

UNITED STATES PATENT AND TRADEMARK OFFICE

BEFORE THE PATENT TRIAL AND APPEAL BOARD

AVIDBOTS CORP. and AVIDBOTS USA CORP.,

Petitioners,

v.

BRAIN CORPORATION,
Patent Owner.

Case No. IPR2025-01604
U.S. Patent No. 10,728,436

**DECLARATION OF LINA J. KARAM, PH.D.
IN SUPPORT OF PETITION FOR *INTER PARTES* REVIEW
OF U.S. PATENT NO. 10,728,436**

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TABLE OF CONTENTS

	<u>Page</u>
I. INTRODUCTION	1
II. BASIS FOR OPINIONS	2
A. Qualifications	2
III. LEGAL UNDERSTANDINGS.....	17
A. A Person of Ordinary Skill in the Art	18
B. Legal Standard for Prior Art and Obviousness	19
C. General Claim Construction Principles.....	21
IV. BACKGROUND TECHNOLOGY.....	23
V. THE '436 PATENT.....	25
A. Summary of the '436 Patent.....	25
B. Summary of the Prosecution History of the '436 Patent.....	27
C. Overview of the Challenged Claims	29
VI. PRIOR ART CONSIDERED	33
A. Identification of the Primary Prior Art References	33
B. General Overview of the Primary Prior Art References	34
1. WO 2011/146259 A2 (“Rosenstein”) (Ex1004).....	35
2. John Canny, <i>A Computational Approach to Edge Detection</i> , IEEE Transactions on Pattern Analysis and Machine Intelligence, November 1986 (“Canny”)(Ex1005).....	36
3. Qian Xu, et. al., <i>A Distributed Canny Edge Detector and its Implementation on FPGA</i> , Proceedings of the IEEE Digital Signal Processing Workshop, January 2011 (“Xu”) (Ex1006)	37
4. U.S. Patent No. 5,793,900 (“Nourbakhsh”) (Ex1007).....	39
5. U.S. Patent No. 9,076,214 (“Tsutsumi”) (Ex1008)	40

VII.	ANALYSIS OF THE CHALLENGED CLAIMS AGAINST THE PRIOR ART	42
A.	Ground 1: Claims 1–18 are Rendered Obvious in View of Rosenstein in Combination with Canny and Xu	42
1.	Motivation to Combine Rosenstein, Canny, and Xu	43
2.	Element-by-Element Analysis	44
B.	Ground 2: Claims 1–2, 6–7, 11, 13–14, and 16–17 are Rendered Obvious in View of Nourbakhsh in Combination with Tsutsumi.....	83
1.	Motivation to Combine Nourbakhsh with Tsutsumi	83
2.	Element-by-Element Analysis	85
VIII.	SECONDARY CONSIDERATIONS	99
IX.	CONCLUSION	100

I, Dr. Lina J. Karam, Ph.D., do hereby declare as follows.

I. INTRODUCTION

1. I am making this declaration at the request of Avidbots Corp. and Avidbots USA Corp., (Petitioners, collectively Avidbots) in the matter of the *Inter Partes* Review of U.S. Patent No. 10,728,436 (“ ’436 Patent ”).

2. I am being compensated for my work in this matter at my standard hourly rate. I am also being reimbursed for reasonable and customary expenses associated with my work and testimony in this proceeding. My compensation is not contingent on the outcome of this matter or the specifics of my testimony.

3. I have been asked to provide my opinions regarding whether the subject matter of claims 1-18 (“the Challenged Claims”) of the ’436 Patent would have been obvious to a person having ordinary skill in the art (“POSITA”) at the time of the alleged invention, in light of the prior art. It is my opinion that the Challenged Claims would have been obvious to a POSITA.

4. In the preparation of this declaration, I have studied:

- International Publication No. WO 2011/146259 A2 (Ex1004, “Rosenstein”).
- Qian Xu, et. al., *A Distributed Canny Edge Detector and its Implementation on FPGA*, Proceedings of the IEEE Digital Signal Processing Workshop (January 2011):500-505 (Ex1006, “Xu”).

- John Canny, *A Computational Approach to Edge Detection*, IEEE Transactions on Pattern Analysis and Machine Intelligence, Vol. PAMI-8, No. 6 (November 1986):679-698 (Ex1005, “Canny”).
- U.S. Patent No. 5,793,900 (Ex1007, “Nourbakhsh”)
- U.S. Patent No. 9,076,214 (Ex1008, “Tsutsumi”)

5. In forming the opinions expressed below, I have considered: the documents listed above, the relevant legal standards, including the standard for obviousness; and my own knowledge and experience based upon my work in the field of autonomous systems and robotics, mapping and navigation, sensing, signal processing, and computer vision as described below.

6. Unless otherwise noted, all **emphasis** in any quoted material has been added.

II. BASIS FOR OPINIONS

A. Qualifications

7. In formulating my opinions, I have relied upon my knowledge, training, and experience in the relevant art. My qualifications are stated more fully in my curriculum vitae (CV), a copy of which can be found in Exhibit 1010. The following is a brief summary of my relevant qualifications and professional experience. Among other things, my CV includes a list of my issued patents and publications for at least the last 30 years.

8. I earned a Bachelor of Engineering (B.E.) in Computer and Communications Engineering from the American University of Beirut in 1989, and a M.S. and a Ph.D. in Electrical Engineering both from the Georgia Institute of Technology in 1992 and 1995, respectively.

9. I am currently an Emerita Professor in the School of Electrical, Computer, and Energy Engineering at Arizona State University (ASU) and the Director of the R&D Image, Video, & Usability (IVU) Lab at ASU. Prior to becoming Emerita Professor, I was a tenured Full Professor, Computer Engineering Program Chair and Computer Engineering Director for Industry Engagement at ASU. From 2020 to 2022, I served as Dean of the School of Engineering at the Lebanese American University. From 2019 to 2021, I served as the Editor-In-Chief of the high-impact IEEE Journal of Special Topics in Signal Processing. I am also the President of PICARIS, LLC. I also served as Chief Technical Advisor at AIAEC LLC.

10. My research includes topics such as Signal, Image, and Video Processing, Compression, and Transmission; Computer Vision; Machine Learning; Autonomous Systems and Robotics; Perceptual-based Processing; Visual Attention Models; Automated Quality Assessment and Monitoring; Multidimensional Signal Processing; and Digital Filter Design. I have various awards in recognition of my research, including U.S. National Science Foundation

CAREER Award, Intel Outstanding Researcher Award, U.S. National Aeronautics and Space Administration (NASA) Technical Innovation Award, the IEEE Signal Processing Society (SPS) Best Journal Paper Award, and IEEE Phoenix Section Outstanding Faculty Award. I am featured in the 8th, 9th, 10th, and 11th editions of Research.com (2022-2025) among World Top Computer Science Scientists.

11. In addition, I am an Institute of Electrical and Electronics Engineers (IEEE) Fellow, which is the highest grade level conferred by IEEE each year to no more than one-tenth of 1% of all IEEE voting members. In addition to serving as Editor-In-Chief of a prestigious IEEE journal, I also served on several journal editorial boards, including but not limited to the IEEE Transactions on Image Processing, the IEEE Signal Processing Magazine, the IEEE Signal Processing Letters, and as Lead Guest Editor of the Proceedings of IEEE, Special Issue on Perceptual-Based Media Processing, IEEE Journal of Selected Topics in Signal Processing, Special Issue on Visual Quality Assessment, and IEEE Signal Processing Magazine, Special Issue on Autonomous Driving. I have also served on several IEEE Boards and chaired multiple IEEE committees. For example, I served on the IEEE Signal Processing Society (SPS) Board of Governors (2016-2018), IEEE SPS Publications Board (2019-2021), IEEE SPS Award Board (2019-2020), IEEE SPS Conference Board (2003-2005 & 2017-2018), IEEE

Publication Services and Products Board (PSPB) Strategic Planning Committee (2014-2016), IEEE Technical Activities Board (TAB)/PSPB Product and Services Committee (2023), IEEE Educational Activities Board (EAB) Faculty Resources Committee (2023-2024), IEEE SPS Fellow Nomination Committee (2025), IEEE Industry Engagement Committee and Chair of its Industry Impact Factor initiative (2024-present) and IEEE TechRxiv Advisory and Editorial Boards (2022-present). I am also an expert delegate of the ISO/IEC JTC1/SC29 Committee (Coding of audio, picture, multimedia, and hypermedia information) and have participated in JPEG/MPEG standardization activities.

12. As part of my various roles at ASU, PICARIS, AIAEC, ISO, and IEEE, I have been actively involved with industry. For example, I contributed to the development of image and video processing and compression at AT&T Bell Labs (Murray Hill), and multi-dimensional data processing and visualization at Schlumberger. Later in my career, I directed the research and development of image/video processing, compression, computer vision, machine learning, autonomous systems and robotics technologies and I collaborated on projects in these areas with various industries, including but not limited to Intel, NTT, Motorola, Freescale, NXP, General Dynamics, and NASA. More recently, I took on the role of Chief Technical Advisor/CTO at AIAEC, LLC, supervising work and product development in the field of AI and machine learning.

13. At ASU, I helped in establishing two graduate programs, the Computer Engineering Program and the Robotics and Autonomous Systems (RAS) Program. I also developed and taught courses and supervised both undergraduate and graduate-level projects related to autonomous systems and robotics, mapping and navigation, sensing, perception, machine learning, signal processing, embedded systems, and associated computer-implemented control and processing. I served as ADAS lead advisor as part of the DoE/GM-sponsored Advanced Vehicular Technologies (AVTC) ECOCAR (EcoCAR3) Mobility Challenge in collaboration with various industry partners. I established and led an industry-academia-government collaborative initiative on automated mobility together with Intel, ADOT, DPS and GPEC as founding partners, which culminated in the establishment of the Governor's Institute on Automated Mobility at the state level.

14. The developed computer vision and machine learning systems for automated defect detection, 3D characterization, gender/age prediction, and autonomous vehicles were adopted at Intel. The developed image-based non-wet solder joints detection system was granted a Divisional Recognition Award by Intel. More details can be found in A.F. Said, B.L. Bennett, L.J. Karam, and J.S. Pettinato, "Robust Automatic Void Detection in Solder Balls," *IEEE International Conference on Acoustics, Speech, and Signal Processing (ICASSP)*, pp. 1650-53,

March 2010; A.F. Said, B.L. Bennett, F. Toth, L.J. Karam, and J.S. Pettinato, “Non-Wet Solder Joint detection in Processor Sockets and BGA Assemblies,” Electronic Components and Technology Conference (ECTC), pp. 1147-53, May 2010; and in A.F. Said, B.L. Bennett, L.J. Karam, and J.S. Pettinato, “Automated Detection and Classification of Non-Wet Solder Joints,” *IEEE Transactions on Automation Science and Engineering*, vol. 8, no. 1, pp. 67-80, Jan. 2011. The developed image-based automated void detection system helped in enabling two industry standards, JEDEC JC 14-1 void guideline and IPC-7095C. More details can be found in A.F. Said, B.L. Bennett, L.J. Karam, A. Siah, K. Goodman, and J.S. Pettinato, “Automated Void Detection in Solder Balls in the Presence of Vias and Other Artifacts,” *IEEE Transactions on Components, Packaging and Manufacturing Technology*, vol. 2, no. 11, pp. 1890-901, Nov. 2012. More details about the developed 3D characterization system, including image-based solder ball height and warpage measurements, can be found in J. Li, B.L. Bennett, L.J. Karam, and J.S. Pettinato, “Stereo Vision Based Automated Solder Ball Height and Substrate Coplanarity Inspection,” *IEEE Transactions on Automation Science and Engineering*, vol. 13, no. 2, pp. 757-71, Apr. 2016; and in L. Karam and J. Li, “Stereo Vision Measurement System and Method,” U.S. Patent No. 9,704,232 B2, issued July 11, 2017. Details about machine-learning-based computer vision for defect detection can be found in B.M. Haddad, S. Yang, L.J. Karam, J. Ye, N.S.

Patel, and M.W. Braun, “Multi-Feature, Sparse-Based Approach for Defects Detection and Classification in Semiconductor Units,” *IEEE Transactions on Automation Science and Engineering*, vol. 15, no. 1, pp. 145-59, Jan. 2018; and in B.M. Haddad, S.F. Dodge, Yang, L.J. Karam, Ye, N.S. Patel, and M.W. Braun, “Locally Adaptive Statistical Background Modeling with Deep Learning-Based False Positive Rejection for Defect Detection in Semiconductor Units,” *IEEE Transactions on Semiconductor Manufacturing*, vol. 33, no. 3, pp. 357-72, Aug. 2020.

15. The developed 3D imaging and computer vision systems for autonomous vehicles include Advanced Driver Assist Systems (ADAS) technologies. The developed real-time forward collision warning system prototype was demonstrated by our Intel industry collaborators at the 2015 Consumer Electronics Show (CES) in Las Vegas. More details can be found in C.D. Prakash, J. Li, F. Akhbari, and L.J. Karam, “Sparse Depth Calculation Using Real-Time Key-Point Detection and Structure from Motion for Advanced Driver Assist Systems,” in G. Bebis et al. (eds.), *Advances in Visual Computing*, ISVC 2014, Lecture Notes in Computer Science, pp. 740-751, Dec. 2014; and in C.D. Prakash, F. Akhbari, and L.J. Karam, “Robust Obstacle Detection for Advanced Driver Assistance Systems Using Distortions of Inverse Perspective Mapping of

a Monocular Camera,” *Robotics and Autonomous Systems*, vol. 114, pp. 172-86, Apr. 2019.

16. In addition, I directed the development of automated biomedical image processing and imaging technologies. The developed automated biomedical image processing technologies enabled high-throughput cancer diagnostics and drug discovery and were licensed for cancer research at different industries and institutions, including the Translational Genomics Institute (TGEN) and the New York School of Medicine. More details can be found in L.J. Karam and A. Said, “Automatic Cell Migration and Proliferation Analysis,” U.S. Patent No. 9,082,164 B2, issued July 14, 2015; A.F. Said, L.J. Karam, and S.R. Gehler, “Use of Muscale CMA_{cfz} Automated Image Analysis Software to Accurately Quantitate Cell Migration,” *16th Annual Society for Biomolecular Sciences Conference (SBS)*, Apr. 2010; A. Said and L.J. Karam, “Cell Migration Analysis using a Statistical Level-Set Segmentation on a Wavelet-Based Structure Tensor Feature Space,” *7th International Symposium on Signal Processing and Information Technology (ISSPIT)*, pp. 473-78, Dec. 2007; and in A. Said, L.J. Karam, M.E. Berens, Z. Lacroix, and R.A. Renaut, “Migration and Proliferation Analysis for Bladder Cancer Cells,” *IEEE International Symposium on Biomedical Imaging*, pp. 320-23, Apr. 2007.

17. The developed imaging technologies were adopted at medical institutions including the Barrow Neurological Institute (BNI). More details can be found in B. Kanberoglu, J.P. Debbins, and L.J. Karam, "Accurate Brain Tumor Biopsy Using 3D ^1H -MRS Neuronavigation," *18th Annual ISMRM meeting*, April 2010; B. Kanberoglu, L.J. Karam, J.P. Debbins, "Context-Based GRAPPA Reconstruction using a Small Kernel," *18th Annual ISMRM meeting*, April 2010; B. Kanberoglu, T. Trouard, L. Karam, and J.P. Debbins, "Scanner Calibration For Multisite Geometric Accuracy: How To Do It," *17th Annual ISMRM meeting*, April 2009; B. Kanberoglu, N. Zobenica, R. Ryan, M. C. Preul, L.J. Karam, and J.P. Debbins, "Accurate Brain Tumor Biopsy Using 3D ^1H -MRS Neuronavigation," *17th Annual ISMRM meeting*, April 2009; C-Y Lee, L.J. Karam, and J.P. Debbins, "High-Order Diffusion Imaging Used to Differentiate Cytotoxic and Vasogenic Edema in Humans," *17th Annual ISMRM meeting*, April 2009; B. Lenoski, L.C. Baxter, L.J. Karam, J. Maisog, and J.P. Debbins, "On the Performance of Autocorrelation Estimation Algorithms for fMRI Analysis," *IEEE Journal on Special Topics in Signal Processing, Special Issue on Functional Magnetic Resonance Imaging*, vol. 2, no. 6, pp. 828-38, Dec. 2008; B. Lenoski, L. Karam, J. Debbins, and L. Baxter, "Autocorrelation Correction Methods in Clinical fMRI: Fixed Versus Variable P-Value Thresholding of 3T fMRI Datasets," *13th Annual Meeting Human Brain Mapping*, Jun. 2007; and in B.

Lenoski, L. Karam, L. Baxter, and J. Debbins, “Clinical Significance of Global versus Local fMRI Autocorrelation Estimation,” *Joint Annual Meeting ISMRM-ESMRMB*, Berlin, Germany, May 2007.

18. Furthermore, I directed the development of scalable visual compression technologies. The developed codecs were commercialized by General Dynamics. More details can be found in W.-J. Chien, N.G. Sadaka, G.P. Abousleman, and L.J. Karam, “Region-of-Interest-Based Ultra-Low-Bit-Rate Video Coding,” *SPIE Symposium on Defense & Security*, Mar. 2008. I directed the development of perceptual-based visual compression methods and algorithms. The work on JPEG2000 Encoding with Perceptual Distortion Control enabled the integration of adaptive perceptual-based visual processing and compression in the JPEG 2000 image coding standard and demonstrated improved performance in terms of visual quality and compression while maintaining full compatibility with the JPEG 2000 standard.

