a reference position relative to the field of view) changes.

Ex. 1015, 67; Ex. 1014, 21. A POSITA would have found it obvious to incorporate Frank's pulse-modulated light source as Gallagher's light source to enable Gallagher's computer 8 to determine the "distance D between vehicle 101 to the retroreflector" for each reference position relative to the field of view to accurately determine an observation angle for each light intensity measurement. Frank, 4:37-42.

134. Frank, similar to Gallagher, discloses an apparatus that "may be mounted in any location on the vehicle where the apparatus can be provided with a view of at least one retroreflector ahead of the vehicle" and identifies the retroreflectors along a roadway. Frank, 4:10-51, 6:4-11. In one embodiment, Frank discloses a light source in the form of a laser diode 932 that "outputs floodlight beam 946 covering all of predetermined area 947," similar to Gallagher's light source 4. Frank, 10:54-58. An optical receiver then "receives light pulses reflected back from retroreflectors" and, based on "[t]he time delay between the transmitted and received pulses," the apparatus calculates "the distance D between vehicle 101 and each retroreflector." Frank, 10:61-67. Frank's optical receiver is a "photodiode array" or any "other type of photosensitive array." Frank, 10:67-11:4, 13:64-14:15.

135. A POSITA would have been motivated to implement Frank's laser diode that outputs a pulse-modulated floodlight beam as Gallagher's light source and to implement Frank's determination of the distance to each identified retroreflector to improve Gallagher's determination of the observation angle. Gallagher assumes that the observation angle "is generally about 0.2 degrees." Gallagher, [0041]. But it was well known that the observation angle changes as the distance between the vehicle and the reflective surface changes. Ex. 1015, 69; Ex. 1014, 21. For example, the observation angle changes "rapidly" once the vehicle gets close to the retroreflective surface. Ex. 1015, 67. Accordingly, for a "fixed source-detector separation" in a moving system like Gallagher's, it was well known to implement techniques to determine "the actual distance to the target" (e.g., using "a laser rangefinder") and take measurements within "a 'distance window'" "to maintain sufficient accuracy." Ex. 1014, 15, 21, 24. A POSITA would have understood that, based on a known, fixed geometry between the light source and light sensor, the distance to the measured reflective surface would have allowed the observation angle to be estimated through simple, well-known trigonometry.

136. While the change in observation angle is less significant at greater distances, Gallagher discloses that its "beam projects a short distance to account for various road conditions and placement of markers," motivating a POSITA to

determine the observation angle for each of its light intensity measurements and select those measurements whose observation angle aligns with “road[] authorities standards.” Gallagher, [0037], [0041]. For example, certain road authorities standards required measurement of retroreflective raised pavement markers from an observation angle of 0.2°. ASTM, 453 (Table 1). Doing so would have been desirable because reflectivity was known to vary with observation angle, so determining the observation angle of each of Gallagher’s light intensity measurements would have improved its ability to determine whether a surface’s reflectivity measures “less than the predetermined minimum acceptable reflectance level.” Gallagher, [0068].

137. A POSITA would have reasonably expected success in such a combination because Gallagher discloses that “a wide variety of light sources can be suitable” for its testing, leading a POSITA to reasonably expect that implementing Frank’s light source as the light source in Gallagher would predictably yield the result of a reflectivity measuring apparatus that also determines the distance to each object of interest. Gallagher, [0037]. Additionally, Frank discloses that its determination can be carried out using a “photodiode array,” like the one disclosed in Gallagher, or any “other type of photosensitive array,” like Schofield’s array. Frank, 10:67-11:4, 13:64-14:15. Accordingly, a POSITA would have only needed to apply conventional data-processing

techniques and simple, well-known trigonometry to determine distance and the corresponding observation angle based on the light intensity values for each light intensity measurement using “[t]he time delay between the transmitted and received pulses,” which was well known at the time. Frank, 10:64-67, Ex. 1014, 24.

4. **Claim 16: “The automated system of claim 15, wherein each of the exemplary angular displacements of incident light comprises an observation angle corresponding to one of a plurality of distances of the light source from the road marker.”**

138. Gallagher and Frank render obvious the additional limitations of claim 16 for the reasons stated in connection with claim 15. *Supra* Section VIII.B.3.

5. **Claim 19: “The automated method of claim 17, further wherein the computer processing system is further configured to determine a lateral distance between the light source and the illuminated portion of the reflective road marker.”**

139. Gallagher and Frank render obvious the additional limitations of claim 19.

140. As discussed in connection with claim 15, a POSITA would have found it obvious to incorporate Frank’s pulse-modulated light source as Gallagher’s light source to enable Gallagher’s computer 8 to determine the “distance D between vehicle 101 to the retroreflector” for each reference position

relative to the field of view to accurately determine an observation angle for each light intensity measurement. *Supra* Section VIII.B.3; Frank, 4:37-42.

