

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

In re Patent of:	Erez Galil	
U.S. Patent No.:	8,447,132	Attorney Docket No.: 39521-0044IP1
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Appl. Serial No.:	12/961,400	
Filing Date:	December 6, 2010	
Title:	DYNAMIC RANGE CORRECTION BASED ON IMAGE CONTENT	

DECLARATION OF ALAN C. BOVIK, PH.D., P.E

1. My name is Alan C. Bovik. I hold a Ph.D. in Electrical and Computer Engineering from the University of Illinois, Urbana-Champaign (awarded in 1984). I also hold a Master's degree in Electrical and Computer Engineering from the University of Illinois, Urbana-Champaign (awarded in 1982). I am a tenured full Professor and I hold the Cockrell Family Regents Endowed Chair at the University of Texas at Austin. My appointments are in the Department of Electrical and Computer Engineering, the Department of Computer Sciences, and the Department of Biomedical Engineering. I am also the Director of the Laboratory for Image and Video Engineering ("LIVE"). My research is in the general area of digital television, digital cameras, image and video processing, computational neuroscience, and modeling of biological visual perception. I have published over 800 technical articles in these areas and hold seven U.S. patents. I am also the author of The Handbook of Image and Video Processing, Second Edition (Elsevier Academic Press, 2005); Modern Image Quality Assessment (Morgan & Claypool,

2006); The Essential Guide to Image Processing (Elsevier Academic Press, 2009); and The Essential Guide to Video Processing (Elsevier Academic Press, 2009); and numerous other publications. Among other relevant research, I have worked with the National Aeronautics and Space Administration (“NASA”) to develop high compression image sequence coding and animated vision technology, on various military projects for the Air Force Office of Scientific Research, Phillips Air Force Base, the Army Research Office, and the Department of Defense. These projects have focused on developing local spatio-temporal analysis in vision systems, scalable processing of multi-sensor and multi-spectral imagery, image processing and data compression tools for satellite imaging, AM-FM analysis of images and video, the scientific foundations of image representation and analysis, computer vision systems for automatic target recognition and automatic recognition of human activities, vehicle structure recovery from a moving air platform, passive optical modeling, and detection of speculated masses and architectural distortions in digitized mammograms. My research has also recently been funded by Netflix, Qualcomm, Facebook, Texas Instruments, Intel, Cisco, and the National Institute of Standards and Technology (NIST) for research on image and video quality assessment. I have also received numerous grants from the National Science Foundation for research on image and video processing and on computational vision.

2. I have been selected to receive the 2019 IEEE Fourier Award with citation: “For seminal contributions and high-impact innovations to the theory and application of perception-based image and video processing.” This Technical Field Award and medal is one of the highest honors accorded by the 423,000-member IEEE. I received the 2017 Edwin H. Land Medal from the Optical Society of America in September 2017 with citation: For substantially shaping the direction and advancement of modern perceptual picture quality computation, and for energetically engaging industry to transform his ideas into global practice. I received a Primetime Emmy Award for Outstanding Achievement in Engineering Development, for the Academy of Television Arts and Sciences, in October 2015, for the widespread use of my video quality prediction and monitoring models and algorithms that are widely used throughout the global broadcast, cable, satellite and internet Television industries. Among other awards and honors, I have received the 2013 IEEE Signal Processing Society’s “Society Award,” which is the highest honor accorded by that technical society (“for fundamental contributions to digital image processing theory, technology, leadership and education”). In 2005, I received the Technical Achievement Award of the IEEE Signal Processing Society, which is the highest technical honor given by the Society, for “broad and lasting contributions to the field of digital image processing”; and in 2008 I received the Education Award of the IEEE Signal Processing Society, which is the

highest education honor given by the Society, for “broad and lasting contributions to image processing, including popular and important image processing books, innovative on-line courseware, and for the creation of the leading research and educational journal and conference in the image processing field.” I have also been honored by other technical organizations, including the Society for Photo-optical and Instrumentation Engineers (SPIE), from which I received the Technology Achievement Award (2013) “For Broad and Lasting Contributions to the Field of Perception-Based Image Processing,” and the Society for Imaging Science and Technology, which accorded me Honorary Membership, which is the highest recognition by that Society given to a single individual, “for his impact in shaping the direction and advancement of the field of perceptual image processing.” I was also elected as a Fellow of the Institute of Electrical and Electronics Engineers (IEEE) “for contributions to nonlinear image processing” in 1995, a Fellow of the Optical Society of America (OSA) for “fundamental research contributions to and technical leadership in digital image and video processing” in 2006, and as a Fellow of SPIE for “pioneering technical, leadership, and educational contributions to the field of image processing” in 2007.