19. My work has been published numerous times in prestigious journals, including *IEEE Transactions on Signal Processing*, *IEEE Transactions on Image Processing*, *IEEE Transactions on Pattern Analysis and Machine Intelligence (PAMI)*, *IEEE Transactions on Broadcasting, Robotics and Autonomous Systems*, and *IEEE/CVF Computer Vision and Pattern Recognition (CVPR) Conference*. Some selected publications include L.J. Karam, “Two-Dimensional FIR Filter

Design by Transformation,” IEEE Transactions on Signal Processing, vol. 47, pp. 1474-1478, May 1999; Y.M.Y. Hassan, L.J. Karam, “Morphological Reversible Contour Representation,” IEEE Transactions on Pattern Analysis and Machine Intelligence, vol. 22, no. 3, pp. 227-240, Mar. 2000; Y.M.Y. Hassan, L.J. Karam, “Morphological Text Extraction from Images,” IEEE Transactions on Image Processing, vol. 9, no. 11, pp. 1978-83, Nov. 2000; I. Höntsch, L.J. Karam, “Adaptive Image Coding with Perceptual Distortion Control,” IEEE Transactions on Image Processing, vol. 11, no. 3, pp. 213-222, March 2002; R. Ferzli, L.J. Karam, “A No-Reference Objective Image Sharpness Metric Based on the Notion of Just Noticeable Blur (JNB),” IEEE Transactions on Image Processing, vol. 18, no. 4, pp. 717-28, Apr. 2009; S. Varadarajan, L.J. Karam, D. Florencio, “Background Recovery from Video Sequences using Motion Parameters,” IEEE International Conference on Speech, and Signal Processing (ICASSP), pp. 989-992, Apr. 2009; L.J. Karam, I. AlKamal, A. Gatherer, G. Frantz, D. Anderson, B. Evans, “Trends in Multi-Core DSP Platforms,” IEEE Signal Processing Magazine, Special Issue on Signal Processing on Platforms with Multiple Cores, pp. 38-49, Nov. 2009; S. Varadarajan, L.J. Karam, D. Florencio, “Background Subtraction using Spatio-Temporal Continuities,” European Workshop on Visual Information Processing (EUVIP), pp. 144-148, July 2010; A.F. Said, B.L. Bennett, L.J. Karam, and J.S. Pettinato, “Automated Detection and Classification

of Non-Wet Solder Joints,” IEEE Transactions on Automation Science and Engineering, vol. 8, no. 1, pp. 67-80, Jan. 2011; S. Chikkerur, V. Sundaram, M. Reisslein, and L.J. Karam, “Objective Video Quality Assessment Methods: A Classification, Review, and Performance Comparison,” IEEE Transactions on Broadcasting, vol. 57, no. 2, pp. 165-182, June 2011; L.J. Karam, N.G. Sadaka, R. Ferzli, Z.A. Ivanovski, “An Efficient Selective Perceptual-Based Super-Resolution Estimator,” IEEE Transactions on Image Processing, vol. 20, no. 12, pp. 3470-82, Dec. 2011; J. Li, L.J. Karam, “Depth Estimation from Multi-View Images,” International Conference on Emerging Signal Processing Applications (ESPA), pp. 151-154, Jan, 2012; S.F. Dodge, L.J. Karam, "Attentive Gesture Recognition," IEEE International Conference on Image Processing (ICIP), pp. 177-180, Sep. 2012; B. Kanberoglu, N.Z. Moore, D. Frakes, L.J. Karam, J.P. Debbins, M.C. Preul, “Integration of 3D ¹H-magnetic resonance spectroscopy data into neuronavigation systems for tumor biopsies,” Proceedings of SPIE, Medical Imaging, Image-Guided Procedures, Robotic Interventions, and Modeling, vol. 8671, id. 86711B, 7 pages, March 2013; S.F. Dodge, L.J. Karam, “Is Bottom-Up Attention Useful for Scene Recognition?,” 6th International Symposium on Attention in Cognitive Systems (ISACS), held in conjunction with the International Joint Conference on Artificial Intelligence (IJCAI), 10 pages, Aug. 2013; A. Shrotre, L.J. Karam, “Background recovery from multiple images,”

IEEE Digital Signal Processing Workshop, pp. 135-140, Aug. 2013; L.J. Karam, W.B. Kleijn, K. MacLean, "Perception-based Media Processing," Proceedings of the IEEE, vol. 101, no. 9, pp. 1900-1904, Sep. 2013; S. Dodge, L. Karam, "An Evaluation of Attention Models for Use in SLAM," Proc. SPIE 9025, Intelligent Robots and Computer Vision XXXI: Algorithms and Techniques, 90250M, Feb. 2014; B. Kanberoglu, N.Z. Moore, D. Frakes, L.J. Karam, J.P. Debbins, M.C. Preul, "Neuronavigation using Three-Dimensional Proton Magnetic Resonance Spectroscopy Data," Stereotactic and Functional Neurosurgery, pp. 306-314, vol. 92, no. 5, Sep. 2014; Q. Xu, S. Varadarajan, C. Chakrabarti, and L.J. Karam, "A Distributed Canny Edge Detector: Algorithm and FPGA Implementation," IEEE Transactions on Image Processing, vol. 23, no. 7, pp. 2944-2960, July 2014; C. Prakash, J. Li, F. Akhbari, L. Karam, "Sparse Depth Calculation using Real-time Key-point Detection and Structure from Motion for Advanced Driver Assist Systems," Springer Lecture Notes, ISVC, pp. 740-751, Dec. 2014; J. Andrade, C. Prakash, F. Akhbari, L.J. Karam, "Low-Complexity and Low-Delay Structure from Motion Approach for Advanced Driver Assist Systems," International Conference on Image Processing, Computer Vision, and Pattern Recognition (IPCV), pp. 191-197, 2015; Varadarajan, L.J. Karam, "A No-Reference Texture Regularity Metric Based On Visual Saliency," IEEE Transactions on Image Processing, vol. 24, no. 9, pp. 2784-2796, Sep. 2015; J. Li, B.L. Bennett, L.J.

Karam, J.S. Pettinato, "Stereo Vision Based Automated Solder Ball Height and Substrate Coplanarity Inspection," IEEE Transactions Automation Science and Engineering, vol. 13, no. 2, pp. 757-771, April 2016; M.M. Subedar and L.J. Karam, "3D Blur Discrimination," ACM Transactions on Applied Perception, vol. 13, no. 3, pp. 1-13, May 2016; S.F. Dodge, L.J. Karam, "Understanding How Image Quality Affects Deep Neural Networks," International Conference on the Quality of Multimedia Experience (QoMEX), 6 pages, June 2016; S.A. Golestaneh and L.J. Karam, "Spatially-Varying Blur Detection Based on Multiscale Fused and Sorted Transform Coefficients of Gradient Magnitudes," IEEE Conference on Computer Vision and Pattern Recognition (CVPR), pp. 596-605, July 2017; S. Dodge, J. Mounsef, and L. Karam, "Unconstrained Ear Recognition Using Deep Neural Networks," IET Biometrics, vol. 7, no. 3, pp. 207-214, Jan. 2018; L.J. Karam, T. Borkar, J. Chae, Y. Cao, "Generative Sensing: Transforming Unreliable Data for Reliable Recognition," IEEE Multimedia Information Processing and Retrieval (IEEE MIPR), Apr. 2018; S.F. Dodge and L.J. Karam, "Visual Saliency Prediction Using a Mixture of Deep Neural Networks," IEEE Transactions on Image Processing, vol. 27, no. 8, pp. 4080-90, Aug. 2018; S.F. Dodge and L.J. Karam, "Quality Robust Mixtures of Deep Neural Networks," IEEE Transactions on Image Processing, vol. 27, no. 11, pp. 5553-62, Nov. 2018; J. Mounsef and L. Karam, "Augmented Sparse

Representation Classifier (ASRC) for Face Recognition Under Quality Distortions,” IET Biometrics, vol. 8, no. 6, pp. 431-442, Oct. 2019; T.S. Borkar and L.J. Karam, “DeepCorrect: Correcting DNN Models Against Image Distortions,” IEEE Transactions on Image Processing, vol. 28, no. 12, pp. 6022-34, Dec. 2019; and in C.D. Prakash and L.J. Karam, “It GAN Do Better: GAN-based Detection of Objects on Images with Varying Quality,” IEEE Transactions on Image Processing, vol. 30, pp. 9220-30, Nov. 2021.

20. I am an inventor, and I have been awarded eight patents in the fields of image and video processing, compression, transmission, computer vision, and machine learning: U.S. Patent Nos. 6,154,493 (“The Compression of Color Images Based on a 2-Dimensional Discrete Wavelet Transform Yielding a Perceptually Lossless Image”), 6,124,811 (“Real-time Algorithms and Architectures for Coding Images Compressed by DWT-Based Techniques”), 6,717,990 (“Communication System and Method for Multi-Rate, Channel-Optimized Trellis-Coded Quantization”), 7,551,671 (“System and Method for Transmission of Video Signals Using Multiple Channels”), 9,082,164 (“Automatic Cell Migration and Proliferation Analysis”), 9,501,710 (“Systems, Methods, and Media for Identifying Object Characteristics Based on Fixation Points”), and 9,704,232 (“Stereo Vision Measurement System and Method”), and 11,030,485 (“Systems and Methods for Feature Corrections and Regeneration for

Robust Sensing, Computer Vision, and Classification”). I am also a named inventor on two additional patent applications, published as U.S. 2008/0259796 (“Method and Apparatus for Network-Adaptive Video Coding”) and as WO PCT Application PCT/US24/56544 (WO 2025/097186) (“Systems, Methods, and Media for Generating Documents Using Machine Learning”).

21. Based on my background, experience, education, and professional activities, I consider myself an expert in the fields of signal processing, image and video processing, computer vision (2D and 3D), machine learning, sensing, robotics, and associated computer-implemented control and processing. I am not an attorney and offer no legal opinions, but, in my work, I have had experience studying and analyzing patents and patent claims from the perspective of a person skilled in the art. I believe that I am qualified to opine as to the knowledge and level of skill of a POSITA at the time of the ’436 Patent (which I further describe below), in addition to the general state of the art during that time.

III. Legal Understandings

22. In this section, I describe my understanding of certain legal standards that I may have relied upon in forming my opinions set forth in this declaration. I have been informed of these legal standards by Petitioners’ attorneys. Although I am not an attorney and have not researched the law on patent invalidity, I have

formed the following understanding about the legal standards through Petitioners' attorneys.

A. A Person of Ordinary Skill in the Art

23. I understand there are multiple factors relevant to determining the level of ordinary skill in the pertinent art, including (1) the levels of education and experience of persons working in the field at the time of the invention; (2) the sophistication of the technology; (3) the types of problems encountered in the field; and (4) the prior art solutions to those problems.

24. I further understand that the hypothetical POSITA is presumed to have knowledge of all references that are sufficiently related to one another and to the pertinent art, and to have knowledge of all arts reasonably pertinent to the particular problem that the claimed invention purports to address.

25. In my opinion, as it relates to the '436 Patent, a person of ordinary skill in the art around July of 2014 would have had a Bachelor's degree or higher in electrical, computer, or mechanical engineering or computer science (or equivalent discipline) and at least two years of experience in research, design and/or development of autonomous robotics and/or robotic mapping/navigation and/or a related field. This experience might have included, for example, sensing, perception, signal processing, computer vision, and/or associated computer-

implemented control and processing. Additional education might substitute for less work experience, or vice versa.

26. I meet the criteria described above and believe myself to be a person with at least ordinary skill in the art pertaining to the '436 Patent. I would have qualified as such a person by at least July 1, 2014 which I understand is the earliest priority date of the '436 Patent.

27. For the purposes of this Declaration, in general, and unless otherwise noted, my statements and opinions, such as those regarding my own experience and what a POSITA would have understood or known generally (and specifically related to the references I consulted herein), reflect the knowledge that existed in the relevant field as of the priority date of the '436 Patent.

B. Legal Standard for Prior Art and Obviousness

28. I understand that prior art to the '436 Patent includes patents and printed publications in the relevant art that predate the priority date of the '436 Patent. For the purposes of this Declaration, I am applying July 1, 2014 as the priority date of the '436 Patent.

29. I have been informed by counsel that a claimed invention is unpatentable under the AIA 35 U.S.C. § 103 if the differences between the claimed invention and the prior art are such that the subject matter as a whole would have been obvious to a POSITA at the time of filing. I have also been

informed by counsel that the obviousness analysis considers factual inquiries, including the level of ordinary skill in the art, the scope and content of the prior art, and the differences between the prior art and the claimed subject matter.

30. I have been further informed by counsel that there are several recognized rationales for combining references or modifying a reference to show obviousness. These rationales include: (a) combining prior art elements according to known methods to yield predictable results; (b) simple substitution of one known element for another to obtain predictable results; (c) use of a known technique to improve a similar device (method, or product) in the same way; (d) applying a known technique to a known device (method, or product) ready for improvement to yield predictable results; (e) choosing from a finite number of identified, predictable solutions, with a reasonable expectation of success; and (f) some teaching, suggestion, or motivation in the prior art that would have led a POSITA to modify the prior art or to combine prior art teachings to arrive at the claimed invention.

31. I understand that in evaluating whether patent claims are invalid as obvious, secondary considerations of non-obviousness are considered, including considerations such as commercial success, long-felt but unsolved needs, copying, praise, teaching away from the claimed invention by the prior art, unexpected results, industry acceptance, failure of others, and skepticism by experts. I

understand that the secondary considerations are considered with the balance of obviousness evidence in the record to act as a check against impermissible hindsight bias. I further understand that there must be a nexus between the merits of the claimed invention and the evidence of secondary considerations in order to give such considerations substantial weight in the determination of obviousness.

32. I understand that the burden of presenting evidence of secondary considerations is on the Patent Owner. I also understand that the proponent of the evidence of secondary considerations bears the burden of showing that a nexus exists between the claimed features of the invention and the evidence offered to show nonobviousness.

C. General Claim Construction Principles

33. I understand that there are two types of claims: independent claims and dependent claims. I understand that an independent claim stands alone and includes only the limitations it recites. I understand that a dependent claim is a claim that depends on another claim. I understand that a dependent claim includes all of the limitations recited in the dependent claim as well as any limitations included in the corresponding independent claim.

34. I understand that before determining whether the Challenged Claims are invalid, the claims must be construed on a limitation-by-limitation basis. I understand that claim terms are to be afforded their plain and ordinary meaning

as used in the claims and as would be understood by a POSITA at the time of the filing. I understand that this person skilled in the art at the time of the invention is assumed to have read the claim terms in light of the entire patent record, including the other claims, the patent specification, and the patent prosecution history. I have interpreted the claim terms in the '436 Patent in light of this understanding.

35. I understand that to properly understand the meaning of claim terms, one should first consider the intrinsic evidence, which includes the claim language itself, the patent specification, and the patent's prosecution history, as well as any post-issuance history before the Patent Office. For example, the patent specification may show that the inventor used words or terms in a manner inconsistent with their plain and ordinary meaning. Specifically, I understand that where the specification reveals a special definition given to a claim term by the inventor that differs from the meaning it would otherwise possess, the inventor's lexicography governs. I understand that the prosecution history of the patent may also provide guidance in construing a claim term. For example, the prosecution history may show that the patent applicant might have limited the scope of some or all of the claims during prosecution, either affirmatively or by implication.

36. I understand that if the intrinsic evidence is not conclusive regarding the meaning of a particular claim term, extrinsic evidence may also be used to

determine its meaning. I understand that extrinsic evidence may be used, for example, to help determine what a person skilled in the art at the time of the invention would have understood the claim term to mean. Extrinsic evidence may include dictionaries, technical treatises and books, articles, or expert testimony.

IV. BACKGROUND TECHNOLOGY

37. To put in context my opinions on the validity of the claims of the '436 Patent, in this section I provide a brief discussion of the relevant technological background, which relates to object detection.

38. Researchers have investigated sensor-enabled autonomous robotic navigation and automated image-based object detection since at least the 1980s.

39. For example, in 1986, John Canny published, "A Computational Approach to Edge Detection." Ex1005 ("Canny"). A paper published in 2011, by Xu et al, titled "A Distributed Canny Edge Detector and Its Implementation on FPGA," notes that "edge detection is one of the key stages in image processing and object recognition" and that the "Canny edge detector is one of the most widely-used edge detection algorithms due to its good performance." Ex1006 ("Xu"), Abstract.

40. Canny explains in his paper that "[e]dge detectors of some kind, particularly step edge detectors, have been an essential part of many computer vision systems." Ex1005, 679. In surveying the field of edge detectors used in

object recognition, Canny notes that the “Binford-Horn line finder [] used the output of an edge detector as input to a program which could isolate simple geometric solids. More recently the model-based vision system ACRONYM [] used an edge detector as the front end of a sophisticated recognition program.” *Id.*

41. The Canny algorithm employs the techniques claimed as new in the ’436 Patent, including object detection based on an image contrast meeting or exceeding a threshold.

42. Specifically, the Canny edge detector algorithm, as summarized by Xu, consists of the following steps: (1) “Smoothing the input image by Gaussian mask. The output smoothed image is denoted as $I(x, y)$.”; (2) “Calculating the horizontal gradient $G_x(x, y)$ and vertical gradient $G_y(x, y)$ at each pixel location by convolving the image $I(x, y)$ with partial derivatives of a 2D Gaussian function”; (3) Computing the gradient magnitude $G(x, y)$ and direction $\theta_{G(x, y)}$ at each pixel location.”; (4) “Applying non-maximum suppression (NMS) to thin edges.”; (5) “Computing the hysteresis high and low thresholds based on the histogram of the magnitudes of the gradients of the entire image.”; (6) “Performing hysteresis thresholding to determine the edge map.” Ex1006, 501.

43. In 2011, Xu improved upon the Canny edge detector. Instead of the Canny edge detection algorithm operating on the whole image, Xu’s distributed Canny edge detection algorithm divides the input image into blocks. Xu’s

distributed Canny edge detection algorithm discloses that thresholding is performed based on a threshold value that is dynamically adapted based on the local characteristics of each image block. *Id.*, 501–502.

44. Additionally, object detection based on an image contrast meeting or exceeding a threshold had already been disclosed in patent publications well before the priority date of the '436 patent. For example, U.S. Patent No. 9,076,214, Ex1008 (“Tsutsumi”), issued from a U.S. patent application filed on August 5, 2012. Tsutsumi discloses dividing an overlapping area of images into sub-areas, calculating a contrast value for each sub-image, and then comparing that contrast value to a threshold value. *Id.*, 6:55–63, 7:11–19, 12:7–10.

V. The '436 PATENT

A. Summary of the '436 Patent

45. The '436 Patent relates to “computerized apparatus and methods for detecting objects or targets using processing of optical data.” Ex1001, 1:23-25. The '436 Patent states that “[o]bject detection may be required for target approach/obstacle avoidance by autonomous robotic devices” and that it provides “an improved object detection apparatus and associated methods” to “detect an object in an image,” Ex1001, 1:29-33, 46-66.

46. The independent claims of the '436 Patent disclose (1) obtaining an image associated with surroundings of the apparatus (e.g., robot) using a sensor

and (2) determining the presence of an object in the image by (a) calculating a contrast parameter of the at least one image, the contrast parameter corresponding to a maximum absolute deviation of pixels within the at least one image from a reference value and (b) comparing the contrast parameter to a threshold, the threshold being dynamically configured based on one or more parameters. *Id.*, cls. 1, 11, 16.

47. Several of the dependent claims relate either to the contrast parameter or the threshold-related parameters. Other dependent claims relate to the image sensor.