141. Frank additionally discloses determining the angle between the light source and the retroreflector “using a photodiode array” or another “type of photosensitive array.” Frank, 10:67-11:4, 13:64-14:15. Frank discloses that “[t]he position of the received light pulse” on the array is “indicative of the angle θ at which the retroreflector lies in relation to vehicle axis 104,” labeled in Figure 2, below. Frank, 11:2-4, 12:33-39, 13:16-21. From the distance measurement and the angle θ , a POSITA would have understood that determining the lateral distance between the light source and the illuminated portion of the reflective road marker would have been a simple matter of trigonometry: (lateral distance = $D \cdot \sin(\theta)$).

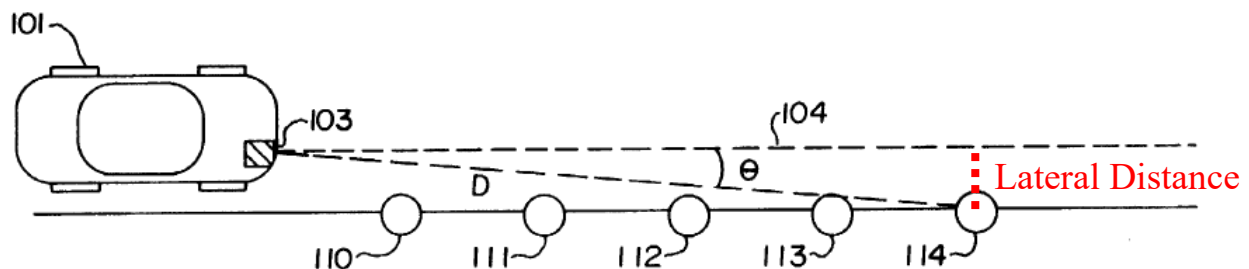


FIG. 2

Frank, Fig. 2 (annotated).

142. A POSITA would have found it obvious to incorporate Frank’s determination of the distance D and angle θ to allow Gallagher’s computer to

easily calculate the lateral distance between the light source and the illuminated portion of the reflective road marker. A POSITA would have been motivated to do so to provide the driver with an indication of the lateral distance between the vehicle and the road markers, and accordingly assist in keeping the road markers within the measuring area of the apparatus. Gallagher suggests to a POSITA that such a combination would have been desirable. Gallagher, [0060]-[0062]. For example, Gallagher discloses “determining the vehicle position on the road and providing an audio and/or visual indicator means for the operator of the vehicle 3,” which “enables the operator to maintain the vehicle 3 in a proper position on the road to allow the apparatus 1 to obtain reflectivity measurements.” Gallagher, [0060]. A POSITA would have understood that the lateral distance between the apparatus’ light source and the road markers would have been one simple way to provide the vehicle driver with the vehicle’s “position on the road.” Gallagher, [0060]. Given the finite number of ways to characterize a vehicle’s position on the road relative to the road markers, the lateral distance would have been one identified, predictable solution, akin to Gallagher’s example of informing the operator “which light sensor 6 is reading the highest reflectance reading.” Gallagher, [0060].

143. A POSITA would have had a reasonable expectation of success for the reasons stated in connection with claim 15. *Supra* Section VIII.B.3.

Additionally, a POSITA would have reasonably expected success because it would have required applying only conventional and well-known data-processing techniques (identifying an angle from a photosensor array and applying basic trigonometry) to yield the predictable result of lateral-distance calculations that would assist the vehicle driver in maintaining the vehicle in the proper position on the road relative to the road markers.

6. **Claim 21: “The automated method of claim 17, wherein the computer processing system is further configured to determine exemplary angular displacements of incident light for each light intensity measurement from a reference position relative to the field of view.”**

144. Gallagher and Frank render obvious the additional limitations of claim 21 for the reasons stated in connection with claim 15. *Supra* Section VIII.B.3.

7. **Claim 22: “The automated method of claim 21, wherein each of the exemplary angular displacements of incident light comprises an observation angle corresponding to one of a plurality of distances of the light source from the road marker.”**

145. Gallagher and Frank render obvious the additional limitations of claim 22 for the reasons stated in connection with claim 15. *Supra* Section VIII.B.3.

C. Ground 3: Gallagher, Schofield, Frank, and ASTM Render Obvious Claims 14 and 20

1. ASTM

146. ASTM is a standard specification for “Plowable, Raised Retroreflective Pavement Marker” that states it was published in 1996 “under the

jurisdiction of ASTM Committee D-4 on Road and Paving Materials.” ASTM, 451.

147. ASTM “covers a type of plowable, retroreflective, raised pavement marker for lane marking and delineation” and specifies minimum values for their “coefficient of (retroreflected) luminous intensity.” ASTM, 451-453.

Retroreflective markers are classified based on their type (e.g., one-way or two-way retroreflective markers) and color (e.g., one color or two colors). ASTM, 452.