3. My technical articles have been widely recognized as well, including the 2009 IEEE Signal Processing Society Best Journal Paper Award for the paper “Image quality assessment: From error visibility to structural similarity,” published

in IEEE Transactions on Image Processing, volume 13, number 4, April 2004; this same paper received the 2017 IEEE Signal Processing Society Sustained Impact Paper Award as the most impactful paper published over a period of at least ten years; the 2013 Best Magazine Paper Award for the paper “Mean squared error: Love it or leave it?? A new look at signal fidelity measures,” published in IEEE Transactions on Image Processing, volume 26, number 1, January 2009; the IEEE Circuits and Systems Society Best Journal Paper Prize for the paper “Video quality assessment by reduced reference spatio-temporal entropic differencing,” published in the IEEE Transactions on Circuits and Systems for Video Technology, vol. 23, no. 4, pp. 684-694, April 2013; the 2017 IEEE Signal Processing Letters Best Paper Award for the paper A. Mittal, R. Soundararajan and A.C. Bovik, “Making a ‘completely blind’ image quality analyzer,” published in the IEEE Signal Processing Letters, vol. 21, no. 3, pp. 209-212, March 2013. This paper describes a unique “blind” (no-reference) video quality tool called NIQE that is being used to control the quality of cloud-based streaming videos globally. Also, the 2018 EURASIP Best Paper Award of the European Association for Signal Processing for 2018, for the paper “Full-Reference Quality Assessment of Stereopairs Accounting for Rivalry,” Signal Processing: Image Communication, vol. 28, no. 10, pp. 1143-1155, October 2013, and the Best Paper Award of the 2018 Picture

Coding Symposium for the paper, “Detecting Source Video Artifacts with Supervised Sparse Filters.”

4. I have also been honored by other technical organizations, including the Society for Photo-optical and Instrumentation Engineers (SPIE), from which I received the Technology Achievement Award (2013) “For Broad and Lasting Contributions to the Field of Perception-Based Image Processing,” and the Society for Imaging Science and Technology, which accorded me Honorary Membership, which is the highest recognition by that Society given to a single individual, “for his impact in shaping the direction and advancement of the field of perceptual image processing.” I was also elected as a Fellow of the Institute of Electrical and Electronics Engineers (IEEE) “for contributions to nonlinear image processing” in 1995, a Fellow of the Optical Society of America (OSA) for “fundamental research contributions to and technical leadership in digital image and video processing” in 2006, and as a Fellow of SPIE for “pioneering technical, leadership, and educational contributions to the field of image processing” in 2007. Additional details about my employment history, fields of expertise, and publications are further described in my curriculum vitae, which is attached as Appendix A to this report.

5. I have been retained on behalf of Apple Inc. to offer technical opinions relating to U.S. Patent No. 8,447,132 (the ’132 Patent) and prior art

references relating to its subject matter. I have reviewed the '132 Patent and relevant excerpts of the prosecution history of the '132 Patent. Additionally, I have reviewed the following: U.S. Publication No. 2002/0181801 to Needham et al. ("Needham" or Ex. 1004), U.S. Publication No. 2008/0007634 to Nonaka et al. ("Nonaka" or Ex. 1005), U.S. Patent 6,891,977 to Gallagher ("Gallagher" or Ex. 1006), and U.S. Publication No. 2008/0291287 to Dvir ("Dvir" or Ex. 1007).

6. Counsel has informed me that I should consider these materials through the lens of a person having ordinary skill in the art related to the '132 Patent at the time of the earliest purported priority date of the '132 Patent, and I have done so during my review of these materials. I understand that the '132 Patent claims priority to U.S. Provisional Application No. 61/285,063, which was filed on December 9, 2009. It is therefore my understanding that the priority date of December 9, 2009 (hereinafter the "Critical Date") represents the earliest possible priority date to which the '132 patent is entitled.