48. The '436 Patent discloses that "[t]he contrast parameter may be evaluated in light of one or more detection or triggering criteria; e.g., compared to a threshold." *Id.*, 12:39-50, 14:55-58, 15:48-50, 18:15-17, 19:28-30, 20:39-41, 21:33-36, cls 1, 11, 16. It further discloses that the threshold can be "configured dynamically based on, e.g., ambient light conditions, time of day, and/or other parameters." *Id.*, 12: 51-57, 13:22-25, 14:66–15:3, 15:60-63, 18:19-22, 19: 32-25, 20:43-46, 21:38-41, cls. 1, 5, 11, 12, 16.

49. The '436 Patent explains that the object detection apparatus (e.g., robotic apparatus) may comprise an image sensor located behind a lens. *Id.*, 7:36–39. Depending on the distance between the object and the lens, the object is either in-focus or out-of-focus. *Id.*, 6:55-63. "In-focus representations of objects may

be characterized by a greater contrast parameter compared to out-of-focus representations.” *Id.*, 6:63-65. As the object detection apparatus approaches an object, the image “may gradually become sharper” and the object detection apparatus detects the presence of an object by the contrast or sharpness exceeding a threshold, indicating that the object is “within the range of focus in front of the lens.” *Id.*, 7:4-10.

50. According to the ‘436 Patent, one or more image sensors can also be configured at an angle with respect to the plane of the lens, enabling a robotic apparatus “to produce one or more areas of focus” and “to detect objects at multiple locations that differ in distance from the lens plane.” *Id.*, 10:2–13, cl. 6. Further, the ‘436 Patent discloses that the “detection of objects at multiple distances may enable a robotic vehicle to determine [] whether [] its [sic] approaching an object (or if it is approached by an object) and undertake a relevant action (e.g., avoid an obstacle and/or move away from a trajectory of another object).” *Id.*, 10:14-19, cl. 6.

B. Summary of the Prosecution History of the ‘436 Patent

51. The ‘436 patent is a continuation of U.S. Patent Application No. 14/321,736, filed on July 1, 2014.

52. The Applicant amended its claims following a non-final rejection. Ex1002, 196-208, 294–302. The Examiner found that all claims were either

anticipated by U.S. Patent No. 9,150,220 (“Clarke”) or were unpatentable over Clarke in view of U.S. Patent No. 8,542,875 (“Eswara”). *Id.*, 204–208.

53. The Examiner explained that Clarke disclosed a method of navigating an apparatus comprising obtaining at least one image associated with surroundings of the apparatus using a sensor, the apparatus comprising a controller, an actuator and the sensor, analyzing the at least one image to detect a presence of an object in the at least one image, determining whether the object comprises one of either a target or an obstacle, and causing the controller to selectively activate the actuator based on the determination. *Id.*, 204–205.

54. The Examiner also explained that Eswara “discloses receiving data from the at least one sensor, the data comprising dynamic lighting parameters of the environment, and adjust[ing] the prescribed contrast parameter threshold for object detection based on the data from the at least one sensor” where the “image data is used” to “determine the mean value and standard deviation of the image, i.e., dynamic lighting parameters of the environment, in order to set the threshold used in the comparison of the image data for contrast evaluation.” *Id.*, 208.

55. In response, the Applicant added the following language: “determining the presence of the object based on comparing a contrast parameter of the at least one image to a threshold, the contrast parameter corresponding to a maximum absolute deviation of pixels within the at least one image from a reference vale

[sic], and the threshold being dynamically configured based on one or more parameters.” *Id.*, 295. As discussed more fully below, this amendment only recites features that were well-known in the object detection art, including the robotic object detection art.

56. With that amendment, the Examiner then issued a Notice of Allowance on March 6, 2020. *Id.*, 305.

C. Overview of the Challenged Claims

57. There are three independent claims in the ’436 patent: claims 1, 11, and 16.

58. I understand that Petitioners are challenging all of the claims in the ’436 patent (the “Challenged Claims”). I have analyzed each of these claims.

No.	Limitation
1[pre]	A method of navigating an apparatus, comprising:
1[a]	obtaining at least one image associated with surroundings of the apparatus using a sensor, the apparatus comprising a controller, an actuator and the sensor;
1[b]	analyzing the at least one image to detect a presence of an object in the at least one image;
1[c]	determining the presence of the object based on comparing a contrast parameter of the at least one image to a threshold, the contrast parameter corresponding to a maximum absolute deviation of pixels within the at least one image from a reference value, and the threshold being dynamically configured based on one or more parameters; and
1[d]	causing the controller to selectively activate the actuator based on the determination that the object is within the range of the apparatus.

No.	Limitation
2	The method of claim 1, further comprising: adapting movement of the apparatus as the object is detected in the surroundings of the apparatus.
3	The method of claim 1, wherein the contrast parameter corresponds to partitioning of the at least one image into a low spatial frequency portion and a high spatial frequency portion.
4	The method of claim 1, wherein the partitioning is configured by selecting a first area and a second area within the at least one image, the first area corresponds to region around zero frequency, and the second area corresponds to the remaining portion of the spectrum.
5	The method of claim 1, wherein the one or more parameters include ambient light conditions surrounding the apparatus and time of day.
6[a]	The method of claim 1, further comprising: detecting the object at multiple locations from the apparatus based on the sensor being at a slanted angle; and
6[b]	determine, based on the detection of the object, whether the apparatus is approaching the object or the object is approaching the apparatus.
7	The method of claim 1, wherein the sensor comprising a linear array of photo sensitive elements.
8	The method of claim 7, wherein the linear array of photo sensitive elements disposed along axial direction of a lens.
9	The method of claim 1, wherein the sensor comprises one or more sensing layers axially displaced from one another, each one of the one or more sensing layers comprise a plurality of photo sensitive elements.
10	The method of claim 9, wherein the axial displacement of the one or more sensing layers is configured to produce an axial distribution of multiple focal planes, and wherein the axial distribution of multiple focal planes is configurable to enable detection of object positioned in front of the apparatus.
11[pre]	A non-transitory computer-readable storage medium having computer readable instructions stored thereon, that when executed by at least one controller device configure the at least one controller device to:

No.	Limitation
11[a]	receive data from at least one sensor, the data comprising at least one image of an environment;
11[b]	analyze an image, from the data generated by the at least one sensor, to determine a contrast parameter of the image, the contrast parameter comprising a deviation parameter, a reference value, and/or threshold associated with object detection, the contrast parameter corresponding to a maximum absolute deviation of pixels within the at least one image from a reference value;
11[c]	determine presence of the object based on comparing the contrast parameter of the image to a threshold, the threshold being dynamically configured based on one or more parameters; and
11[d]	determine a location of the object from the contrast parameter meeting or exceeding the threshold at the location of the object.
12[a]	The non-transitory computer-readable storage medium of claim 11, wherein the at least one controller device is further configurable to execute the computer readable instructions to: receive data from the at least one sensor, the data comprising dynamic lighting parameters of the environment; and
12[b]	adjust the threshold for object detection based on the data from the at least one sensor.
13	The non-transitory storage medium of claim 11, wherein the at least one controller device is further configurable to execute the computer readable instructions to: determine a contrast parameter criterion comprising a fixed or a dynamic value from statistics of multiple images gathered by the at least one sensor.
14[a]	The non-transitory storage medium of claim 11, wherein the at least one controller device is further configurable to execute the computer readable instructions to: partition a first image into at least two sub-images, the at least two sub-images comprise different energy spectra or regions of the first image; and
14[b]	apply filtering operations to the at least one of the two sub-images prior to the determination of a contrast parameter criterion.

No.	Limitation
15	The non-transitory storage medium of claim 11, wherein the at least one controller device is further configurable to execute the computer readable instructions to: apply an asymmetrical filter to the at least one image received from the at least one sensor to facilitate the detection of an object at a target orientation.
16[pre]	A method for detection of objects near an apparatus, comprising:
16[a]	gathering data from at least one sensor, the data comprising at least one image of an environment surrounding the apparatus;
16[b]	analyzing the at least one image, to determine a contrast parameter of the at least one image, the contrast parameter comprising a deviation parameter, a reference value, and/or threshold associated with object detection, the contrast parameter corresponding to a maximum absolute deviation of pixels within the at least one image from a reference value;
16[c]	determining if an object is present in the image based on comparing the contrast parameter of the at least one image to a threshold, the threshold being dynamically configured based on one or parameters.
17[a]	The method of claim 16, further comprising: partitioning a first image, from the plurality of images, into at least two sub-images comprising two different energy spectra or regions of the first image; and
17[b]	applying filtering and/or cropping operations to the at least one of the two sub-images prior to the determination of a contrast parameter criterion.
18	The method of claim 16, further comprising: applying an asymmetrical filter to the data from the at least one sensor to facilitate detection of objects at a target orientation.

59. For the reasons I detail below, it is my opinion that each of these claims is unpatentable over the prior art discussed below.

VI. Prior Art Considered

60. In this declaration, I provide five prior art references (among others) with exemplary citations identifying the relevant features related to the claim language of the Challenged Claims. I have also described combinations of these prior art references that, when combined, render the Challenged Claims obvious. It is my opinion that the Challenged Claims are rendered obvious in light of the prior art specifically discussed in this declaration.

61. The citations presented in the body of this declaration correspond to the teachings disclosed in exemplary items of prior art that identify: (1) the problem(s) confronted by one of ordinary skill in the art; (2) an express suggestion to make one or more of the combinations; (3) an implicit suggestion to make one or more of the combinations; or (4) the knowledge of one of ordinary skill in the art in the applicable field of technology as of the priority date of the '436 Patent.

A. Identification of the Primary Prior Art References

62. It is my opinion that a person of ordinary skill in the art would consider at least the prior art references below:

Prior Art Reference	Qualifying Date	Exhibit No.
WO 2011/146259 A2 ("Rosenstein")	May 6, 2011	1004
John Canny, <i>A Computational Approach to Edge Detection,</i>	November 1986	1005

IEEE Transactions on Pattern Analysis and Machine Intelligence (“Canny”)		
Qian Xu et al., <i>A Distributed Canny Edge Detector and its Implementation on FPGA</i> , Proceedings of the IEEE Digital Signal Processing Workshop (“Xu”)	January 2011	1006
U.S. Patent No. 5,793,900 (“Nourbakhsh”)	December 29, 1995	1007
U.S. Patent No. 9,076,214 (“Tsutsumi”)	August 6, 2012	1008

63. A POSITA considering the problem of image-based object detection would search for printed publications that describe solutions to that problem. Such printed publications would include patents, journal articles, technical books and/or manuals, and other academic publications like doctoral theses. A POSITA would use search terms that are readily apparent according to the nature of the problem, such as “edge detection,” “object recognition,” “image processing,” and “machine vision.” It is my understanding that each of the references listed above would have been found using one or more of these search terms. Ex1009, ¶¶ 25, 36.

B. General Overview of the Primary Prior Art References

64. The following sections provide a brief description of the prior art systems and methods that invalidate the ’436 patent. This discussion is not meant

to be exhaustive, and my full element-by-element analysis is provided in more detail below in the analysis section. I have personally reviewed the references cited in this declaration. It is my opinion that (1) Rosenstein in combination with Canny and Xu and (2) Nourbakhsh in combination with Tsutsumi render obvious the features of the Challenged Claims.

1. WO 2011/146259 A2 (“Rosenstein”) (Ex1004)

65. International Publication No. WO 2011/146259 A2, titled “Mobile Human Interface Robot” issued on November 24, 2011, from International Application No. PCT/US2011/035488 filed on May 6, 2011.

66. Rosenstein discloses a mobile human interface robot with a drive system, a controller in communication with the drive system, and an imaging device. Ex1004, Title, Abstract. The controller “receives [] signals from the imaging device and issues drive commands to the drive system.” *Id.*, Abstract. The robot includes “one or more types of sensors,” including “obstacle detection obstacle avoidance (ODOA) sensors, communication sensors, navigation sensors, etc.” *Id.*, [00137]. In some implementations, the “robot 100” can include “first and second 3-D image sensors 450a, 450b” and the “first 3-D image sensor 450a is mounted on the torso 140 and pointed downward at a fixed angle to the ground G.” *Id.*, [00162]. Further, the robot “may tilt the second 3-D image sensor 450b downward slightly to increase a total or combined field of view of both 3-D image

sensors 450a, 450b, [] to avoid an obstacle.” *Id.* The 3-D imaging sensor 450 includes a camera that can include a “complementary metal oxide semiconductor (CMOS) sensor 1520 (or charge-coupled device (CCD)), a lens 1530, and control logic or a camera controller 1540 having processing resources (and/or the robot controller 599).” *Id.*, [00182]. “The CMOS sensors 1520 may include an array of pixel detectors 1522, or other arrangement of pixel detectors.” *Id.*

67. Rosenstein additionally recognizes that “[p]roperly sensing objects 12 using the imaging sensor 450, despite ambient light conditions,” is important. *Id.*, [00189]. The “imaging sensor 450 can be used for identifying and resolving people and objects 12 in all situations with relatively little impact from ambient light conditions (e.g., ambient light rejection).” *Id.*

2. John Canny, *A Computational Approach to Edge Detection*, IEEE Transactions on Pattern Analysis and Machine Intelligence, November 1986 (“Canny”)(Ex1005)

68. Canny’s *A Computational Approach to Edge Detection* was publicly available by November 1986. Ex1009, ¶ 34.

69. The Canny paper describes a “computational approach to edge detection.” Ex1005, Abstract. The approach includes “deriv[ing] a single operator shape which is optimal at any scale” and which “has a simple approximate implementation in which edges are marked at maxima in gradient magnitude of a Gaussian-smoothed image.” *Id.*

3. **Qian Xu, et. al., *A Distributed Canny Edge Detector and its Implementation on FPGA*, Proceedings of the IEEE Digital Signal Processing Workshop, January 2011 (“Xu”) (Ex1006)**

70. Xu et al.’s *A Distributed Canny Edge Detector and its Implementation on FPGA* was publicly available by March 24, 2011. Ex1009, ¶ 23.

71. Xu states that “[e]dge detection is one of the key stages in image processing and object recognition.” Ex1006, Abstract, 500. Xu further indicates that “[t]he Canny edge detector [(which was disclosed in a publication by John Canny in November 1986 in IEEE Transactions on PAMI; see reference [5] in Xu)] is one of the most widely-used edge detection algorithms due to its good performance” and that “[t]he Canny edge detector is predominantly used in many real-world applications due to its ability to extract significant edges with good detection and good localization performance.” Ex1006, Abstract, 500. Xu presents a “distributed Canny edge detection algorithm that results in significantly reduced memory requirements, decreased latency and increased throughput with no loss in edge detection performance as compared to the original Canny algorithm.” *Id.*

72. Xu describes that the Canny edge detector algorithm, as originally proposed by John Canny in November 1986, consists of the following steps: (1) “Smoothing the input image by Gaussian mask” with “[t]he [resulting] output smoothed image [] denoted as $I(x, y)$ ”; (2) “Calculating the horizontal gradient

$G_x(x,y)$ and vertical gradient $G_y(x,y)$ at each pixel location by convolving the image $I(x,y)$ with partial derivatives of a 2D Gaussian function”; (3) Computing the gradient magnitude $G(x,y)$ and direction $\theta_G(x,y)$ at each pixel location”; (4) “Applying non-maximum suppression (NMS) to thin edges”; (5) “Computing the hysteresis high and low thresholds based on the histogram of the magnitudes of the gradients of the entire image”; (6) “Performing hysteresis threshold to determine the edge map.” Ex 1006, 501.

73. Steps 1 to 4 and Step 6 of Xu’s distributed Canny edge detection algorithm “are the same as in the original Canny [edge detection] algorithm except that these are [] applied at the block level.” *Id.*, 501. Importantly, while Canny’s edge detection algorithm “operates on the whole image,” Xu’s distributed Canny edge detection algorithm divides the input image into $m \times m$ blocks. and “removes the inherent dependency between the various blocks so that the image can be divided into blocks and each block can be processed in parallel.” *Id.* Additionally, Xu discloses that thresholding is performed based on a threshold value that is dynamically adapted based on the local characteristics of each image block. *Id.*, 501-502, Fig. 4.

4. U.S. Patent No. 5,793,900 (“Nourbakhsh”) (Ex1007)

74. U.S. Patent No. 5,793,900, titled “Generating Categorical Depth Maps Using Passive Defocus Sensing,” issued on August 11, 1998 from a U.S. patent application filed on December 29, 1995.

75. Nourbakhsh discloses “[a] method of generating a categorical depth map of a scene using passive defocus sensing.” Ex1007, Abstract. In one application, this method is used for collision avoidance and object detection as part of a mobile robot control system. *Id.* The mobile robot includes multiple cameras focused at different distances, which simultaneously capture images of the same scene. *Id.*, Abstract, 4:62-5:1. The images are passed to a microprocessor and memory for image processing. *Id.*, 5:4-6. Each of the images is broken into regions, and a sharpness value is calculated for each region, representing “a nonnegative measure of the contrast between pixel intensities in that region.” *Id.*, 5:9-10, 6:20-41. “A larger sharpness value indicates that the portion of the image in a given region is more in focus.” *Id.*, 6:41-42.

76. The sharpness values are used to generate a depth map, which is “an array of categorical depth values, each value indicating the depth of the scene for a given region,” for example “[d]epth values of 2, 1, and 0 correspond[ing] to close, medium, and far, respectively.” *Id.*, 5:9-15, 6:42-50.

77. Once generated, the depth map is communicated to a robot motion control computer, which sends motion control signals to the robot, “directing the robot to move while preventing collision with objects in the environment.” *Id.*, 5:36-42. For example, the robot motion control computer may compare the depth map to the “normal depth map” of a flat open floor, where bottom rows of the depth map are medium range and the top rows are far range. *Id.*, 5:50-65. “If the depth map deviates from the normal depth map, then it is presumed that an obstacle is in front of the robot.” *Id.*, 5:62-65. Depending on whether the object is determined to be “dangerously close” or not, the robot either stops (if the obstacle is dangerously close) or moves forward slowly (if the obstacle is not dangerously close) and turns in the direction (left or right) that is more open. *Id.*, 6:1-14.

5. U.S. Patent No. 9,076,214 (“Tsutsumi”) (Ex1008)

78. U.S. Patent No. 9,076,214, titled “Image Acquisition Apparatus and Image Processing Apparatus Using Selected In-Focus Image Data,” issued on July 7, 2015 from a U.S. patent application filed on August 6, 2012.