The colors of markers include white, yellow, red, blue, and green. ASTM, 452-453. ASTM specifies a different minimum coefficient of luminous intensity for each color based on a particular entrance angle and observation angle. ASTM Those values are shown in Table 1 of ASTM, reproduced below. ASTM, 453 (Table 1).

TABLE 1 Coefficient of Luminous Intensity R_l						
NOTE—Entrance angle component β_1 and rotation angle ϵ are 0° .						
Entrance Angle β_2	Observation Angle α	Minimum Value R_l , mcd/lx				
		White	Yellow	Red	Green	Blue
0°	0.2°	279	167	70	93	26
$+20^\circ/-20^\circ$	0.2°	112	67	28	37	10
Entrance Angle β_2	Observation Angle α	Minimum Value R_l , cd/lc				
		White	Yellow	Red	Green	Blue
0°	0.2°	3.0	1.8	0.75	1.0	0.28
$+20^\circ/-20^\circ$	0.2°	1.2	0.72	0.3	0.4	0.11

ASTM, 453 (Table 1).

148. In the above table, entrance angle refers to “the angle in the horizontal plane between the direction of incident light and the normal to the leading edge of the marker,” and observation angle refers to “the angle at the reflector between the illumination axis and the observation axis.” ASTM, 452. As in Gallagher, values are specified in units of millicandela per lux (mcd/lux) in the top two rows. ASTM, 453 (Table 1); *see* Gallagher, [0067], [0079]. The bottom two rows express the same values in different units, candelas per foot-candle.

2. ASTM Is Analogous Art

149. ASTM is analogous art to the '328 patent because it is reasonably pertinent to problems addressed by the '328 patent, including automatically identifying road markers without relying solely on “template matching of shape and color.” Ex. 1001, 1:39-47; ASTM, 451-454. For example, ASTM discloses relationships between an entrance angle, an observation angle, and a minimum coefficient of luminous intensity value for various colors of raised pavement markers, allowing an automatic system (like Gallagher's) to determine the predetermined minimum reflectivity for a given entrance angle and observation angle. ASTM, 451-454.

3. Claim 14: “The automated system of claim 9, wherein the computer processing system is further configured to determine an entrance angle and an observation angle of the road marker as part of the assessment of the discrete location of the road marker within the field of view.”

150. Gallagher, Frank, and ASTM render obvious the additional limitations of claim 14.

151. As discussed in connection with Ground 2, claim 15, Gallagher and Frank render obvious the computer processing system being configured to determine an observation angle of the road marker as part of the assessment of the discrete location of the road marker within the field of view. *Supra* Section VIII.B.3. A POSITA would have found it obvious to likewise configure the computer processing system to determine an entrance angle as part of this assessment to ensure that it has selected the correct “predetermined minimum acceptable reflectance level” for a given road marker to compare to the determined reflectance level. Gallagher, [0067]-[0068].

152. Gallagher discloses that, to determine whether a road marker meets a “predetermined minimum acceptable reflectance level,” it determines “the reflectance level of the road marker in a value of millicandela per Lux (CIL).” Gallagher, [0067]-[0068]. ASTM teaches that the minimum reflectance level for a road marker varied depending on both the observation angle *and* entrance angle. ASTM, 452-453. For example, ASTM discloses that the minimum coefficient of

luminous intensity, another term for the CIL value, for a red road marker is 70 for an observation angle of 0.2 degrees and entrance angle of 0 degrees, but the coefficient of luminous intensity value drops to 28 when the entrance angle changes to 20 degrees. ASTM, 453 (Table 1); *see* V. J. Pezoldt et al., Raised Pavement Marker Reflectivity, Report No. TX-90/1151-1F (Nov. 1990) (Ex. 1016), 5 (defining “the coefficient of luminous intensity” as “CIL”).

153. A POSITA would have, therefore, been motivated to implement Frank’s laser diode that outputs a pulse-modulated floodlight beam as Gallagher’s light source and to implement Frank’s determination of the distance to each identified retroreflector and angle of the light source relative to the vehicle’s heading to improve Gallagher’s determination of whether a road marker’s reflectivity is “less than the predetermined minimum acceptable reflectance level” by factoring in both the observation angle and entrance angle for each of its light intensity measurements. Gallagher, [0067]-[0068]. Given the variance between minimum reflectivity values between different entrance angles and observation angles, a POSITA would have seen this combination as advantageous to improve Gallagher’s accuracy in assessing whether a road marker is satisfactory.

154. A POSITA would have understood that Frank’s determination of its angle α , depicted in Figure 2A below, is one common way to estimate the entrance angle. Frank, 10:67-11:4, Fig. 2A.