7. A person of ordinary skill in the art as of the Critical Date (a "POSITA") would have had a Bachelor of Science degree in computer science or a similar technical field together with 3-5 years of educational practicum or work experience in the field of computer vision and/or image processing. I base this on my own practical and educational experiences, including my knowledge of colleagues and others at the time.

8. I am familiar with the knowledge and capabilities of a POSITA as noted above. Specifically, my experience working with industry, undergraduate and post-graduate students, colleagues from academia, and designers and engineers practicing in industry has allowed me to become directly and personally familiar with the level of skill of individuals and the general state of the art.

9. I have no financial interest in either party or in the outcome of this proceeding. I am being compensated for my work as an expert on an hourly basis, for all tasks involved. My compensation is not dependent in any manner on the outcome of these proceedings or on the content of my opinions.

10. My opinions, as explained below, are based on my education, experience, and background in the fields discussed above. Unless otherwise stated, my testimony below refers to the knowledge of a POSITA in the fields as of the Critical Date, which I understand to be December 9, 2009, or before.

11. This declaration is organized as follows:

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XI. Conclusion (page 46)

I. Brief Overview of the ’132 Patent

12. The ’132 Patent “pertains to dynamic range correction of digital image data.” Ex. 1001, 10-13. Specifically, the ’132 Patent discloses an “Image Processing Unit (IPU) 11” shown schematically in Fig. 1, which is reproduced below. *Id.*, 4:26-28. The IPU 11 includes an “object detection unit 118” and a “DRC [dynamic range correction] unit 117.” *Id.*, 4:33-34, 4:51-52.

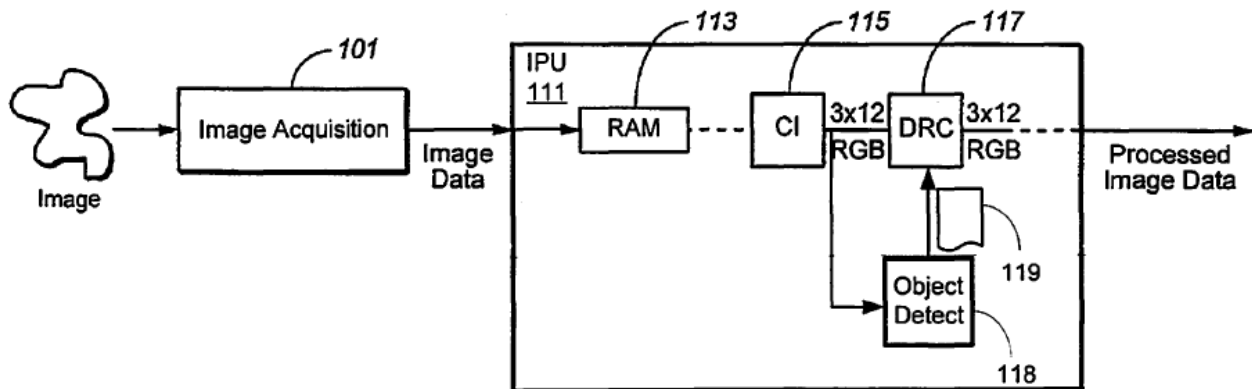


Fig. 1

13. The object detection unit 118 receives image data and “detects the presence and locations of objects of a predetermined type or types (e.g., faces)” in the image data using “any known or convenient algorithm or architecture for this

purpose.” *Id.*, 4:52-58. The object detection unit 118 generates a content map 119 indicating the locations of any objects in the image data and provides it to the DRC unit 117. *Id.*, 4:58-5:7.

14. The DRC unit 117 determines a “digital gain for each pixel for purposes of DRC based on the content map 119.” *Id.*, 4:60-62. The content map 119 can be used by the DRC unit 117 in various ways to determine “a gain (or attenuation), $G(s)$, for each sensor pixel.” *Id.*, 5:16-17, 5:61-62. The ’132 Patent discloses five embodiments of the DRC unit 117 as illustrated in Figs. 2A-2D and in Fig. 6. *Id.*, 5:15-6:44, Figs. 2A-2D, 6.