79. Tsutsumi discloses an apparatus for providing a “range image” (i.e., spatial distance data for each region of an image) based on images acquired by a camera array. Ex1008 1:8-11, 14:15-18. The overlapping area of the acquired images is divided into N_i by N_j sub-areas. *Id.*, 6:55-63. For each sub-area, the

apparatus calculates a contrast value and uses the contrast values to select an in-focus image for each sub-area. *Id.*, 7:11-19. Using the identification of which images are in-focus for each sub-area, the apparatus generates a range image. *Id.*, 13:64-14:21.

80. The contrast value for an image sub-area (e.g., “image area (ii, jj)” in an acquired image) is calculated using the maximum and minimum monochrome pixel values ($I_{\max}$ and $I_{\min}$, respectively) in the image sub-area, determined by calculating a histogram based on the pixel values in the image sub-area. *Id.*, 10:51-67. The contrast value $C(ii,jj,m)$ for image area (ii,jj) of image m is calculated according to the formula: $C(ii,jj,m) = (I_{\max}(ii,jj,m) - I_{\min}(ii,jj,m)) / (I_{\max}(ii,jj,m) + I_{\min}(ii,jj,m))$. *Id.*, 10:60-67. The contrast value $C(ii,jj,m)$ is then compared to a threshold value, Th , to determine whether or not the image m is in focus in the image area (ii, jj). *Id.*, 12:7-15. The threshold is set at an initial value; however, if the number of in-focus images is fewer than two, the threshold value Th is decreased and the comparison step is repeated. *Id.*, 11:66-12:3, 12:37-51. This enables the apparatus to “obtain a plurality of in-focus images in order from an image having the highest contrast value in the image area (ii,jj).” *Id.*, 12:48-51.

VII. ANALYSIS OF THE CHALLENGED CLAIMS AGAINST THE PRIOR ART

81. Based upon my review of the prior art, particularly the references detailed in this declaration, it is my opinion that the subject matter of each of the Challenged Claims would have been obvious to one of ordinary skill in the art in view of the known prior art references.

82. It is my understanding that each of the prior art references analyzed in this declaration meets the legal requirements for prior art to the '436 patent. I have performed my analysis with this understanding.

83. Based upon my analysis, it is my opinion that the Challenged Claims of the '436 patent are rendered obvious by the following prior art grounds:

Ground	Claims	Basis for Rejection
1	1-18	Obviousness in view of Rosenstein, Canny, and Xu
2	1-2, 6-7, 11, 13-14, 16-17	Obviousness in view of Nourbakhsh and Tsutsumi

84. Unless specifically noted otherwise below, I have accorded claim terms their ordinary and customary meaning as understood by a POSITA and in light of the patent specification and prosecution history.

A. Ground 1: Claims 1–18 are Rendered Obvious in View of Rosenstein in Combination with Canny and Xu

85. It is my opinion that it would have been obvious to combine Rosenstein, Canny, and Xu to render each claim of the '436 patent obvious.

1. Motivation to Combine Rosenstein, Canny, and Xu

86. It is my opinion that a POSITA reviewing Xu and Canny would have been motivated to combine their teachings with the autonomous mobile human interface robot of Rosenstein. The '436 Patent contemplates edge detection. *See* Ex1001, 5:65-6:3 (“As used herein the term feature may refer to a representation of an object edge, determined by change in color, luminance, brightness, transparency, texture, and/or curvature. The object features may comprise, inter alia, individual edges, intersections of edges (such as corners), orifices, and/or curvature.”).

87. Rosenstein discloses that “[t]hresholds may be recognized by edge detection.” Ex1004, [00146]. Specifically, the “controller 500 may receive imaging data from the cliff detecting proximity sensors 420 (or another imaging sensor on the robot 100), execute an edge detection routine, and issue a drive command based on results of the edge detection routine.” *Id.*

88. It is my opinion that a POSITA would have looked to well-known methods of edge detection in order to perform Rosenstein’s “edge detection routine.”

89. In my opinion, it would have been obvious for a POSITA to look to Canny because the “Canny edge detector is one of the most widely used edge detection algorithms [.]” Ex1006, 501. In my opinion, it would have additionally

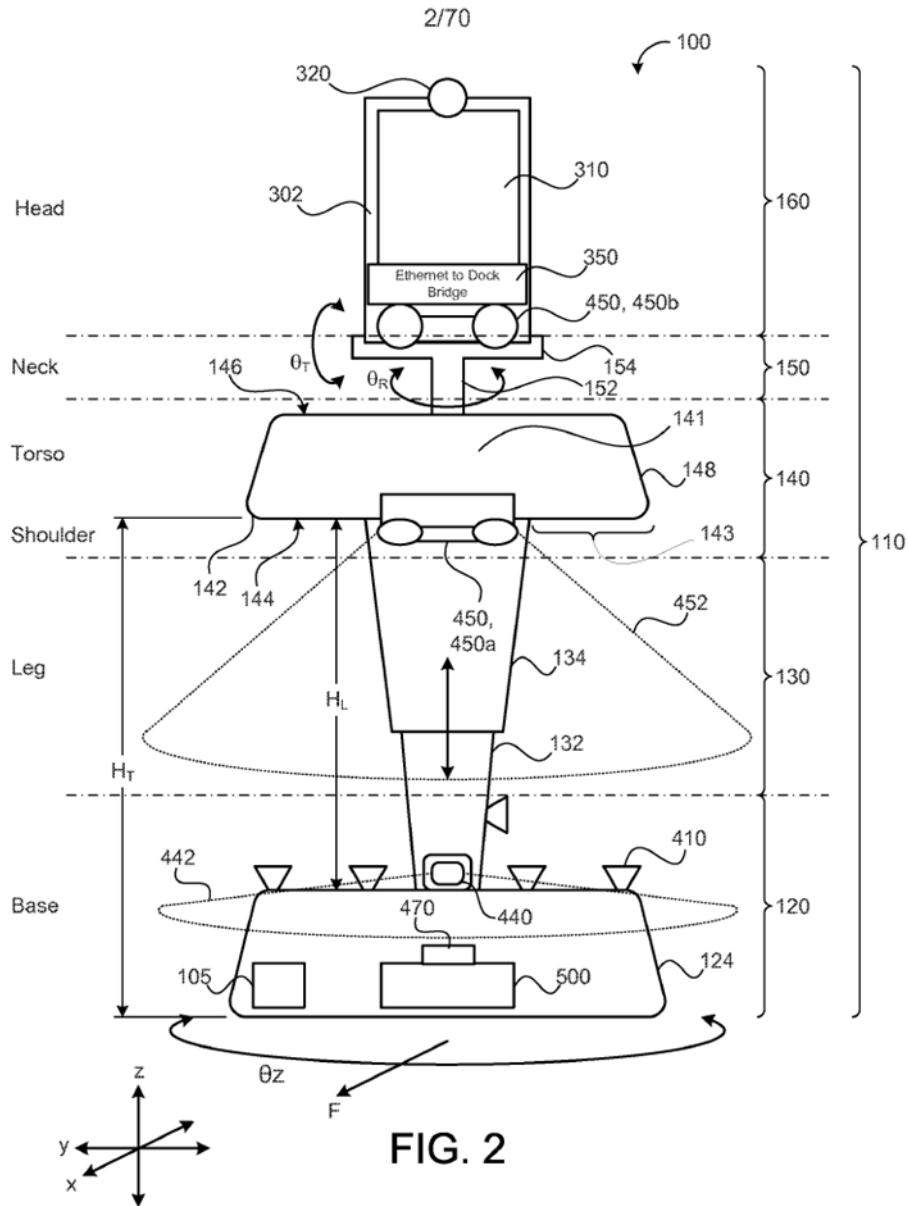
been obvious for a POSITA to look to Xu, which discloses an improvement of the well-known Canny method, one “that results in significantly reduced memory requirements, decreased latency and increased throughput with no loss in edge detection performance as compared to the original Canny algorithm.” Ex1006, 501. And, a POSITA would have reasonably expected success in combining Rosenstein, Canny, and Xu. As explained, the Canny edge detector is “one of the most widely used” edge detection algorithms and Xu renders the Canny edge detector even more efficient, including for use in “real-time implementation[s]” like that in Rosenstein’s autonomous mobile human interface robot. *Id.*, 500.

2. Element-by-Element Analysis

90. My element-by-element analysis is as follows.

a) Element 1[pre]: A method of navigating an apparatus, comprising:

91. To the extent the preamble is limiting, it is my opinion that the Rosenstein/Canny/Xu combination discloses this limitation. Rosenstein discloses a mobile robot 100 that includes a drive system 200 and a controller 500 in communication with the drive system. Ex1004, [00121].



Ex1004, FIG. 2.

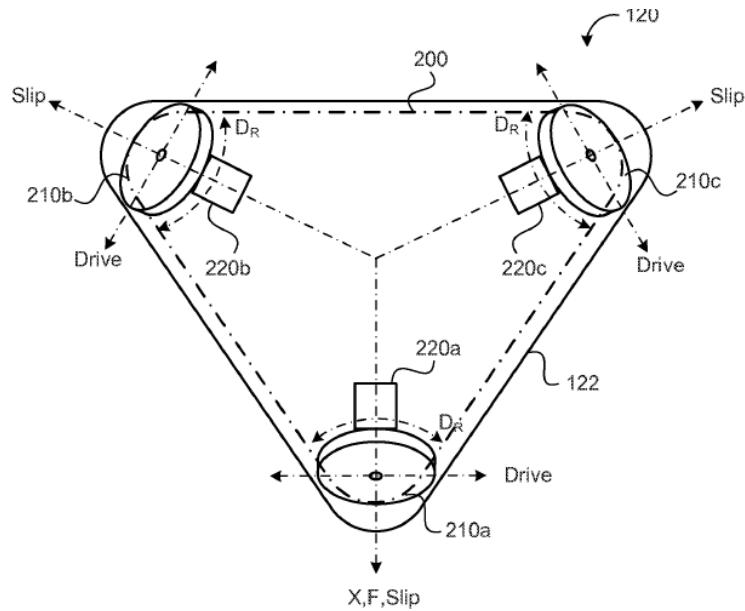


FIG. 5B

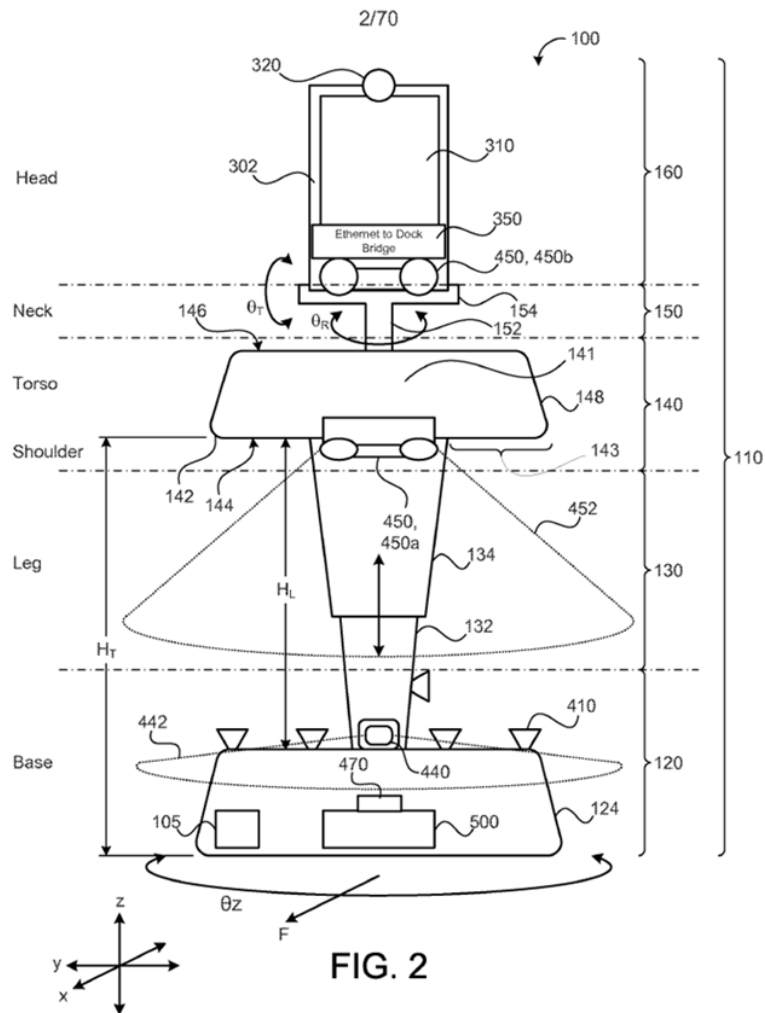
Ex1004, Fig. 5B.

92. Rosenstein's mobile robot 100 corresponds to the claimed "apparatus." Rosenstein further discloses methods through which the controller "issues drive commands to the drive system to maneuver the robot in the scene." *Id.*, [0010]. As such, it is my opinion that Rosenstein discloses a method for "navigating an apparatus."

- b) **Element 1[a]: obtaining at least one image associated with surroundings of the apparatus using a sensor, the apparatus comprising a controller, an actuator and the sensor;**

93. It is my opinion that the Rosenstein/Canny/Xu combination discloses this limitation.

94. Rosenstein discloses that its mobile robot 100 “includes a drive system 200,” and a “sensor system 400,” all in “communication with a controller 500[.]” Ex1004, [00121]. Rostentein’s drive system “maneuver[s] the robot in the scene,” and therefore corresponds to the claimed “actuator.” *Id.*, [0010]. Rosenstein’s “imaging sensor may capture image of the scene along a drive direction of the robot.” *Id.*, [0010]. In my opinion, Rosenstein’s captured image corresponds to the claimed “image associated with surroundings of the apparatus.”



Ex1004, FIG. 2.

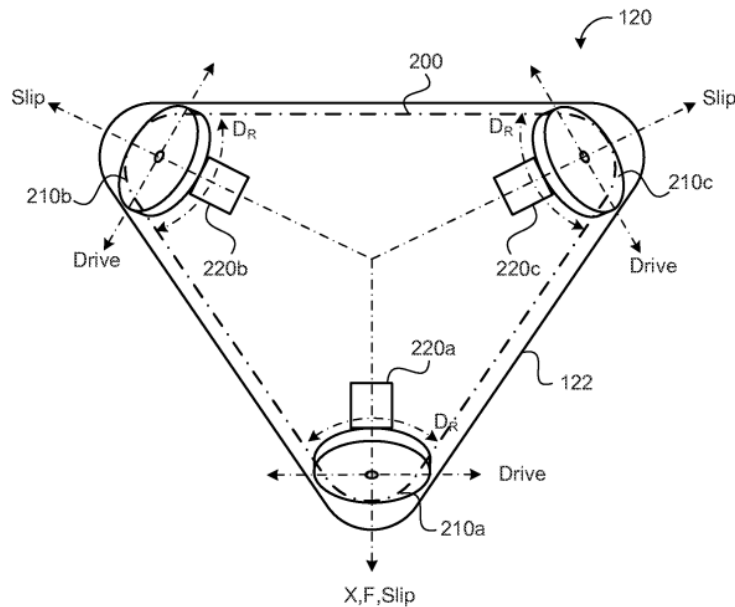


FIG. 5B

Ex1004, FIG. 5B.

- c) Element 1[b]: analyzing the at least one image to detect a presence of an object in the at least one image;**

95. It is my opinion that the Rosenstein/Canny/Xu combination discloses this element. As explained above in Section VII.A.2.b (Element 1[a]), Rosenstein discloses a sensor system 400 that captures an “image of the scene along a drive direction of the robot.” Ex1004, [0010]. Then, “based on [an] image comparison,” the “controller determines a location of an object in the scene.” *Id.* Rosenstein’s “image comparison” to “determine a location of an object in the scene” corresponds, in my opinion, to this claim element.

- d) Element 1[c]: determining the presence of the object based on comparing a contrast parameter of the at least one image to a threshold, the contrast parameter corresponding to a maximum absolute deviation of**

pixels within the at least one image from a reference value, and the threshold being dynamically configured based on one or more parameters; and

96. It is my opinion that the Rosenstein/Canny/Xu combination discloses this limitation.

97. To the extent Rosenstein is found not to disclose this limitation, it is my opinion that Xu discloses it.

98. Xu discloses a Canny edge detection algorithm, which is described in Figure 1 illustrated below.

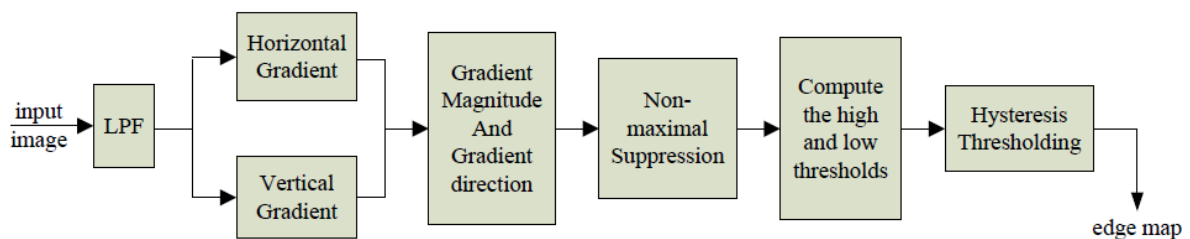


Fig. 1. Block diagram of the Canny edge detection algorithm.

Ex1006, Fig. 1.

99. The Canny edge detection algorithm is “one of the key stages in image processing and object recognition,” Ex1006, 500, i.e., the claimed “determining the presence of the object.” Steps 1 to 4 and Step 6 of Xu’s distributed Canny algorithm are the same as in the original Canny algorithm, disclosed by Canny, “except that they are now applied at the block level.” *Id.*, 501. Step 3 consists of “computing the gradient magnitude $G(x, y)$ and direction $[\]$ at each pixel

location.”*Id.*, 501, Fig. 1. This is followed, in Step 4, by “[a]pplying non-maximal suppression (NMS)” along the gradient direction (directional non-maximal suppression or directional NMS) at each pixel location to retain only the maximum gradient magnitude in each pixel’s neighborhood, i.e., local maximum gradient magnitudes are retained while any “no local maximum gradient magnitude is eliminated.” *Id.*, 501, 503-504, Fig. 1, Fig. 9. A POSITA would have understood that Xu’s disclosed “maximum gradient magnitude” corresponds to the claimed contrast parameter.