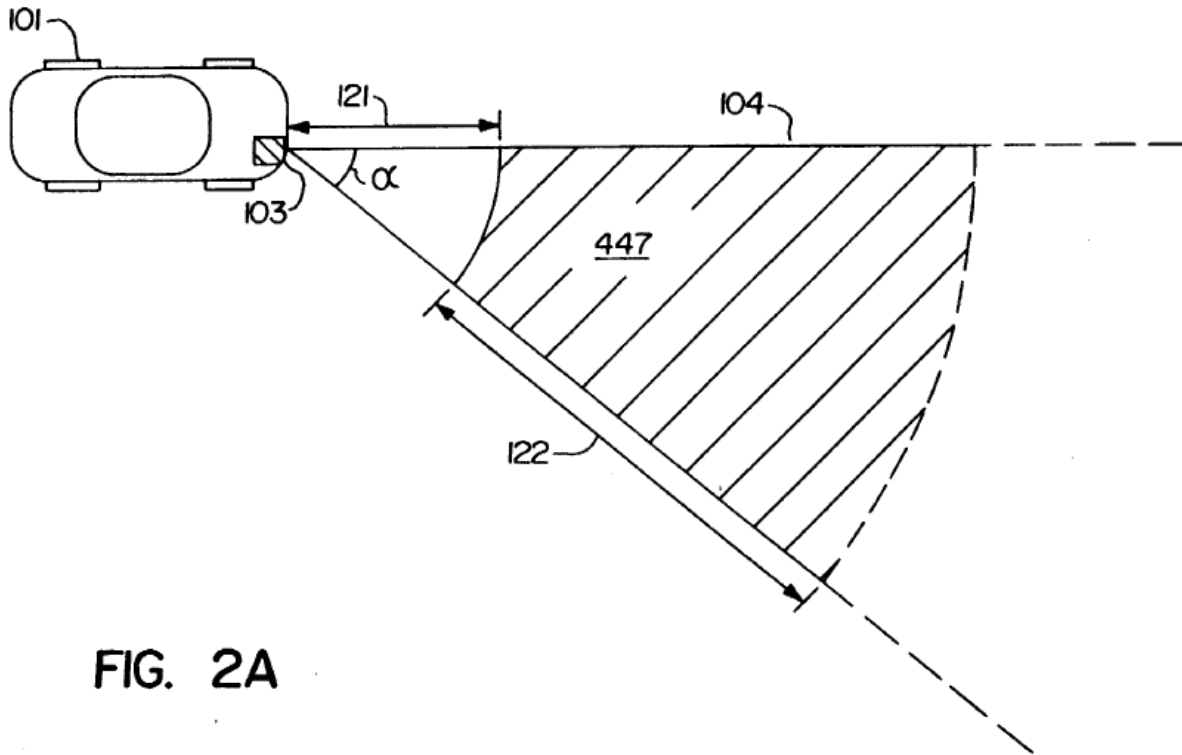


FIG. 2A

Frank, Fig. 2A.

155. For example, ASTM discloses that the entrance angle is “the angle in the horizontal plane between the direction of incident light and the normal to the leading edge of the marker.” ASTM, 452. A POSITA would have recognized that, when the road marker is properly mounted, traveling parallel to the lanes of the road would set the vehicle’s axis 104 parallel to the road marker’s normal direction, making Frank’s angle α and the entrance angle equivalent.

156. A POSITA would have had a reasonable expectation of success for the reasons discussed in connection with Ground 2, claim 15. *Supra* Section VIII.B.3. Calculating the entrance angle using Frank’s angle α as a proxy would

have required a POSITA to apply only conventional data-processing techniques to determine an angle based on the light sensor in the array that receives the reflected light, as taught by Frank and as was well known at the time, to predictably yield the result of an improved reflectivity measuring apparatus that can more accurately assess whether a road marker meets minimum specified levels. Frank, 10:67-11:4, 12:21-39, Fig. 11.

4. Claim 20: “The automated method of claim 17, wherein the computer processing system is further configured to determine an entrance angle and an observation angle of the road marker.”

157. Gallagher, Frank, and ASTM render obvious the additional limitations of claim 20 for the reasons discussed in connection with claim 14. *Supra* Section VIII.C.3.