15. In the embodiment of the DRC unit 117 shown in Fig. 2A (reproduced below), a selection unit 209 selects an appropriate gain value $G(s)$ for a given input pixel from a gain lookup table 207 according to whether or not a given input pixel is part of a detected object as indicated by the content map 119. *Id.*, 5:62-6:4. The gain lookup table 207 contains gain value(s) $G(s)$ for pixels that are part of the detected object and gain value(s) $G(s)$ for pixels that are not part of the detected object. *Id.*

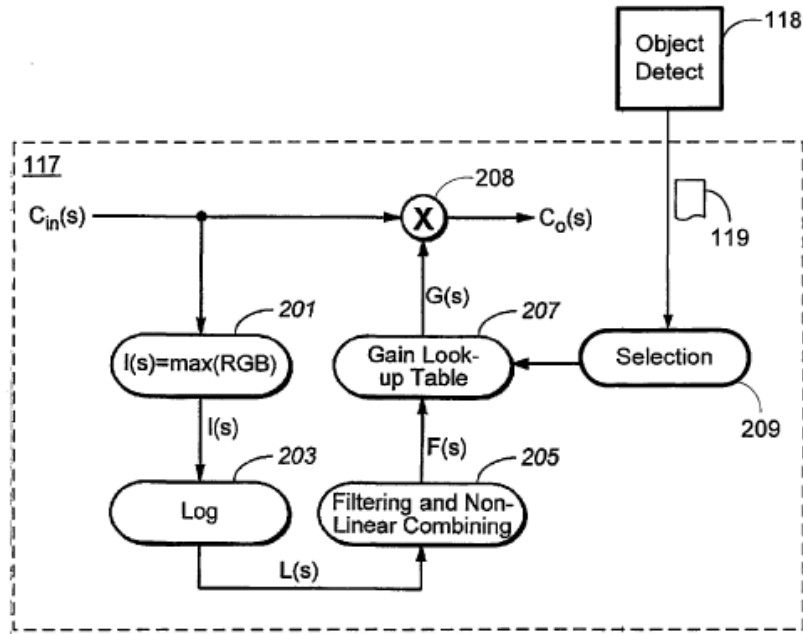


FIG. 2A

16. In the embodiment of the DRC unit 117 shown in Fig. 2B (reproduced below), a weight selection unit 210 selects an appropriate weight value $W(s)$ according to whether or not a given input pixel is part of a detected object as indicated by the content map 119. *Id.*, 6:5-15. The weight value $W(s)$ is applied to a multiplier 208, which modifies the gain value $G(s)$ obtained from the gain lookup table 207. *Id.*

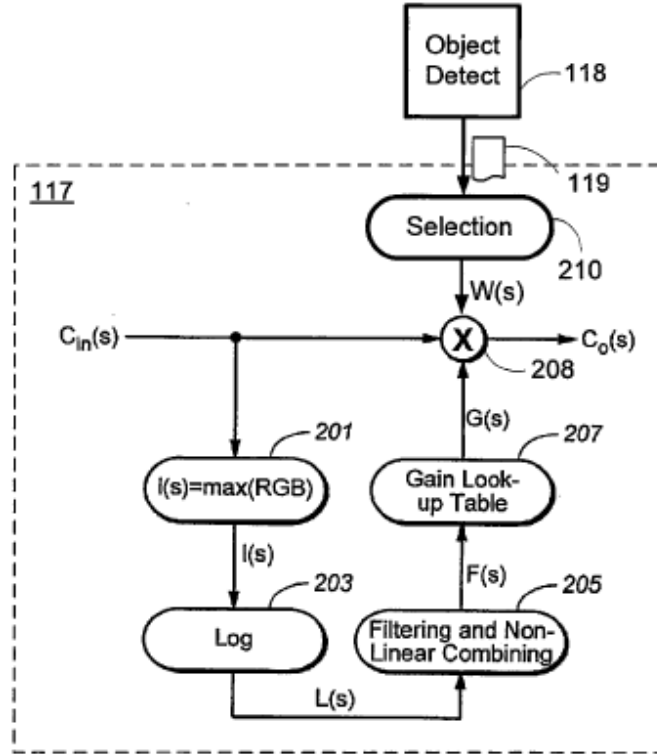


FIG. 2B

17. In the embodiment of the DRC unit 117 shown in Fig. 2C (reproduced below), two separate gain lookup tables 207-1 and 207-2 are provided, one for pixels that are part of the detected object and the other for pixels that are not part of the detected object. *Id.*, 6:16-25. A selection unit 211 selects a gain value $G(s)$ from the appropriate lookup table according to whether or not a given input pixel is part of the detected object as indicated by the content map 119. *Id.*