100. “[A]pplying non-maximum suppression (NMS)” ensures that the computed contrast parameter corresponds, as claimed, to a maximum absolute deviation of pixels within the at least one image from a reference value. *Id.* Specifically, and as seen in Figure 9 of Xu, at a considered pixel location, NMS checks if the computed gradient magnitude, marked as $M(x,y)$, at that pixel’s location is a maximum by comparing it with the gradient magnitude value at one or more neighboring pixels along the computed gradient direction. Ex1006, 504. In my opinion, a POSITA would have understood that the gradient magnitude value of the one or more neighboring pixels corresponds to the claimed “reference value.” In particular, a POSITA would have understood that if the disclosed “computed gradient magnitude,” when compared with the gradient magnitude of

[one or more neighboring] pixel[s],” is not the maximum, “the pixel that has no local maximum gradient magnitude is eliminated.” *Id.*

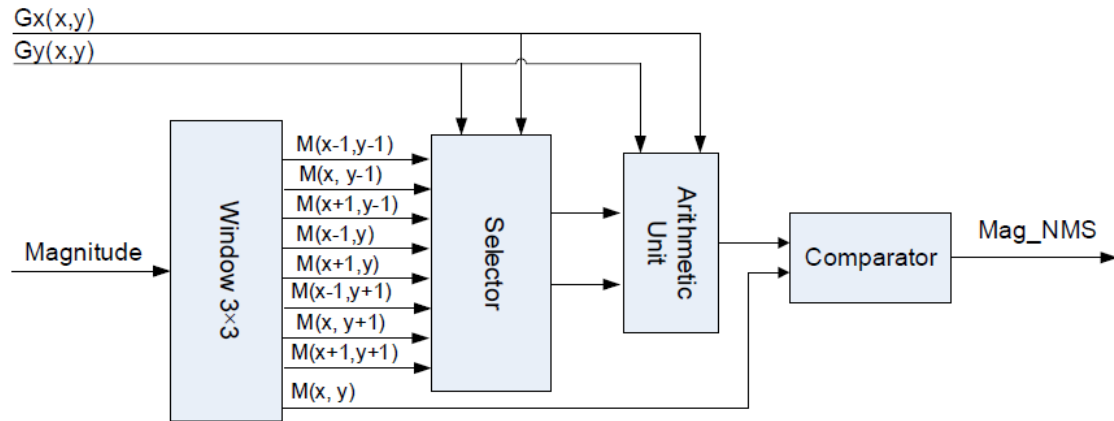


Fig. 9. Directional Non Maximum Suppression Unit.

Ex. 1006, Fig. 9.

101. In my opinion, Xu further discloses that the computed local maximum gradient magnitude (contrast parameter) is compared to a threshold by performing hysteresis thresholding (Step 6 of the Canny edge detection algorithm). Ex1006, 501-502, 504.

102. Additionally, Xu discloses “the threshold being dynamically configured based on one or more parameters,” as claimed. As Xu discloses, “[i]t is known that the original Canny edge detection algorithm needs two adaptive image-dependent high and low thresholds to remove false edges.” Ex. 1006, 500. A POSITA would have understood that the threshold is dynamically configured

because, as Xu discloses, the original Canny edge detection algorithm requires “computing the hysteresis high and low thresholds based on the histogram of the magnitudes of the gradients (after NMS is applied) of the entire image.” *Id.*, 501; *see also id.*, 500.

103. Additionally, Xu discloses that the threshold is dynamically configured based on the local characteristics of image blocks by “propos[ing] a new threshold selection algorithm based on the distribution of pixel gradients in a block of pixels to overcome the dependency between the blocks.” *Id.*, 501-502, 504, Fig. 4.

- e) **Element 1[d]: causing the controller to selectively activate the actuator based on the determination that the object is within the range of the apparatus.**

104. It is my opinion that the Rosenstein/Canny/Xu combination discloses this limitation.

105. Rosenstein discloses a “controller 500” and an actuator in the form of a “drive system 200.” Ex1004, [0010], [00121], [00169], [00171]. Rosenstein further discloses the “controller 500 . . . detecting 1208 one or more features of an object 12 in the scene 10 using image data derived from the light detection signals” and then performing a set of “operations.” Ex1004, [00169]. The operations performed by the controller include “outputting 1214 navigation data for circumventing the object 12 in the scene 10.” *Id.*, [00171]. In “some

implementations, the controller 500 uses the outputted navigation data to issue drive commands to the drive system 200 to move the robot 100 in a manner that avoids collision with the object 12.” *Id.*

22/70

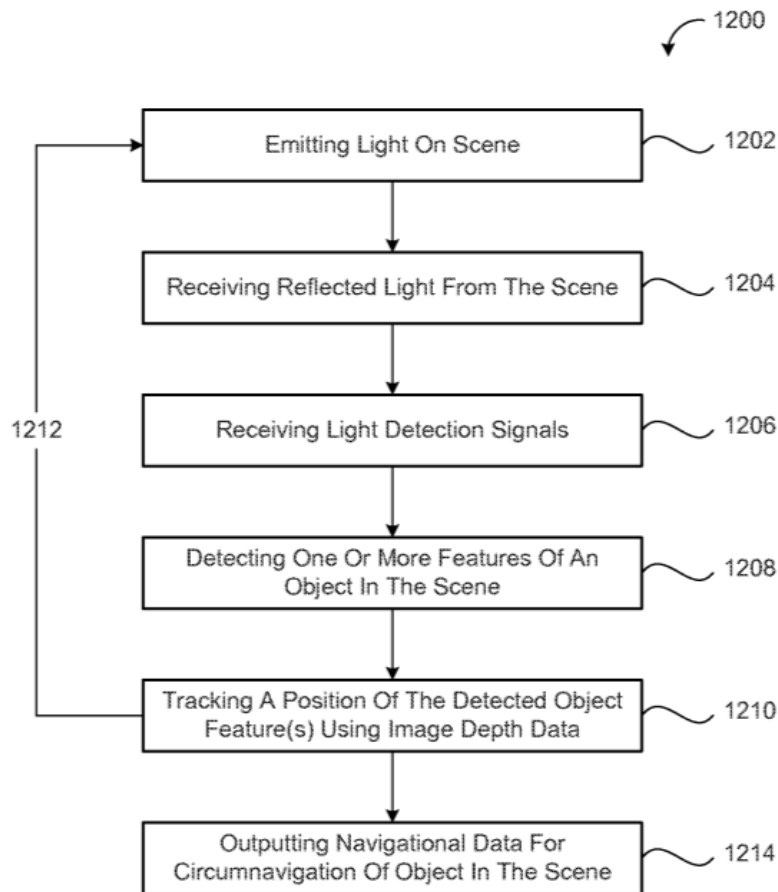


FIG. 12

Ex1004, Fig. 12.

106. In my opinion, a POSITA would have understood that Rosenstein's "controller 500" activates the "drive system 200," e.g., the claimed actuator, once it detects an object nearby or sufficiently close in the scene (corresponding to claimed "based on the determination that the object is within the range of the apparatus"), issuing "drive commands" in order to "avoid[] collision with the object." Ex1004, [00171].

**f) Claim 2: The method of claim 1, further comprising:
adapting movement of the apparatus as the object is
detected in the surroundings of the apparatus.**

107. It is my opinion that the Rosenstein/Canny/Xu combination discloses this limitation.

108. The disclosures provided under Claim 1 are incorporated herein by reference. *See supra* §§ VII.A.2.a-e. As demonstrated above (*see supra* § VII.A.2.e), Rosenstein discloses the "controller 500," issuing "drive commands" to the "drive system 200 to move the robot 100," e.g., the apparatus, in order to "avoid[] collision with the object," which corresponds to the claimed "adapting movement of the apparatus as the object is detected in the surroundings of the apparatus." Ex1004, [00171].

109. Rosenstein further discloses an "obstacle detection obstacle avoidance (ODOA) navigation strategy for the control system 510" which "may include either accepting or rejecting potential robot positions that would result

from commands.” Ex1004, [00234]. For each “robot position 2120 in the robot path 2110,” the ODOA executes “a method for object detection and obstacle avoidance that includes identifying each cell in the grid 2100 that is in a bounding box around a corresponding position of the robot 100, receiving a classification of each cell.” *Id.* For each “cell classified as an obstacle or unknown,” a “grid point corresponding to the cell” is retrieved and, if the “grid point is within [a] collision circle [about a location of the robot 100], the method further includes executing a triangle test of whether the grid point is within the collision triangle.” *Id.* If the “grid point” is “within the collision triangle,” then the method includes “rejecting the grid point.” *Id.* In my opinion, a POSITA would have understood this ODOA navigation strategy to correspond to the claimed “adapting movement of the apparatus as the object is detected in the surroundings of the apparatus.”

g) Claim 3: The method of claim 1, wherein the contrast parameter corresponds to partitioning of the at least one image into a low spatial frequency portion and a high spatial frequency portion.

110. It is my opinion that the Rosenstein/Canny/Xu combination discloses this limitation.

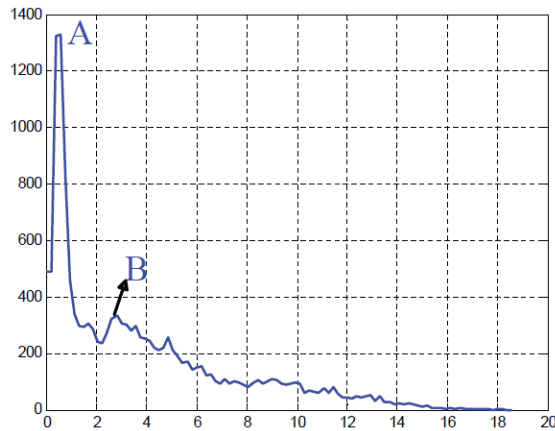
111. To the extent Rosenstein is found not to disclose this limitation, Xu discloses it.

112. The disclosures provided under Claim 1 are incorporated herein by reference. *See supra* §§ VII.A.2.a-e. As discussed above (*see supra* §

VII.A.2.d), Xu's local maximum gradient magnitude corresponds to the claimed contrast parameter. Additionally, Xu discloses that "the largest peak in the gradient magnitude histograms after NMS of the Gaussian smoothed natural images occurs near the origin and corresponds to low spatial frequency content, while edge pixels form a series of smaller peaks where each peak corresponds to a class of edges having similar gradient magnitudes." Ex1006, 501. The "high threshold should be selected between the largest peak and the second largest edge peak." *Id.* Figure 2(b) of Xu shows a sample gradient magnitude histogram. A low spatial frequency portion corresponds to "A," and a high spatial frequency portion corresponds to "B."



(a)



(b)

Fig. 2. (a) Original 512×512 House image; (b) Histogram of the gradient magnitude after non-maximal suppression of the House image.

Ex1006, Fig. 2. In my opinion, a POSITA would have understood that the local maximum gradient magnitude (gradient magnitude after NMS), *e.g.*, the contrast parameter, corresponds to the claimed partitioning of the image into a low spatial frequency portion, A, and a high spatial frequency portion, B.

113. Xu additionally discloses a distributed Canny edge detection algorithm where “the image can be divided into blocks.” Ex1006, 501. Further Xu discloses that the local maximum gradient magnitude (gradient magnitude after NMS), *e.g.*, the contrast parameter, is used to partition the image blocks into “blurred”, “moderately-edged” or “high-detailed” blocks as described in Xu’s Fig. 4, reproduced below. *Id.*

```

Let  $G_t$ : set of pixels with gradient magnitudes greater
      than a threshold  $t$ 
 $N_{G_t}$ : the number of elements in the set  $G_t$ 

Step 1: Determine  $G_t$  for  $t = 2, 4$ , and  $6$  and  $N_{G_t}$  for  $t = 2, 4, 6$ 
Step 2: If ( $N_{G_4} > 0.25 * \text{Total\_block\_pels}$ )
         $C = 6$  /*High-detailed*/
      else If ( $N_{G_4} > 0.05 * \text{Total\_block\_pels}$ )
         $C = 4$  /*moderately-edged*/
      else If ( $N_{G_2} < 0.25 * \text{Total\_block\_pels}$ )
         $C = 2$  /*blurred*/
      Else
        Exit; /*textured*/
Step 3: Compute the 8-bin non-uniform gradient magnitude
        histogram of  $G_c$  and the corresponding cumulative
        distribution function  $F(G_c)$ .
Step 4: Compute High_threshold as  $F(\text{High\_threshold}) = 0.8$ 
Step 5: Compute Low_threshold =  $0.4 * \text{High\_threshold}$ 

```

Ex1006, Fig. 4. In my opinion, a POSITA would have understood that partitioning the image into blocks that are blurred corresponds to the claimed “partitioning of the image into a low spatial frequency portion” and into blocks that are moderately-edged or high-detailed corresponds to the claimed “partitioning of the image into a high spatial frequency portion.”

- h) Claim 4: The method of claim 1, wherein the partitioning is configured by selecting a first area and a second area within the at least one image, the first area corresponds to region around zero frequency, and the second area corresponds to the remaining portion of the spectrum.**

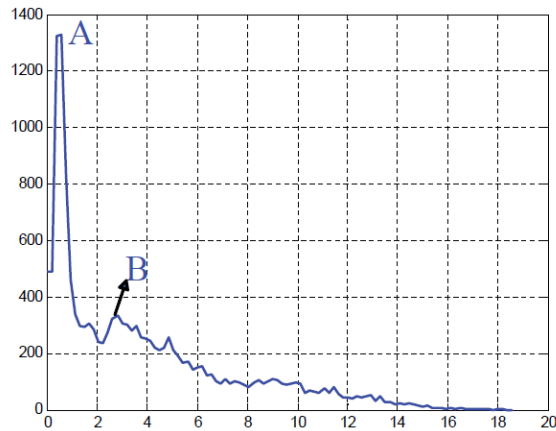
114. It is my opinion that the Rosenstein/Canny/Xu combination discloses this limitation.

115. To the extent Rosenstein is found not to disclose this limitation, Xu discloses it.

116. The disclosures provided under Claim 1 are incorporated herein by reference. *See supra* §§ VII.A.2.a-e. As discussed above (*see supra*, § VII.A.2.g) with respect to Xu's Figure 2(b), Xu discloses partitioning of the image into a low spatial frequency portion, A, and a high spatial frequency portion, B. Xu additionally discloses that, as claimed, the first area corresponds to a region around zero frequency (*see* "A" in Figure 2(b) below) and the second area corresponds to the remaining portion of the spectrum.



(a)



(b)

Fig. 2. (a) Original 512×512 House image; (b) Histogram of the gradient magnitude after non-maximal suppression of the House image.

Ex. 1006, Fig. 2.

- i) **Claim 5: The method of claim 1, wherein the one or more parameters include ambient light conditions surrounding the apparatus and time of day.**

117. It is my opinion that the Rosenstein/Canny/Xu combination discloses this limitation.

118. The disclosures provided under Claim 1 are incorporated herein by reference. *See supra* §§ VII.A.2.a-e. Rosenstein recognizes that “[p]roperly sensing objects 12 using the imaging sensor 450, despite ambient light conditions can be important.” Ex1004, [00189]. Rosenstein notes that “[i]n many environments the lighting conditions cover a broad range from direct sunlight to bright fluorescent lighting to dim shadows, and can result in large variations in

surface texture and basic reflectance of objects 12. Lighting can vary within a given location and from scene 10 to scene 10 as well.” *Id.* The “imaging sensor 450” in Rosenstein “can be used for identifying and resolving people and objects 12 in all situations and with relatively little impact from ambient light conditions (e.g., ambient light rejection).” *Id.* Additionally, in Rosenstein, the “3-D imaging sensor 450 [can] provide[] three types of information,” including ambient light intensity at each pixel detector location,” which corresponds to “[t]he ambient light image [resulting from] ambient light reflected off of the target object 12” and is meant to “provide additional robustness, particularly when lighting conditions are poor (e.g., too dark or excessive ambient lighting).” *Id.*, [00185]. It would have been obvious to a POSITA to utilize Xu’s edge detection with dynamic thresholding method in combination with Rosenstein’s imaging sensor, wherein the threshold is dynamically adapted based on the ambient lighting conditions by means of analyzing local image statistics, to achieve Rosenstein’s goal of allowing its “imaging sensor 450” to be used in “identifying and resolving people and objects 12 in all situations and with relatively little impact from ambient light conditions.” Ex1004, [00189]; Ex1006, 501-502, Fig. 4.

- j) **Element 6[a]: The method of claim 1, further comprising: detecting the object at multiple locations from the apparatus based on the sensor being at a slanted angle; and**

119. It is my opinion that the Rosenstein/Canny/Xu combination discloses this limitation.

120. The disclosures provided under Claim 1 are incorporated herein by reference. *See supra* §§ VII.A.2.a-e. As demonstrated above (*see supra* § VII.A.2.a (Element 1[pre])), Rosenstein discloses a mobile robot, which is the claimed apparatus. Rosenstein's robot may detect an "object" based on "first and second 3-D image sensors 450a, 450b (depth cameras)." Ex1004, [00162]. The "first 3-D image sensor 450a is mounted on the torso 140 and pointed downward at a fixed angle to the ground G." *Id.* This allows the robot to receive "dense sensor coverage in an area immediately forward or adjacent to the robot." *Id.* The "second 3-D image sensor 450b is mounted on the head 160, which can pan and tilt via the neck 150," and the "tilt and/or pan" allows the sensor "to see both close and distant objects." *Id.*, [00163]. Rosenstein further discloses "the robot 100 may tilt the second 3-D image sensor 450b downward slightly to increase a total of combined field of view of both 3-D sensors 450a, 450b, and to give sufficient time for the robot 100 to avoid an obstacle." *Id.*

121. A POSITA would have understood that Rosentein's "3-D image sensor[s]" one "pointed downward at a fixed angle" and the other which can "pan and tilt," allows for the claimed "detecting the object at multiple locations from

the apparatus,” including the area “immediately forward or adjacent to the robot” and “distant objects.”

- k) Element 6[b]: determine, based on the detection of the object, whether the apparatus is approaching the object or the object is approaching the apparatus.**

122. It is my opinion that the Rosenstein/Canny/Xu combination discloses this limitation.

123. As demonstrated above (*see supra* § VII.A.2.a (Element 1[pre])), Rosenstein discloses a mobile robot, which is the claimed apparatus. Rosenstein further discloses that the “robot 100 may include first and second 3-D image sensors 450a, 450b (depth cameras).” Ex1004, [00162]. “During fast travel, the robot 100 may tilt the second 3-D image sensor 450b downward slightly to increase a total or combined field of view” and “to give sufficient time for the robot 100 to avoid an obstacle.” *Id.*, [00163]. At “slower speeds, the robot 100 may tilt the second 3-D image sensor 450b upward or substantially parallel to the ground G to track a person that the robot 100 is meant to follow.” *Id.* Rosenstein further discloses “[i]f the person [] approaches too close to the robot 100, the robot can optionally back away from the person [] to maintain a safe distance.” *Id.*, [00259]; *see also id.*, [0025], [00251]-[00252].