D. Ground 4: Gallagher, Schofield, Leonard, and Popovich Render Obvious Claims 5-7

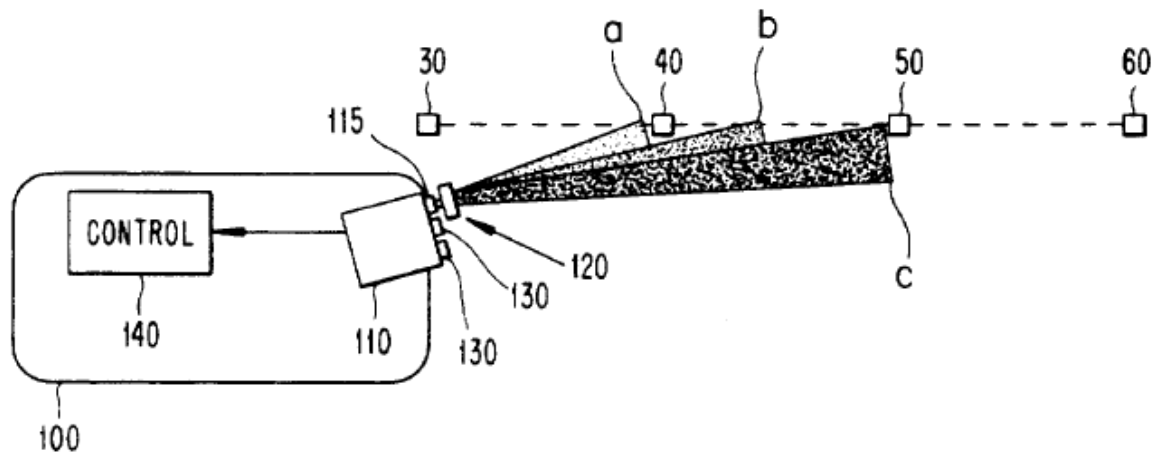
1. Leonard (Ex. 1009)

158. Leonard discloses “detecting objects to control a vehicle” using an expanded field of view “to permit plural objects to be detected simultaneously.” Leonard, 1:7-9, 2:8-13. Leonard recognized that, to detect “retro-reflector markers located along a path over which a vehicle is to be guided,” “a beam must be generated with a relatively large field of view.” Leonard, 1:19-24. This had typically been done by “splitting the beam into a plurality of lower intensity beams.” Leonard, 1:24-27. If “the intensity of the beam is increased ... so that

distant objects in the field can still be detected,” this could cause “a false return” at “close distances.” Leonard, 1:56-63.

159. Leonard discloses instead splitting the beam into “sub-fields,” where “[s]ub-fields associated with distant objects are set to a greater intensity to ensure reflection of the sub-fields back to the receiver,” and “[s]ub-fields directed to closer objects have a lesser intensity to avoid detection of false objects.” Leonard, 2:8-19. For example, as depicted in Figure 3 below, Leonard discloses a vehicle including a diode laser 110 “for generating a beam of light” that is passed through a “transmitting lens 115” and “an additional separating means, such as a grating 120” or a prism. Leonard, 4:62-5:20. Because “the angle of an expected marker location with respect to the vehicle is proportional to the distance of the marker from the vehicle for a vehicle path that is straight,” the intensities of the sub-fields decrease as the angle of the beam relative to the vehicle path increases. Leonard, 3:45-52, 5:43-62, 7:1-3.

Fig. 3



Leonard, Fig. 3.

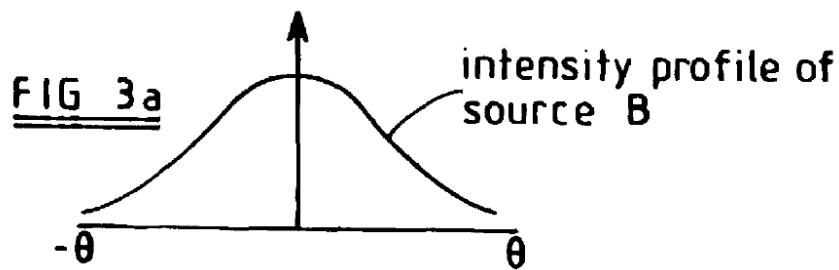
160. “Each sub-field can be used to detect the distance and angular orientation of any number of objects located within the sub-field” Leonard, 3:18-23, 5:58-62. Leonard discloses that any type of light-detecting element may be used “for receiving the reflected sub-fields from the markers.” Leonard, 8:52-55. Once light is detected, “the detected signals are processed by a controller” “to detect the position of the vehicle relative to the detected objects.” Leonard, 8:52-59.

2. Popovich (Ex. 1010)

161. Popovich discloses “[a]n optical triangulation tracking system” that generates two divergent beams of light with “a predetermined spatial and angular relationship” that illuminate a space including “at least one reflector.” Popovich,

Abstract. A light detection device is “adapted to receive light from each of the two beams which has been reflected back along its path of transmission by the reflector,” and an image processing system determines “spatial coordinates of the reflector” within the space. Popovich, Abstract.

162. Popovich, similar to Leonard, discloses that the system may use a beam with “a smoothly varying intensity profile.” Popovich, 5, 10. For example, Figure 3a, below, depicts the “angular intensity distribution profile” of a light source, where “the ‘Y’-axis is intensity and the ‘X’-axis is the angle theta with $x=0$ corresponding to the optical axis” of the light source. Popovich, 10.



Popovich, Fig. 3a.

163. A sensor array measures the intensity of the reflected light. Popovich, 6-8, 10. By determining “the peak of the spot’s intensity profile” in the array, “it is possible to define a ray vector that passes through the cent[er] of the retroreflector. Popovich, 6-7. Additionally, Popovich discloses that the “non-uniform light pattern” can be used to determine the position of a retroreflector “merely by

analy[z]ing the intensities of reflected light ... and comparing that with an intensity look-up table ... held within computation means.” Popovich, 13.

3. Leonard and Popovich Are Analogous Art

164. Leonard and Popovich are analogous art to the '328 patent because they are in the same field of endeavor, namely automated object recognition. Ex. 1001, 1:31-32; Leonard, 1:7-9, 5:54-62, 8:52-64; Popovich, 5-7. Leonard and Popovich are also analogous art to the '328 patent because they are reasonably pertinent to problems addressed by the '328 patent, including automatically identifying objects of interest without relying solely on “template matching of shape and color.” Ex. 1001, 1:39-47; Leonard, 1:7-9, 5:54-62, 8:52-64 (identifying road markers based on “receiving the reflected sub-fields from the markers” using a “light detecting element”); Popovich, 5-7 (identifying the position of a “retroreflective target” by determining the position of the sensor in the sensor array that received the reflected light’s “spot intensity”).

4. Rationale for Combining Gallagher, Leonard, and Popovich

165. A POSITA would have found it obvious to implement Leonard’s expanded field of view that includes a light source with sub-fields of different intensities to improve its detection and measuring of the reflectivity of road markers, and would have found it obvious to implement Popovich’s triangulation of a retroreflective object by measuring the angle of light vectors at two known

points to determine the location of the road markers detected in the expanded field of view.

166. Gallagher discloses a light source that, in one embodiment, illuminates “a 3 [meter] by 0.5 [meter] area” beginning about 2.3 meters in front of the vehicle. Gallagher, [0035]. But Gallagher discloses that “[t]he incident angle between the angle of the beam to road level is held constant over any one test,” which requires adjusting the beam between tests “to account for factors such as testing markers 2 around bends and on undulating roads.” Gallagher, [0036]. A POSITA would have looked to Leonard to expand the field of view with a light source like Leonard’s to avoid needing to adjust the beam angle between tests and to increase the numbers of measurements that Gallagher’s reflectivity measuring apparatus may take for each road marker at any given pass, thereby improving the accuracy of its reflectivity measurements.

167. Leonard discloses a system with an expanded field of view to identify three “reflectors spaced by a predetermined distance along the vehicle path” at any given time. Leonard, 3:6-10, 3:25-27, 4:62-5:39. Leonard discloses accomplishing this by implementing a “separating means,” such as a diffraction grating, prismatic lens, or prism, to create sub-areas that decrease in intensity as the angle deviates from the path of the vehicle. Leonard, 3:45-52, 4:3-13, 4:62-5:22. “Each sub-field can be used to detect the distance and angular orientation of any number of objects

located within the sub-field in a manner similar to that described in” another commonly assigned application that Leonard incorporates by reference, U.S. patent application Ser. No. 661,001. Leonard, 3:18-23, 5:58-62.

168. A POSITA would have been motivated to implement Leonard’s teaching of an expanded field of view using a light source whose intensity decreases as the angle relative to the heading of the vehicle increases in Gallagher’s apparatus to simultaneously detect and measure the reflectivity of multiple road markers at once. A POSITA would have seen this as advantageous to avoid the need to adjust the light source’s “incident angle” between measurements “to account for factors such as testing markers 2 around bends and on undulating roads.” Gallagher, [0036]. By increasing the field of view, a POSITA would have “ensur[ed] the detection of the objects,” and thus the measurements of their reflectivity, regardless of the road slope or curvature. Leonard, 1:22-24. Additionally, expanding the field of view would have been advantageous because it would have allowed Gallagher’s reflectivity measuring apparatus to increase the number of reflectivity measurements taken because the reflectors would be in the field of view of the sensor array module longer, thereby increasing the likelihood that the apparatus takes an accurate measurement.

169. Gallagher also suggests implementing Leonard’s expanded field of view because it discloses that increasing the “width of [the] beam may be desirable

for testing markers 2 that are spaced apart on the road.” Gallagher, [0043]. By implementing Leonard’s light source with varying intensity and expanded field of view, Gallagher’s apparatus would have been improved by allowing for simultaneous reflectivity measurements of multiple road markers located both close to the vehicle and far away from the vehicle.

170. Gallagher discloses determining “the location of each road marking” that it measures based on the location of the vehicle (e.g., using a GPS interface). Gallagher, [0048], [0063]-[0064]. By increasing the field of view to simultaneously measure the reflectivity of multiple road markers at varying distances, a POSITA would have looked to Popovich for a way to identify the location of each road marker measured.