124. Rosenstein further discloses “operations for operating” its imaging sensor(s) including repeating operations “(e.g., continuously) to track

motion of the object 12 within the scene 10.” *Id.*, [00180]. Additionally, Rosenstein discloses the sensors “may repeatedly capture scene depth images for real-time decision making by the controller 500 to navigate the robot 100 about the scene without colliding into any objects in the scene.” *Id.*, [00167].

125. A POSITA would have understood that Rosenstein’s sensors that allow for “real-time decision making” in order to navigate the “robot” about the “scene” and that prevent the robot from “colliding into any objects in the scene” and that “track the motion of the object(s)” and that “maintain a safe distance” by backing away from an approaching object, discloses the claimed determination of whether the robot is approaching the object or the object is approaching the robot.

I) Claim 7: The method of claim 1, wherein the sensor comprising a linear array of photo sensitive elements.

126. It is my opinion that the Rosenstein/Canny/Xu combination discloses this limitation.

127. The disclosures provided under Claim 1 are incorporated herein by reference. *See supra* §§ VII.A.2.a-e. Rosenstein discloses its mobile robot includes a “sensor system 400” which “includes a set or an array of proximity sensors 410, 420 in communication with the controller 500 and arranged in one or more zones or portions of the robot 100.” Ex1004, [00139]. The “proximity sensors 410, 420” may be “imaging sensors.” *Id.* In some implementations, “the 3-D imaging sensors 450” include “an imager 1174 (e.g., an array of light-

sensitive pixels 1174p) which captures reflected light from the scene.” Ex1004, [00168]. Rosenstein further discloses “an image sensor 1324 having an array of light detectors.” *Id.*, [00174]; *see also id.*, [0005] (disclosing “imager includes an array of light detecting pixels”), [0039] (disclosing “imager may include an array of light detecting pixels”), [00169] (disclosing “an Imager (e.g., array of light-sensitive pixels”), [00182] (disclosing imaging sensor “may include an array of pixel detectors 1522, or other arrangement of pixel detectors 1522, where each pixel detector 1522 is capable of detecting the intensity and phase of photonic energy impinging on it”).

128. A POSITA would have understood Rosenstein’s disclosed image sensor(s) (e.g., “imager 1174” or “image sensor 1324”) as comprising the claimed linear array of photo sensitive elements.

m) Claim 8: The method of claim 7, wherein the linear array of photo sensitive elements disposed along axial direction of a lens.

129. It is my opinion that the Rosenstein/Canny/Xu combination discloses this limitation.

130. The disclosures provided under Claim 7 are incorporated herein by reference. *See supra* § VII.A.2.1. Referring to FIG. 11 in Rosenstein, reproduced below, the imaging sensor 450 includes “an imager 1174 (e.g., an array of light-sensitive pixels 1174p) which captures reflected light from the scene

10.” Ex1004, [00168]. As discussed above (*see supra* § VII.A.2.1), the “imager 1174” comprises the claimed array of photo sensitive elements (1174p in FIG. 11, reproduced below). Rosenstein further discloses that the “imaging sensor 450” may also include “a light source lens 1176 and/or a detector lens 1178 for manipulating (e.g., speckling or focusing) the emitted and received reflected light.” *Id.*

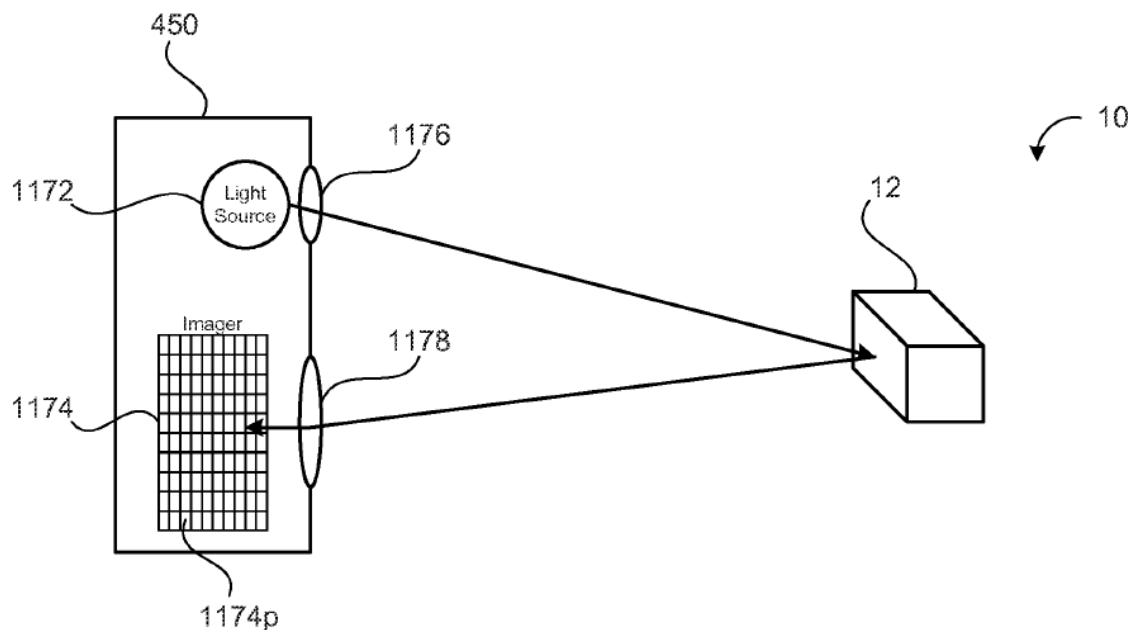


FIG. 11

Ex1004, FIG. 11. As seen in FIG. 11, Rosenstein’s array of photo sensitive elements (e.g., 1174p in FIG. 11), comprises a linear array of photo sensitive elements that are disposed along an axial direction of a lens (e.g., lens 1178 in

FIG. 11), as claimed.

- n) **Claim 9: The method of claim 1, wherein the sensor comprises one or more sensing layers axially displaced from one another, each one of the one or more sensing layers comprise a plurality of photo sensitive elements.**

131. It is my opinion that the Rosenstein/Canny/Xu combination discloses this limitation.

132. The disclosures provided under Claim 1 are incorporated herein by reference. *See supra* §§ VII.A.2.a-e.

133. As discussed above (see *supra* §§ VII.A.2.l-m), Rosenstein discloses a sensor 450 which comprises an imager 1174 made up of an array of photo sensitive elements, the claimed “sensing layers” which “comprise a plurality of photo sensitive elements.” As seen in FIG. 11, reproduced below, the photo sensitive elements are arranged in sensing layers axially displaced from one another.

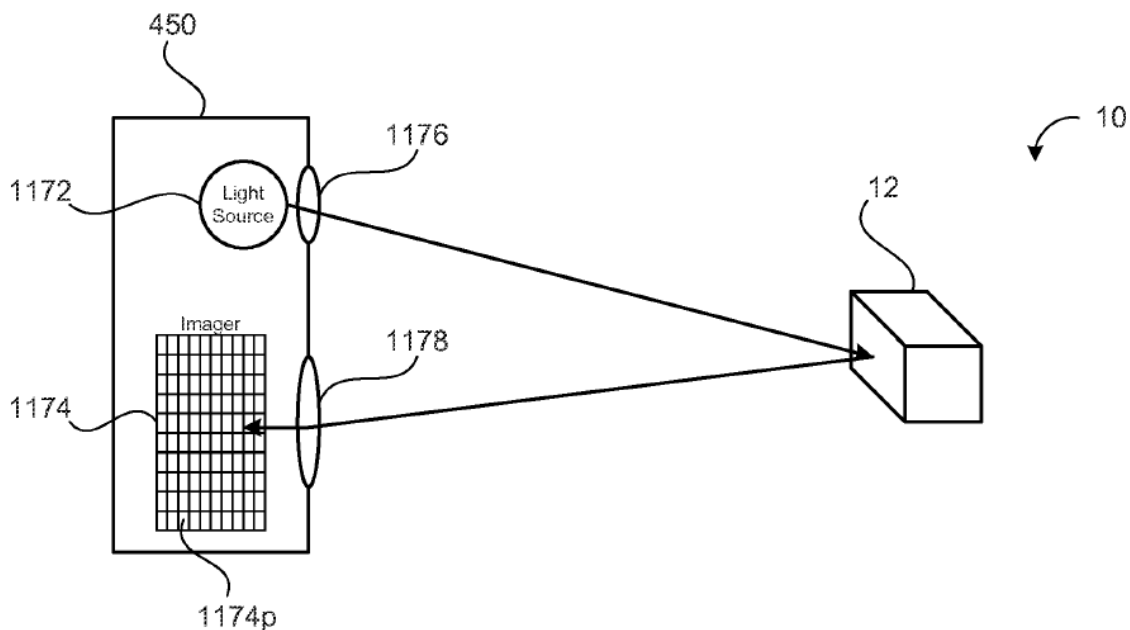


FIG. 11

Ex1004, FIG. 11.

134. Additionally, referring to FIG. 15 reproduced below, Rosenstein also discloses that “in some implementations, the 3-D imaging sensor 450 includes a 3D time-of-flight (TOF) camera 1500 for obtaining depth image data. The 3D TOF camera 1500 includes a light source 1510, a complementary metal oxide semiconductor (CMOS) sensor 1520 (or charge-coupled device CCD), a lens 1530, and control logic or a camera controller 1540.” Ex1004, [00182]. The CMOS or CCD sensor 1520 “may include an array of pixel detectors 1522, or other arrangement of pixel detectors 1522, where each pixel detector 1522 is capable of detecting the intensity and phase of photonic energy impinging on it.”

Id. As seen in FIG. 15 reproduced below, the pixel detectors 1522, which are the claimed photo sensitive elements, make up one or more sensing layers and each sensing layer is axially displaced from one another.

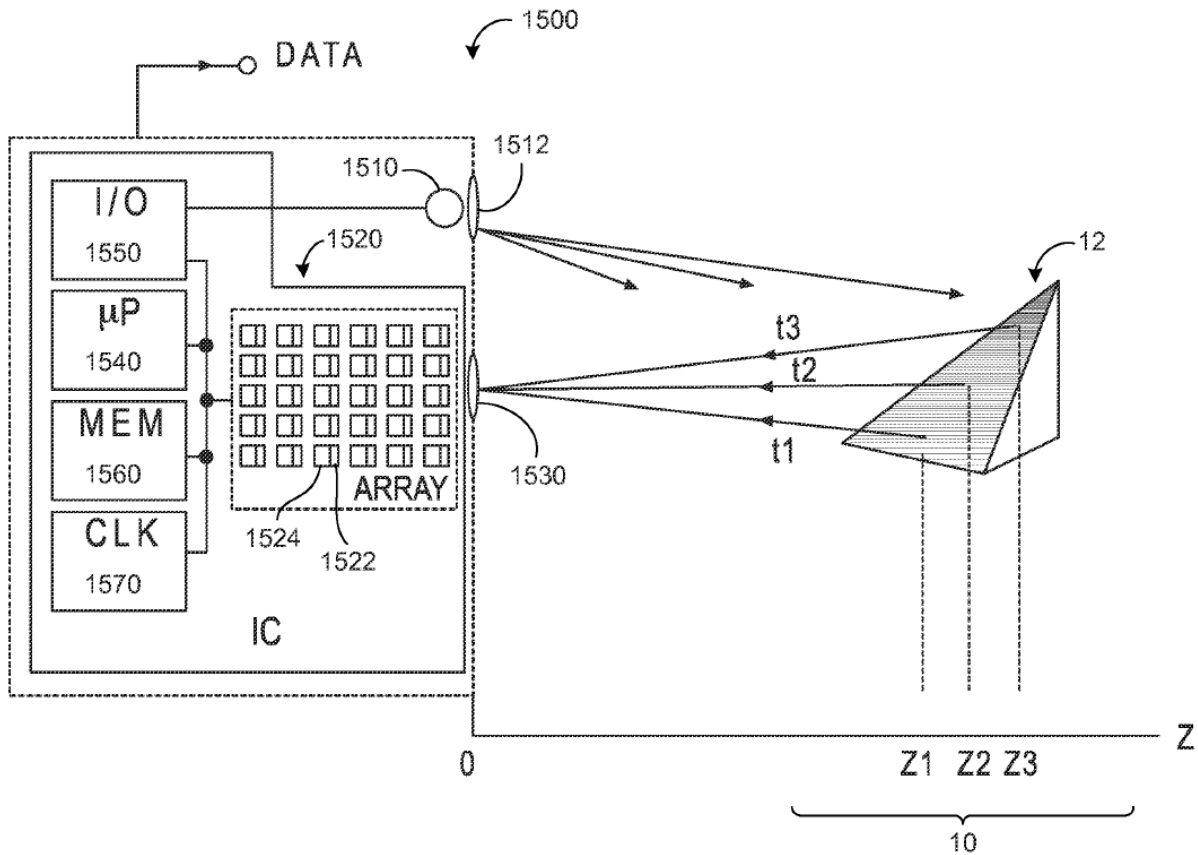


FIG. 15

Ex1004, FIG. 15.

- o) **Claim 10: The method of claim 9, wherein the axial displacement of the one or more sensing layers is configured to produce an axial distribution of multiple focal planes, and wherein the axial distribution of multiple focal planes is configurable to enable detection of object positioned in front of the apparatus.**

135. It is my opinion that the Rosenstein/Canny/Xu combination discloses this limitation.

136. The disclosures provided under Claim 9 are incorporated herein by reference. *See supra* § VII.A.2.n. Referring to FIG. 15 reproduced below, the photo sensitive elements, pixel detectors 1522, make up one or more sensing layers and each sensing layer is axially displaced from one another. *See supra* § VII.A.2.n. Additionally, Rosenstein discloses that the one or more sensing layers are configured to produce an axial distribution of multiple focal planes, corresponding to a range of depths, e.g., Z1, Z2, Z3 as shown in FIG. 15, reproduced below.

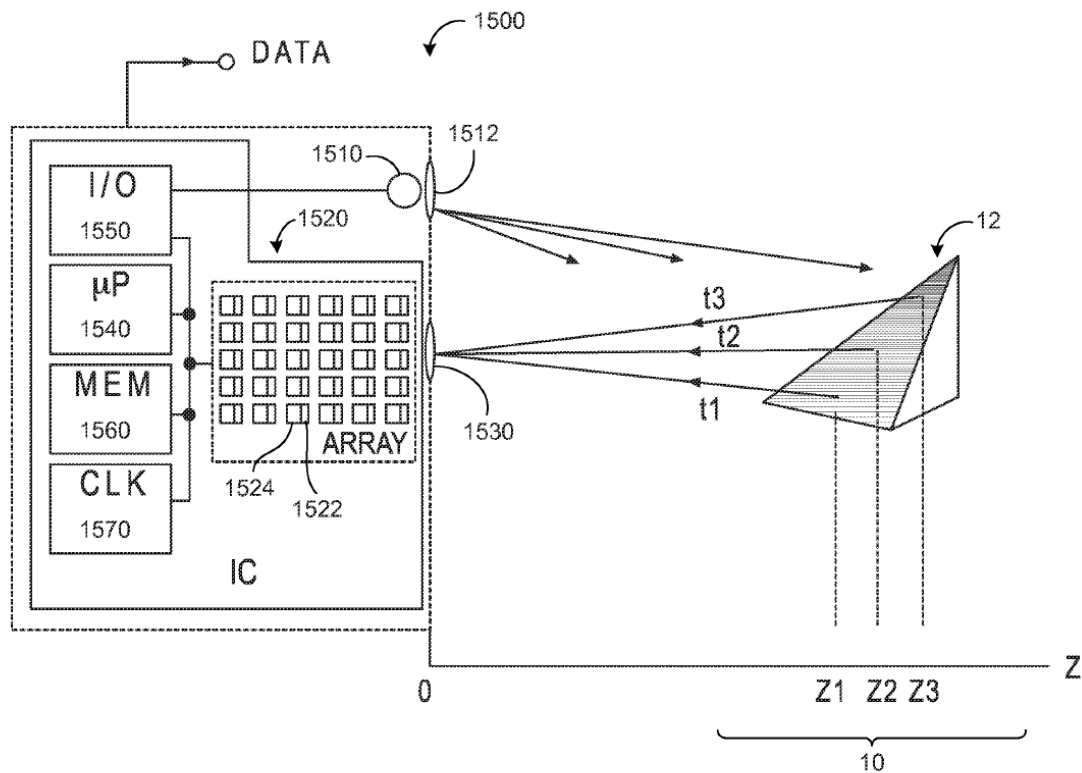


FIG. 15

Ex1004, FIG. 15. A POSITA would have understood that the multiple focal planes, (e.g., corresponding to Z1, Z2, and Z3 in FIG. 15), would enable the claimed detection of the object positioned in front of the apparatus.

137. Additionally, referring to FIG. 13 reproduced below, Rosenstein discloses that its robot may include an “imager 1320” which “may include objective optics 1322, which focus the image onto an image sensor 1324 having an array of light detectors 1326, such as a CCD or CMOS-based image sensor.” Ex1004, [00174]. A “speckle emitter 1310 emits a speckle pattern into the scene 10 and the imager 1320 captures reference images of the speckle pattern in the

scene 10 at a range of different object distances Z_n from the speckle emitter 1310.” *Id.*, [00175]. The “reference images of the projected speckle pattern are captured at a succession of planes at different, respective distances from the origin, such as at the fiducial locations marked Z_1 , Z_2 , Z_3 , and so on.” *Id.* Rosenstein further discloses that the captured reference images allow “to perform distance ranging of objects 12 captured in subsequent images.” *Id.*

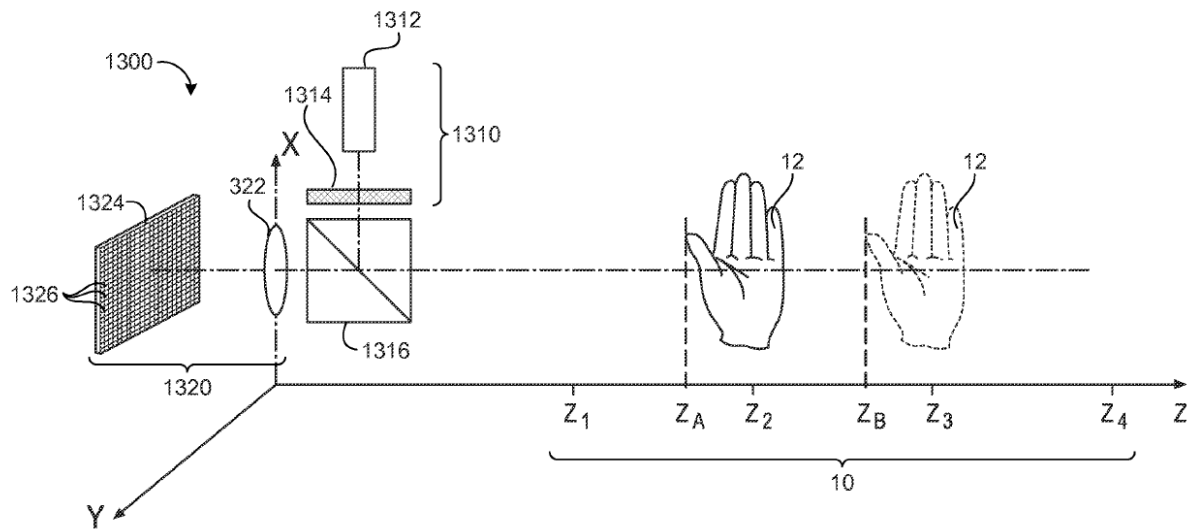


FIG. 13

Ex1004, FIG. 13.