171. Popovich discloses a technique for triangulating a retroreflector in space by triangulating the “spatial coordinates of the reflector” using a light detection device that receives light from two beams with a known spacing between them. Popovich, 1-2, 5-7. Popovich’s light detection device is an array of photodetectors “whose responses are thresholded such that a binary image consisting of a single spot moving against a black background is formed.” Popovich, 6. By measuring the location of the peak intensity within the array, Popovich’s system defines “a ray vector that passes through the cent[er] of the retroreflector.” Popovich, 6-7. “By computing the intercept of the ray vectors” for

two measurements, “the position of the target retroreflector 3 in three dimensional space is obtained.” Popovich, 7.

172. A POSITA would have been motivated to implement Popovich’s triangulation in Gallagher’s modified apparatus with the expanded field of view to improve the accuracy of the determined location for each road marker. For example, Gallagher discloses that “the apparatus 1 is capable of sampling road marking reflectance level data at frequent intervals” and includes “a GPS interface 15 [that] can be used to pinpoint the position of the vehicle and/or markers 2 as measurements are being taken.” Gallagher, [0047]-[0048]. A POSITA would have recognized that determining the angle of the road marker relative to the light source at multiple points and the GPS location of each measurement would have allowed Gallagher’s apparatus to “comput[e] the intercept of the ray vectors” from each measurement and determine “the position of” each identified road marker “in three dimensional space.” Gallagher, [0047]-[0048]; Popovich, 7. A POSITA would have found implementing this triangulation technique advantageous so that the apparatus properly tags the location of any road markers whose reflectivity is “less than the predetermined minimum acceptable reflectance level.” Gallagher, [0068].

173. A POSITA would have had a reasonable expectation of success in combining Gallagher, Leonard, and Popovich because Gallagher already discloses

that the size of the field of view can be modified, and Leonard teaches an apparatus that identifies the same types of road markers as Gallagher. Gallagher, [0037]; Leonard, 1:7-9, 5:54-62, 8:52-64. Accordingly, modifying Gallagher to implement Leonard's teaching of an expanded field of view with varying light-source intensity based on the angle would have merely been the combination of familiar prior art elements according to known methods to predictably yield an apparatus that identifies and measures the reflectivity of multiple road markers at once.

174. Additionally, Gallagher already discloses a GPS interface for identifying the vehicle location and taking multiple measurements, so further implementing Popovich's triangulation technique to determine the location of the road markers in 3-D space would have required a POSITA to apply only conventional techniques for determining the reflected angle off the road marker and each measurement location and using basic trigonometry to triangulate the road marker's location relative to the vehicle. Indeed, Leonard discloses using "[a]ny type of light detecting element," and Popovich discloses using both two-dimensional and linear sensor arrays to implement its triangulation technique, leading a POSITA to reasonably expect that its sensor array would work to implement this technique. Leonard, 8:54-55; Popovich, 8. And Gallagher discloses that "a wide variety of light sources can be suitable for this form of testing,"

leading a POSITA to reasonably expect that a light source with a wide field of view would work for this application. Gallagher, [0037].

5. **Claim 5: “The automated system of claim 1, wherein the computer processing system is configured to determine the location of the road marker using the light intensity values for the reflective surface by using a location and heading of the active sensor and a location of the object of interest to determine a light vector emanating from the light source responsible for one of the light intensity values and comparing the light vector to one of a plurality of predetermined vectors based on a light source angle characterization.”**

175. Gallagher, Leonard, and Popovich render obvious the additional limitations of claim 5.

176. Gallagher discloses that its computer processing system is configured to determine the location of each road marker tested. *Supra* Section VIII.A.11.g (Ground 1, [1H]). Gallagher discloses that this location determination uses “a GPS interface 15 ... to pinpoint the position of the vehicle and/or markers 2 as measurements are being taken.” Gallagher [0048]. Because the light source is in a fixed location on Gallagher’s vehicle, a POSITA would have understood that this GPS position of the vehicle corresponds to the location of the active sensor. Accordingly, a POSITA would have recognized that additional steps would have been necessary to also determine the location of the markers. Gallagher [0048].

177. The combination of Leonard and Popovich discloses the known techniques for determining the location of markers detected by a moving vehicle.

Leonard discloses an expanded field of view that can identify multiple reflective road markers at once. Leonard, 4:62-5:62. This expanded field of view includes sub-fields of varying intensity that “can be used to detect the distance and angular orientation of any number of objects located within the sub-field.” Leonard, 5:43-62. For example, Popovich similarly discloses a light source having “a non-uniform symmetrical intensity profile,” a “light detection means” that “measure[s] the intensity of light incident thereon,” and an image processing system that “determine[s] the trajectory of incident light from the intensities received.” Popovich, 2-3. By measuring the location of the intensity peak within the sensor array, the image processing system “define[s] a ray vector that passes through the cent[er] of the retroreflector.” Popovich, 6-7. A POSITA would have understood this to disclose using a heading of the active sensor and a location of the object of interest to determine a light vector emanating from the light source responsible for one of the light intensity values because, due to the speed of light, the angle of the incident light on the light sensor array corresponds to the angle of the light vector emanating from the light source relative to the light-source heading that is responsible for one of the light intensity values.

178. Because the intensity of the light source varies relative to its heading, a POSITA would have found it obvious to compare the determined light vector to one of a plurality of predetermined vectors based on a light source angle

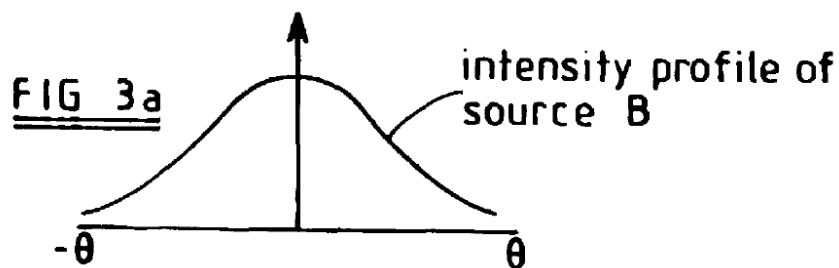
characterization. For example, Gallagher discloses selecting, from the light intensity values, “which reflectance levels indicate a road marker.” Gallagher, [0066]. But it was known that “[t]he received intensity will be a function of the angular bearing with respect to” the light source “and the distance of the retroreflector 3 from each light source.” Popovich, 10. Accordingly, to determine whether the light intensity values correspond to a road marker, a POSITA would have been motivated to compare the determined light vector to the known “angular intensity distribution profile” for the light source to determine whether a particular light intensity value received at the determined angle corresponds to a road marker.

179. As discussed in Section VIII.D.4, a POSITA would have been motivated to combine Gallagher, Leonard, and Popovich, and would have had a reasonable expectation of success in doing so, to use the light source’s position (as determined by the GPS interface) and the angle of the road marker relative to the light source’s heading (as determined through analysis of the light intensity values in the light sensor array) at multiple locations to determine the location of the road marker using the light intensity values through triangulation.

6. **Claim 6: “The automated system of claim 5, wherein the light source angle characterization is a look-up-table that relates an angular displacement from a normal vector for the light source to a light intensity for the light vector associated with the reflective surface.”**

180. Gallagher, Leonard, and Popovich render obvious the additional limitations of claim 6.

181. As discussed in connection with claim 5, to determine whether the light intensity values correspond to a road marker, a POSITA would have been motivated to compare the determined light vector to the known “angular intensity distribution profile” for the light source to determine whether a particular light intensity value received at the determined angle corresponds to a road marker. *Supra* Section VIII.D.5; Popovich, 10. For example, Popovich discloses the graph below that relates an angular displacement from a normal vector for the light source to a light intensity for the light vector associated with the reflective surface. Popovich, 10, Fig. 3a.



Popovich, Fig. 3a.

182. A POSITA would have been motivated to include this intensity profile in a look-up table within the computer processing system because such look-up tables were well-known ways to compare and identify related data. Indeed, Popovich already discloses determining the position of a retroreflector illuminated by a “non-uniform light pattern” “by analy[z]ing the intensities of reflected light 19, 23 and comparing that with an intensity look-up table 710 held within computation means.” Popovich, 13. Accordingly, implementing the comparison of the light source angle characterization as a look-up-table would have been a combination of familiar elements according to known methods to predictably yield a quick and efficient way to identify the intensity of a light source for a given angle.

7. **Claim 7: “The automated system of claim 5, further comprising a global positioning satellite (GPS) unit that determines a location of the vehicle operably coupled to the computer processing system, wherein the location of the vehicle is used in determining the location of the road marker.”**

183. As discussed in connection with claim 5, Gallagher discloses a “GPS interface 15” (GPS unit) that “can be used to pinpoint the position of the vehicle” and is used in determining the location of the road marker. Gallagher, [0048]; *supra* Section VIII.D.5.

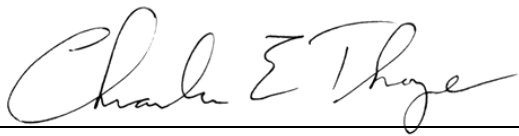
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184. In signing this declaration, I understand that the declaration will be filed as evidence in a contested case before the Patent Trial and Appeal Board of the United States Patent and Trademark Office. I acknowledge that I may be subject to cross-examination in the case and that cross-examination will take place within the United States. If cross-examination is required of me, I will appear for cross-examination within the United States during the time allotted for cross-examination.

185. I declare that all statements made herein of my knowledge are true and that all statements made on information and belief are believed to be true; and further, that these statements were made with knowledge that willful false statements and the like so made are punishable by fine or imprisonment, or both, under 18 U.S.C. § 1001.

186. I declare under penalty of perjury under the laws of the United States of America that the foregoing is true and correct.

Executed on this 19th day of July 2024.

By: 
Charles E. Thorpe