- p) **Element 11[pre]: A non-transitory computer-readable storage medium having computer readable instructions stored thereon, that when executed by at least one controller device configure the at least one controller device to:**

138. To the extent the preamble is limiting, it is my opinion that the Rosenstein/Canny/Xu combination discloses this limitation.

139. Rosenstein discloses “reasoning or control software, executable on a processor (e.g., of the robot controller 500)” which “uses a combination of algorithms executed using various data types generated by the sensor system.” Ex1004, [00165]. The “reasoning software processes the data collected from the sensor system 400 and outputs data for making navigational decisions on where the robot 100 can move without colliding with an obstacle.” *Id.*

140. Rosenstein further discloses “[t]he applications 520 can be stored in memory of or communicated to the robot 100, to run concurrently on (e.g., a processor) and simultaneously control the robot 100.” *Id.*, [00240].

q) Element 11[a]: receive data from at least one sensor, the data comprising at least one image of an environment;

141. It is my opinion that the Rosenstein/Canny/Xu combination discloses this limitation.

142. Rosenstein discloses that the “reasoning software processes the data collected from the sensor system 400” and “accumulat[es] imaging data over time of the robot’s surroundings.” Ex1004, [00165]. A POSITA would have understood this to be the claimed “receiving data from at least one sensor, the data

comprising at least one image of an environment.” *See also supra* § VII.A.2.b (Element 1[a]) incorporated herein by reference.

- r) **Element 11[b]: analyze an image, from the data generated by the at least one sensor, to determine a contrast parameter of the image, the contrast parameter comprising a deviation parameter, a reference value, and/or threshold associated with object detection, the contrast parameter corresponding to a maximum absolute deviation of pixels within the at least one image from a reference value;**

143. This limitation was addressed in the discussion of Elements 1[b] and 1[c] and is disclosed by the Rosenstein/Canny/Xu combination for substantially the same reasons. See §§ VII.A.2.c–d.

- s) **Element 11[c]: determine presence of the object based on comparing the contrast parameter of the image to a threshold, the threshold being dynamically configured based on one or more parameters; and**

144. This limitation was addressed in the discussion of Element 1[c] and is disclosed by the Rosenstein/Canny/Xu combination for substantially the same reasons. See §§ VII.A.2.d.

- t) **Element 11[d]: determine a location of the object from the contrast parameter meeting or exceeding the threshold at the location of the object.**

145. This limitation was addressed in the discussion of Element 1[c] and is disclosed by the Rosenstein/Canny/Xu combination for substantially the same reasons. See § VII.A.2.d.

- u) **Element 12[a]: The non-transitory computer-readable storage medium of claim 11, wherein the at least one controller device is further configurable to execute the computer readable instructions to: receive data from the at least one sensor, the data comprising dynamic lighting parameters of the environment; and**

146. It is my opinion that the Rosenstein/Canny/Xu combination discloses this limitation.

147. The disclosures provided under Claim 11 are incorporated herein by reference. *See supra* §§ VII.A.2.p-t. As explained above (*see supra* § VII.A.2.i), the “3-D imaging sensor 450 provides three types of information,” including “ambient light intensity at each pixel detector location.” Ex1004, [00185]. The “ambient light image is of ambient light reflected off of the target object 12” and the provided sensor information provides “additional robustness, particularly when lighting conditions are poor (e.g., too dark or excessive ambient lighting).” *Id.* *See also supra* § VII.A.2.i (Claim 5) incorporated herein by reference.

148. A POSITA would have understood that the “ambient light image” information provided by the sensor is the claimed “data comprising dynamic lighting parameters of the environment” and that those lighting parameters necessarily change depending on the ambient lighting conditions of the environment being imaged.

- v) **Element 12[b]: adjust the threshold for object detection based on the data from the at least one sensor.**

149. It is my opinion that the Rosenstein/Canny/Xu combination discloses this limitation.

150. To the extent Rosenstein is found not to disclose this limitation, it is my opinion that Xu discloses it.

151. As explained above in Section VII.A.2.d (Element 1[c]), Xu discloses that the computed local maximum gradient magnitude, e.g., contrast parameter, is compared to a threshold by performing hysteresis thresholding (Step 6 of the Canny edge detection algorithm). Ex1006, 501-502, 504. Xu further discloses that the threshold is “adjusted for object detection based on the data from the at least one sensor” because Xu’s distributed Canny edge detection algorithm “proposes a new threshold selection algorithm based on the distribution of pixel gradients in a block of pixels to overcome the dependency between the blocks.” Ex1006, 501-502, 504, Fig. 4.

- w) **Claim 13: The non-transitory storage medium of claim 11, wherein the at least one controller device is further configurable to execute the computer readable instructions to: determine a contrast parameter criterion comprising a fixed or a dynamic value from statistics of multiple images gathered by the at least one sensor.**

152. It is my opinion that the Rosenstein/Canny/Xu combination discloses this limitation.

153. The disclosures provided under Claim 11 are incorporated herein by reference. *See supra* §§ VII.A.2.p-t.

154. As explained above (*see supra* § VII.A.2.p-q), Rosenstein discloses the non-transitory storage medium of claim 11, wherein the at least one controller device is further configurable to execute the computer readable instructions based on data received from a sensor. *See* §§ VII.A.2.p-q (Elements 11[pre] and 11[a]) incorporated herein by reference. Additionally, as discussed in Section VII.A.2.c-d (Elements 1[b] and 1[c]) *supra*, Xu discloses determining a contrast parameter criterion comprising a fixed or a dynamic value from statistics of multiple images. *See* §§ IV.A.2.c–d (Elements 1[b] and 1[c]) incorporated herein by reference.

155. It would have been obvious for a POSITA to configure Rosenstein's computer readable instructions, which are set to interpret image data received from a sensor for purposes of object detection, to determine a contrast parameter criterion as disclosed by Xu.

- x) **Element 14[a]: The non-transitory storage medium of claim 11, wherein the at least one controller device is further configurable to execute the computer readable instructions to: partition a first image into at least two sub-images, the at least two sub-images comprise different energy spectra or regions of the first image;**

and

156. It is my opinion that the Rosenstein/Canny/Xu combination discloses this limitation.

157. The disclosures provided under Claim 11 are incorporated herein by reference. *See supra* §§ VII.A.2.p-t.

158. This limitation was addressed in the discussion of Claim 3 and is disclosed by the Rosenstein/Canny/Xu combination for substantially the same reasons. *See* §§ VII.A.2.g.

y) Element 14[b]: apply filtering operations to the at least one of the two sub-images prior to the determination of a contrast parameter criterion.

159. It is my opinion that the Rosenstein/Canny/Xu combination discloses this limitation.

160. To the extent Rosenstein is found not to disclose this limitation, Xu discloses it.

161. Xu's distributed Canny edge detection algorithm first takes the image and "partition[s] [it] into q sub-images and each sub-image is further divided into $p \times m \times m$ blocks." *Id.*, 502. As explained above in Section VI.B.3, Xu discloses "detect[ing] the edge map of an $m \times m$ block image" using its distributed Canny algorithm and that "Steps 1 to 4 and Step 6 of Xu's distributed Canny

algorithm are the same as in the original Canny algorithm except that these are now applied at the block (sub-image) level.” Ex1006, 501, 503.

162. At Step 1, prior to the determination of a contrast parameter, Xu’s distributed Canny edge detection algorithm applies a “[s]moothing [operation to a block (sub-image)] using Gaussian filter.” *Id.*, 503. Subsequently, Xu’s distributed Canny edge detection algorithm involves, at Step 2, prior to the determination of a contrast parameter criterion, “[c]alculating the horizontal gradient $G_x(x,y)$ and vertical gradient $G_y(x,y)$ at each pixel location by convolving [(filtering)] the image $I(x,y)$ (block or sub-image in Xu) with partial derivatives of a 2D Gaussian function [filter].” Ex1006, 501, 503.

163. Since the contrast parameter (local maximum gradient magnitude) is determined at Step 4 in Xu by means of non-maximal suppression (NMS), a POSITA would have understood that Xu’s distributed Canny edge detection algorithm applies the claimed “filtering operation,” *e.g.*, the “Gaussian filter” (performed in Step 1) or the “partial derivative of a 2D Gaussian” filter (performed in Step 2), to at least “one of the two sub-images” prior to the determination of a contrast parameter criterion.

- z) **Claim 15: The non-transitory storage medium of claim 11, wherein the at least one controller device is further configurable to execute the computer readable instructions to: apply an asymmetrical filter to the at least one image received from the at least one sensor to facilitate the detection of an object at a target**

orientation.

164. It is my opinion that the Rosenstein/Canny/Xu combination discloses this limitation.

165. To the extent Rosenstein is found not to disclose this limitation, Canny discloses it.

166. The disclosures provided under Claim 11 are incorporated herein by reference. *See supra* §§ VII.A.2.p-t. Canny teaches that “when edge contours are locally straight, highly directional operations will give better results than operators with a circular support.” Ex1005, 697. As such, a “method was proposed for the efficient generation of highly directional masks [(i.e., filters)] at several orientations, and their integration into a single description.” *Id.*; *see also id.*, 695 (disclosing “[c]onsidering the advantages, it is obviously preferable to use directional operators whenever they are applicable”), Fig. 10(c) (showing the impulse response of asymmetrical directional filters), reproduced below.

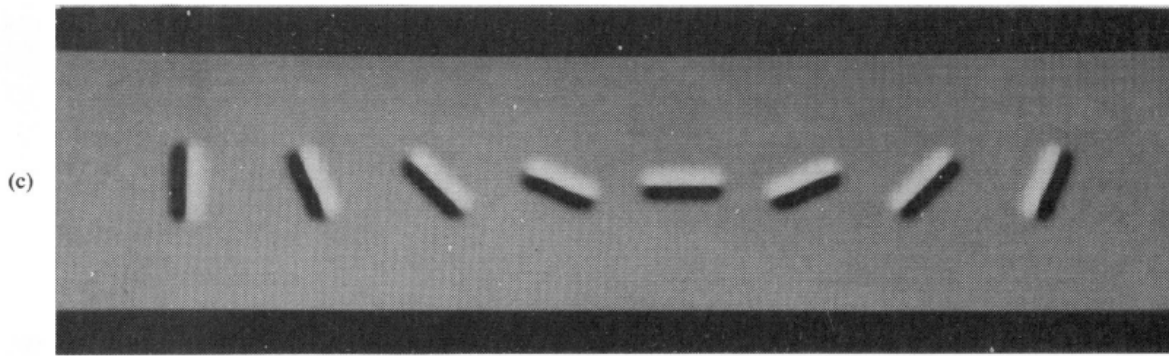


Fig. 10. Directional step edge mask. (a) Cross section parallel to the edge direction. (b) Cross section normal to edge direction. (c) Two-dimensional impulse responses of several masks.

Ex1005, Fig.10(c).

167. A POSITA would have understood that Canny's "directional masks" having each an elongated directional impulse response (also referred to as "directional operators") refer to asymmetrical filters.

aa) Element 16[pre]: A method for detection of objects near an apparatus, comprising:

168. This limitation was addressed in the discussion of Elements 1[a] and 1[b] and is disclosed by the Rosenstein/Canny/Xu combination for substantially the same reasons. See §§ VII.A.2.b-c (Elements 1[a] and 1[b]).

bb) Element 16[a]: gathering data from at least one sensor, the data comprising at least one image of an environment surrounding the apparatus;

169. This limitation was addressed in the discussion of Elements 1[a] and 11[a] and is disclosed by the Rosenstein/Canny/Xu combination for substantially the same reasons. See §§ VII.A.2.b, VII.A.2.q.

cc) Element 16[b]: analyzing the at least one image, to

determine a contrast parameter of the at least one image, the contrast parameter comprising a deviation parameter, a reference value, and/or threshold associated with object detection, the contrast parameter corresponding to a maximum absolute deviation of pixels within the at least one image from a reference value;

170. This limitation was addressed in the discussion of Elements 1[b], 1[c], and 11[b] and is disclosed by the Rosenstein/Canny/Xu combination for substantially the same reasons. See §§ VII.A.2.c–d, VII.A.2.r.

dd) Element 16[c]: determining if an object is present in the image based on comparing the contrast parameter of the at least one image to a threshold, the threshold being dynamically configured based on one or parameters.

171. This limitation was addressed in the discussion of Elements 1[c] and 11[c] and is disclosed by the Rosenstein/Canny/Xu combination for substantially the same reasons. See §§ VII.A.2.d, VII.A.2.s.

ee) Element 17[a]: The method of claim 16, further comprising: partitioning a first image, from the plurality of images, into at least two sub-images comprising two different energy spectra or regions of the first image; and

172. It is my opinion that Claim 16 is disclosed by the Rosenstein/Canny/Xu combination as discussed in Sections VII.A.2.aa-dd, *supra*. Further, this limitation was addressed in the discussion of Claim 3 and Element 14[a] and is disclosed by the Rosenstein/Canny/Xu combination for substantially the same reasons. See §§ VII.A.2.g, VII.A.2.x.

- ff) Element 17[b]: applying filtering and/or cropping operations to the at least one of the two sub-images prior to the determination of a contrast parameter criterion.**

173. This limitation was addressed in the discussion of Element 14[b] and is disclosed by the Rosenstein/Canny/Xu combination for substantially the same reasons. See § VII.A.2.y.

- gg) Claim 18: The method of claim 16, further comprising: applying an asymmetrical filter to the data from the at least one sensor to facilitate detection of objects at a target orientation.**

174. It is my opinion that Claim 16 is disclosed by the Rosenstein/Canny/Xu combination as discussed in Sections VII.A.2.aa-dd, *supra*. Further, this limitation was addressed in the discussion of Claim 15 and is disclosed by the Rosenstein/Canny/Xu combination for substantially the same reasons. See § VII.A.2.z.

B. Ground 2: Claims 1–2, 6–7, 11, 13–14, and 16–17 are Rendered Obvious in View of Nourbakhsh in Combination with Tsutsumi

175. It is my opinion that it would have been obvious to combine Nourbakhsh with Tsutsumi to render each claim of the '436 patent obvious.

1. Motivation to Combine Nourbakhsh with Tsutsumi

176. A POSITA would have been motivated to combine Nourbakhsh's mobile robot and mobile robot control system with Tsutsumi's method of computing a contrast parameter and selecting in-focus images.

177. It is my opinion that Nourbakhsh and Tsutsumi each teach very similar methods for object detection and generating depth (object distance) information. That's because each uses an array of cameras to capture multiple images of the same scene at different focal lengths; each then divides the images into regions and calculates a sharpness or contrast value for each region; each then uses the computed sharpness or contrast value for each region to determine which of the images has one or more of the regions in focus and at which distance (depth); each subsequently determines the depth corresponding to each region.

178. Additionally, a POSITA would have understood that Tsutsumi's method has the advantage over Nourbakhsh of generating actual distance (range) information. Nourbakhsh's method generates categorical or relative depth information.

179. It is my opinion that a POSITA would have been motivated to use Tsutsumi's method with the mobile robot of Nourbakhsh because Tsutsumi's more accurate range information would enable more precise navigation of Nourbakhsh's mobile robot. It is also my opinion that a POSITA would have understood that combining Tsutsumi with Nourbakhsh would mean a simple substitution of Nourbakhsh's in-focus determination method with Tsutsumi's in-focus determination method yielding predictable results.

2. Element-by-Element Analysis

180. My element-by-element analysis is as follows.

a) Element 1[pre]: A method of navigating an apparatus, comprising:

181. To the extent the preamble is limiting, it is my opinion that Nourbakhsh discloses it.

182. Nourbakhsh discloses an “obstacle avoidance system for a mobile robot,” in which the depth map information is used by a “robot motion control computer” to “direct[] the robot to move while preventing collision with objects in the environment.” Ex1007, 4:58-61, 5:36-42. It is my opinion that a POSITA would have recognized that this represents a method of navigating an apparatus (i.e., the mobile robot).

b) Element 1[a]: obtaining at least one image associated with surroundings of the apparatus using a sensor, the apparatus comprising a controller, an actuator and the sensor;

183. It is my opinion that Nourbakhsh discloses this limitation.

184. Nourbakhsh discloses three charge-coupled-device (CCD) cameras mounted on a robot and wired to simultaneously capture images of the robot’s surroundings. Ex1007, 4:62-5:1. These cameras constitute the claimed “sensor,” and the robot is the claimed “apparatus.” Nourbakhsh further discloses that the robot includes a “motor controller 38 for controlling the motion of the robot in three independent degrees of freedom: forward and backward translation,

rotation of the wheel base, and rotation of the turret.” Ex1007, 5:42-49. It is my opinion that a POSITA would have recognized that this disclosure indicates the robot includes both a controller (i.e., motor controller 38) and an actuator (i.e., the motor that motor controller 38 controls).

185. It is my opinion that Tsutsumi also discloses obtaining images using a sensor. Tsutsumi discloses “a camera array image capturing device including a plurality of image capturing units.” Ex1008, 3:35-59. Tsutsumi further discloses an “image acquisition unit” that acquires color images from the image capturing units. *Id.*, 5:33-34.

c) Element 1[b]: analyzing the at least one image to detect a presence of an object in the at least one image;

186. It is my opinion that Nourbakhsh and Tsutsumi each discloses this limitation.

187. Nourbakhsh discloses that a “microprocessor and memory [] breaks each image into an array of image regions, analyzes the regions, and generates a depth map.” Ex1007, 5:9-11. The robot motion control computer “checks if there is an obstacle in front of the robot” based on whether the “depth map deviates from the normal depth map.” *Id.*, 5:36-42, 5:54-65. Further, Nourbakhsh discloses that its invention of “a device for producing a categorical depth map of a scene” has many applications, including “object detection.” *Id.*, 3:51-4:17. Thus, it is my opinion that a POSITA would have recognized that

Nourbakhsh's generating a depth map and using it to check for and avoid obstacles constitutes the claimed "analyzing the at least one image to detect the presence of an object in the image." Additionally, Nourbakhsh discloses that its depth map generating device is "used for detecting the presence of an object." *Id.*, cl. 17.

188. Tsutsumi discloses that "[t]he present invention has an effect to provide a range image including a main object and a background from an image group acquired by a camera array image capturing device." Ex1008 2:18-22. Within "image processing unit 212" (Fig. 4), "[a] distance calculation unit 405 calculates a distance to the object by using parameters supplied from the parameter acquisition unit 403, an image determined to be in focus by the in-focus image selection unit 404, and monochrome images stored in the memory unit 407 and outputs the distance." *Id.*, 5:31-58. A POSITA would have recognized that determining the distance to an object includes detecting the object in the first place. Thus, it is my opinion that a POSITA would have recognized that Tsutsumi's identifying in-focus images and using those to determine the distance to an object constitutes the claimed "analyzing the at least one image to detect the presence of an object in the image."

- d) **Element 1[c]: determining the presence of the object based on comparing a contrast parameter of the at least one image to a threshold, the contrast parameter corresponding to a maximum absolute deviation of pixels within the at least one image from a reference value, and the threshold being dynamically configured**

based on one or more parameters; and

189. It is my opinion that the Nourbakhsh/Tsutsumi combination discloses this limitation.

190. As explained above in Section VII.B.2.c (Element 1[b]), Nourbakhsh teaches using a depth map generated by analyzing a set of images to detect the presence of an object, and Tsutsumi teaches determining the distance to an object, which involves detecting that object. *See* § VII.B.2.c. Specifically, Nourbakhsh generates the depth map by dividing each of the images into regions and subsequently identifying which image is more in-focus for each of the regions. Ex1007, 6:36-50. Similarly, Tsutsumi generates a depth image by selecting in-focus images. Ex1008 5:33-58, 7:16-18.

191. Additionally, Tsutsumi discloses, for the purpose of selecting the in-focus images, a “contrast value $C(ii,jj,m)$ ” calculated using the difference between the maximum and minimum monochrome pixel intensity values in the (ii,jj) image region for each image m , as set forth in Formula 4. *Id.*, 10:54-67. It is my opinion that a POSITA would have recognized that Tsutsumi’s contrast value constitutes the claimed “contrast parameter” and that the minimum monochrome pixel value corresponds to the claimed “reference value.” Further, because Formula 4 involves subtracting the minimum pixel value (i.e., reference value) from the maximum pixel value in the region, Tsutsumi’s contrast value

“correspond[s] to a maximum absolute deviation of pixels . . . from a reference value,” as required by this limitation.

192. Tsutsumi further discloses that the contrast value is compared to a threshold value T_h to determine whether the selected image is in-focus. Ex1008, 11:66-12:1. Depending on the value of N_c , which indicates the number of in-focus images, T_h may be decreased and the comparison process repeated. *Id.*, 12:37-48. It is my opinion that a POSITA would have recognized that this constitutes the claimed “comparing a contrast parameter . . . to a threshold, . . . the threshold being dynamically configured based on one or more parameters.” Specifically, the threshold is dynamically configured based on the parameter N_c .

193. It is my opinion that, by using Tsutsumi’s method for identifying in-focus images in Nourbakhsh’s system of generating a depth map for navigating a mobile robot, the Nourbakhsh/Tsutsumi combination discloses this limitation.

e) Element 1[d]: causing the controller to selectively activate the actuator based on the determination that the object is within the range of the apparatus.

194. It is my opinion that Nourbakhsh discloses this limitation.

195. Nourbakhsh discloses that “[i]f the depth map deviates from the normal depth map, then it is presumed that an obstacle is in front of the robot and it is then determined whether an obstacle is dangerously close or not.” Ex1007, 5:62-65. If an obstacle is dangerously close, then a stop signal is sent to the robot.

Id., 6:1-3. If the obstacle is not dangerously close, then the robot is signaled “to proceed at partial forward speed.” *Id.*, 6:3-6.

- f) **Claim 2: The method of claim 1, further comprising: adapting movement of the apparatus as the object is detected in the surroundings of the apparatus.**

196. As discussed above in Sections VII.B.2.a-e, Claim 1 is rendered obvious by the Nourbakhsh/Tsutsumi combination. See §§ VII.B.2.a-e. Further, this limitation was addressed in the discussion of Element 1[d] and it is disclosed by the Nourbakhsh/Tsutsumi combination for substantially the same reasons. *See* § VII.B.2.e.

- g) **Element 6[a]: The method of claim 1, further comprising: detecting the object at multiple locations from the apparatus based on the sensor being at a slanted angle; and**

197. It is my opinion that Nourbakhsh discloses this limitation.

198. Nourbakhsh discloses that “[t]he cameras are mounted on a robot 26 in a common direction approximately 35 degrees below the horizontal plane.” Ex1007, 4:65-5:1. It is my opinion that a POSITA would have understood that this describes the cameras being at a slanted angle. Further, Nourbakhsh discloses that cameras simultaneously capture their respective images of the scene, such that the object is detected at multiple locations. *Id.* For example, Nourbakhsh explains that “the n camera means are oriented so that the n images represent very

similar but slightly different perspectives of the scene due to their different positions.” *Id.*, 3:67-4:3.

199. It is my opinion that Tsutsumi’s disclosure is compatible with this aspect of Nourbakhsh, because it states that the “the image capturing units can be arranged arbitrarily,” including “radially or linearly” or “at random.” Ex1008, 3:55-59.

h) Element 6[b]: determine, based on the detection of the object, whether the apparatus is approaching the object or the object is approaching the apparatus.

200. It is my opinion that Nourbakhsh discloses this limitation.

201. Nourbakhsh discloses that, as the mobile robot moves, the control loop repeatedly checks the current depth map for obstacles, and classifies obstacles as being “dangerously close or not.” Ex1007, 5:62-6:19. Specifically, “[i]f the depth map deviates from the normal depth map, then it is presumed that an obstacle is in front of the robot and then it is determined whether an obstacle is dangerously close or not.” *Id.* If “the object is not dangerously close,” then the robot “proceed[s] at partial forward speed.” After the robot moves, “the current depth map is again checked,” *id.*, at which point the object may be detected to have approached the robot and become dangerously close.

202. It is my opinion that a POSITA would have recognized that this process enables the robot to determine whether the apparatus and object are

approaching each other as required by this limitation. Nourbakhsh also discloses that one of the objectives is to provide a method “that can operate in a wide variety of environmental conditions” including “in circumstances involving relative motion between the camera and objects in the scene.” Ex1007, 3:9-14.

i) Claim 7: The method of claim 1, wherein the sensor comprising a linear array of photo sensitive elements.

203. It is my opinion that Nourbakhsh discloses this limitation.

204. Nourbakhsh discloses that the cameras are charge-coupled-device (CCD) cameras with a resolution of 768×493. Ex1007, 4:62-65. A POSITA would have recognized that the CCD’s resolution indicates the number of photo sensitive elements and indicates that they are arranged in a grid, which comprises linear arrays as required by this limitation.

205. It is my opinion that Tsutsumi also discloses its sensor in the image capturing units can be a CCD sensor. Ex1008, 4:37-49.

j) Element 11[pre]: A non-transitory computer-readable storage medium having computer readable instructions stored thereon, that when executed by at least one controller device configure the at least one controller device to:

206. To the extent the preamble is limiting, it is my opinion that Nourbakhsh discloses it.

207. Nourbakhsh discloses a “microprocessor and memory 32 for image processing.” Ex1007, 5:4-15. It is my opinion that a POSITA would have

recognized that the memory is a non-transitory computer-readable storage medium with instructions for the microprocessor to perform its image processing operations.

- k) Element 11[a]: receive data from at least one sensor, the data comprising at least one image of an environment;**

208. It is my opinion that Nourbakhsh discloses this limitation.

209. Nourbakhsh discloses that the image signals from the three cameras are digitized and “then transferred over a bus to a microprocessor and memory 32.” Ex1007, 5:2-6.

- l) Element 11[b]: analyze an image, from the data generated by the at least one sensor, to determine a contrast parameter of the image, the contrast parameter comprising a deviation parameter, a reference value, and/or threshold associated with object detection, the contrast parameter corresponding to a maximum absolute deviation of pixels within the at least one image from a reference value;**

210. This limitation was addressed in the discussion of Element 1[c] and it is disclosed by the Nourbakhsh/Tsutsumi combination for substantially the same reasons. *See* § VII.B.2.d.

- m) Element 11[c]: determine presence of the object based on comparing the contrast parameter of the image to a threshold, the threshold being dynamically configured based on one or more parameters; and**

211. It is my opinion that the Nourbakhsh/Tsutsumi combination discloses this limitation.

212. As I explained above in Sections VII.B.2.c-d, Tsutsumi identifies in-focus image regions based on comparing a contrast parameter to a dynamic threshold, and Nourbakhsh uses the determination of in-focus regions to create a depth map that enables the detection of objects. See §§ VII.B.2.c-d (Elements 1[b] and 1[c]).

n) Element 11[d]: determine a location of the object from the contrast parameter meeting or exceeding the threshold at the location of the object.

213. It is my opinion that the Nourbakhsh/Tsutsumi combination discloses this limitation.

214. As I explained above in Sections VII.B.2.c-d, Tsutsumi identifies in-focus image regions based on comparing a contrast parameter to a dynamic threshold, and Nourbakhsh uses the determination of in-focus regions to create a depth map. See §§ VII.B.2.c-d (Elements 1[b] and 1[c]) incorporated herein by reference. The depth map indicates the location of the object(s) within the scene. Ex1007, 5:19-31, 5:62-6:1.

215. As an example, Nourbakhsh's FIG. 2B illustrates the depth map for a scene (FIG. 2A) with an object (i.e., column) in a specific location:

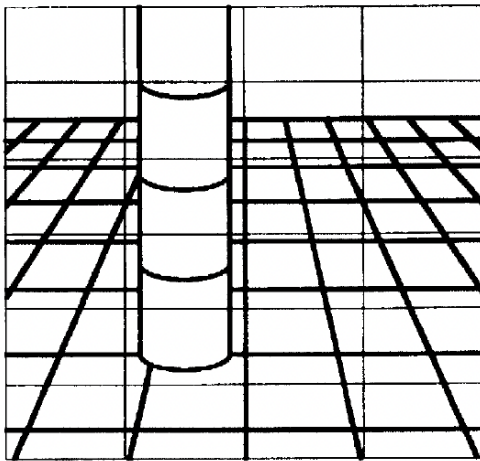


FIG. 2A

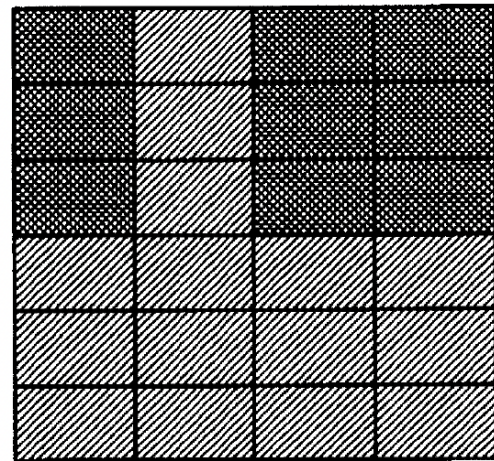


FIG. 2B

Ex1007, FIGs. 2A, 2B.

- o) **Claim 13: The non-transitory storage medium of claim 11, wherein the at least one controller device is further configurable to execute the computer readable instructions to: determine a contrast parameter criterion comprising a fixed or a dynamic value from statistics of multiple images gathered by the at least one sensor.**

216. As discussed above in Sections VII.B.2.j-n, it is my opinion that Claim 11 is rendered obvious by the Nourbakhsh/Tsutsumi combination. Further, it is my opinion that Tsutsumi discloses this limitation. Tsutsumi discloses that the contrast value of the same region from multiple images is compared to the threshold to identify the in-focus images. Ex1008, 12:7-51. Each contrast value is then calculated using values from “a histogram based on values of pixels in the image area.” *Id.*, 10:51-67. It is my opinion that a POSITA would have recognized that the in-focus determination of Tsutsumi involves the claimed contrast

parameter criterion that uses statistics (such as the histograms as disclosed by Tsutsumi) from multiple images gathered by the camera sensors.

- p) **Element 14[a]: “The non-transitory storage medium of claim 11, wherein the at least one controller device is further configurable to execute the computer readable instructions to: partition a first image into at least two sub-images, the at least two sub-images comprise different energy spectra or regions of the first image; and”**

217. It is my opinion that Nourbakhsh and Tsutsumi each individually or in combination disclose this limitation.

218. Nourbakhsh discloses that “[t]he synchronized image signals from the three cameras are fed into the R, G, and B input lines of an RGB framegrabber, which digitizes the signals. The digitized signals are then transferred over a bus to a microprocessor and memory 32 for image processing.” Ex1007 5:2-6. A POSITA would have understood that different colors of light, including the R (red), B (blue), and G (green) signals described in Nourbakhsh, comprise different energy spectra. Thus, Nourbakhsh discloses partitioning the image into sub-images of different energy spectra.

219. Further, Nourbakhsh and Tsutsumi each discloses partitioning an image into different regions. Nourbakhsh discloses that the microprocessor and memory 32 “breaks each image into an array of image regions.” Ex1007, 5:9-11.

Tsutsumi discloses that “area division unit 604 divides the image area . . . into $N_i \times N_j$ sub-areas.” Ex1008, 6:59-63.

- q) **Element 14[b]: apply filtering operations to the at least one of the two sub-images prior to the determination of a contrast parameter criterion.**

220. It is my opinion that the Nourbakhsh/Tsutsumi combination discloses this limitation. As discussed above, Nourbakhsh discloses partitioning the image into sub-images of different energy spectra. Tsutsumi discloses that the image capturing units include “an optical low pass filter 306, an IR cut filter 307, [and] a color filter 308.” Ex1008, 4:37-42. Applying Tsutsumi’s low pass filter to Nourbakhsh’s R, G, and B sub-images discloses this limitation.

- r) **Element 16[pre]: A method for detection of objects near an apparatus, comprising:**

221. To the extent the preamble is limiting, Nourbakhsh discloses it. This limitation was addressed in the discussions of Elements 1[a] and 1[b] and is disclosed by the Nourbakhsh/Tsutsumi combination for substantially the same reasons. *See* §§ VII.B.2.b-c.

- s) **Element 16[a]: gathering data from at least one sensor, the data comprising at least one image of an environment surrounding the apparatus;**

222. This limitation was addressed in the discussion of Elements 1[a] and 11[a] and is disclosed by the Nourbakhsh/Tsutsumi combination for substantially the same reasons. *See* §§ VII.B.2.b, VII.B.2.k.

- t) **Element 16[b]: analyzing the at least one image, to determine a contrast parameter of the at least one image, the contrast parameter comprising a deviation parameter, a reference value, and/or threshold associated with object detection, the contrast parameter corresponding to a maximum absolute deviation of pixels within the at least one image from a reference value;**

223. This limitation was addressed in the discussion of Elements 1[b], 1[c] and 11[b] and is disclosed by the Nourbakhsh/Tsutsumi combination for substantially the same reasons. *See* §§ VII.B.2.c-d, VII.B.2.l.

- u) **Element 16[c]: determining if an object is present in the image based on comparing the contrast parameter of the at least one image to a threshold, the threshold being dynamically configured based on one or parameters.**

224. This limitation was addressed in the discussion of Elements 1[c] and 11[c] and is disclosed by the Nourbakhsh/Tsutsumi combination for substantially the same reasons. *See* §§ VII.B.2.d, VII.B.2.m.

- v) **Element 17[a]: The method of claim 16, further comprising: partitioning a first image, from the plurality of images, into at least two sub-images comprising two different energy spectra or regions of the first image; and**

225. As discussed above in Sections VII.B.2.r-u, it is my opinion that Claim 11 is rendered obvious by the Nourbakhsh/Tsutsumi combination. Further, this limitation was addressed in the discussion of Claim 14[a] and is disclosed by

the Nourbakhsh/Tsutsumi combination for substantially the same reasons. *See* § VII.B.2.p.

- w) **Element 17[b]: applying filtering and/or cropping operations to the at least one of the two sub-images prior to the determination of a contrast parameter criterion.**

226. This limitation was addressed in the discussion of Claim 14[b] and is disclosed by the Nourbakhsh/Tsutsumi combination for substantially the same reasons. *See* § VII.B.2.q.

VIII. SECONDARY CONSIDERATIONS

227. It is my understanding that, in parallel litigation, the Patent Owner has asserted that this patent, along with four other patents asserted, generally resolve a long-felt need, and that the technology claimed within the '436 patent enabled it to become an industry leader in autonomous robots and artificial intelligence. It identified a number of awards and recognition in the industry, and alleged that its products achieved commercial success and industry recognition given the number of robots it has sold and the hours of operation of those robots. It also alleged that the Petitioner has willfully infringed the asserted patents, and that the Petitioner's alleged infringement is a further indicator of non-obviousness. It is my further understanding that the Petitioner denies that it has infringed the asserted patents or copied the Patent Owner's technology.

228. It is my opinion that these vague allegations are not evidence of secondary considerations of non-obviousness tied to the Challenged Claims. For example, the Patent Owner did not establish any nexus between the claims and any of the alleged secondary indicia of non-obviousness. Moreover, it is my understanding that where there is a strong showing of obviousness, as here, even relevant secondary considerations supported by substantial evidence do not dislodge the primary conclusion of obviousness.

229. To the extent Patent Owner is permitted to provide any additional evidence or arguments supporting secondary considerations to rebut my opinions expressed herein, I reserve the right to respond by supplementing and/or amending this declaration or submitting a reply declaration to consider the alleged secondary considerations of nonobviousness.

IX. CONCLUSION

230. For the reasons set forth above, it is my opinion that the Challenged Claims of the '436 patent are invalid.

231. I hereby declare that all statements made herein of my own knowledge are true, and that all statements made on information and belief are believed to be true, and that these statements were made with knowledge that willful false statements and the like are so made punishable by fine or imprisonment, or both, under section 1001 of Title 18 of the United States Code,

and that such willful false statements may jeopardize the Petition for *inter partes* review.

Executed on December 3, 2025
Scottsdale, Arizona

By: 

Dr. Lina J. Karam