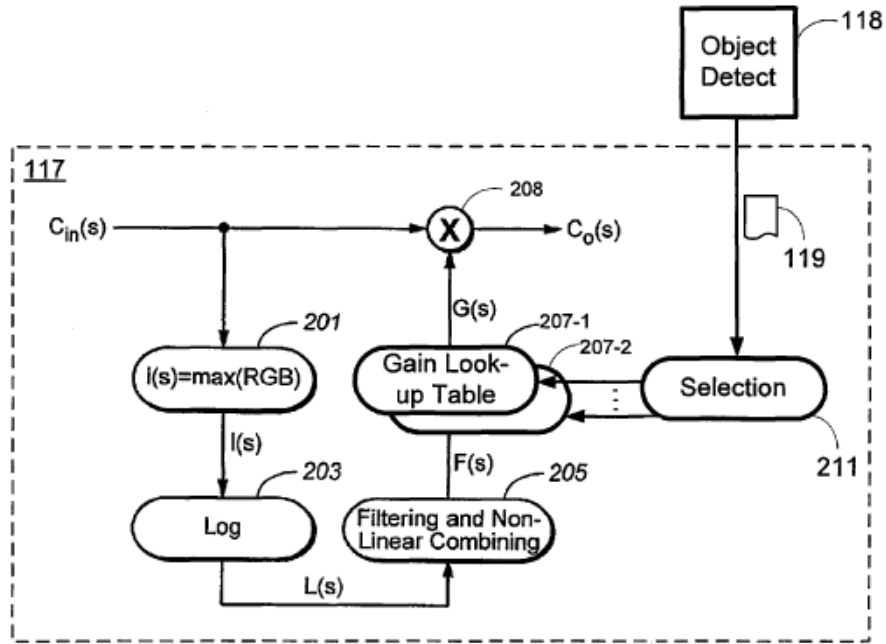


FIG. 2C

18. In the embodiment of the DRC unit 117 shown in Fig. 2D (reproduced below), the content map 119, indicating the presence and location of a detected object, is used to control operation of the filtering and non-linear combining block 205 for the pixels that are part of the detected object. *Id.*, 6:26-29.

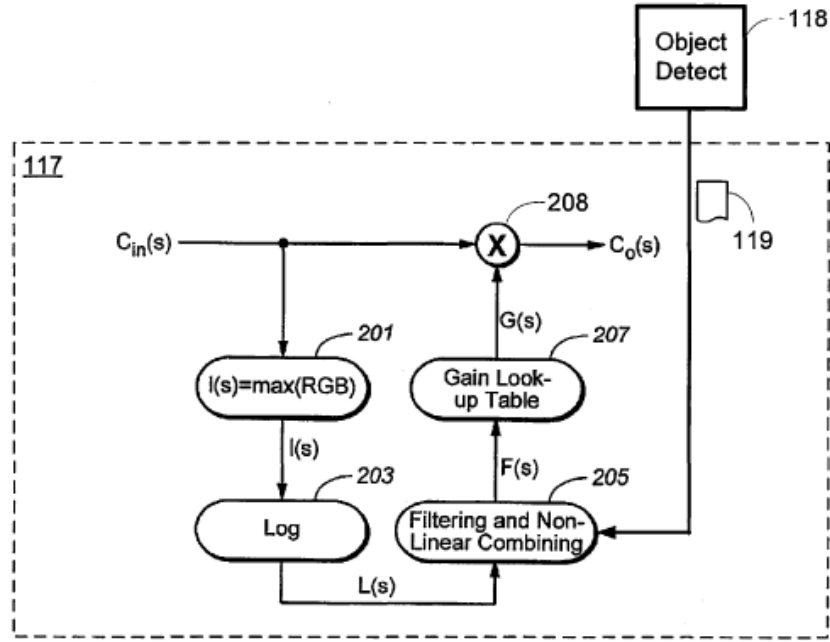


FIG. 2D

19. In each embodiment of the DRC unit 117 shown in Figs. 2A-2D, “[e]ach color component (C_{in}) of the input RGB image (R_{in} , G_{in} , B_{in}) is multiplied by $G(s)$ (via multiplier 208) to produce the output color component for that pixel $C_o(s)$ ” as denoted by the equations:

$$C_o(s) = G(s) * C_{in}$$

with the equations for the individual color components of C being given by:

$$R_o(s) = G(s) * R_{in}$$

$$G_o(s) = G(s) * G_{in}$$

$$B_o(s) = G(s) * B_{in}$$

where $*$ represents multiplication. *Id.*, 5:16-26.

20. Another embodiment of the DRC unit 117 performs a “general process” shown in Fig. 6, which is reproduced below. *Id.*, 6:30-44.

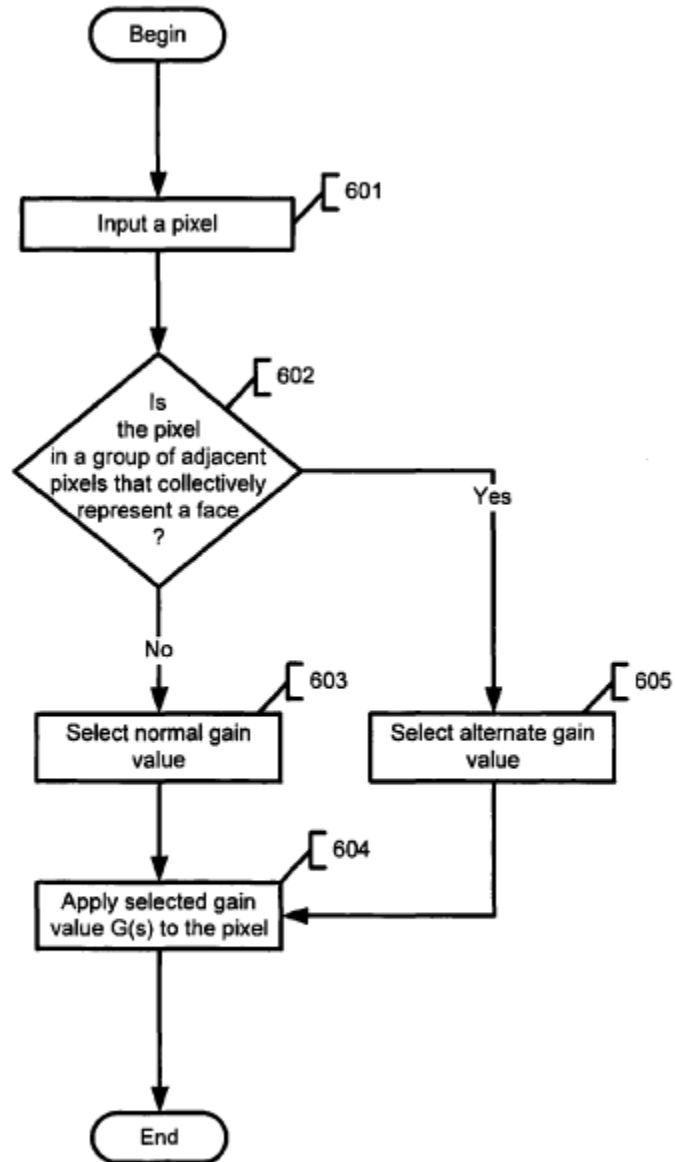


Fig. 6

II. Terminology

21. I have been informed by petitioner’s counsel that claim terms should be given their plain meaning unless, for example, the intrinsic record, including the

patent specification, or the knowledge of a person of ordinary skill in the art, requires otherwise. I have followed this approach in my analysis and for all of the claim terms considered in this Declaration, I have applied the plain and ordinary meaning of those terms unless noted otherwise below. I reserve the right to update my opinions should the parties agree on a construction of any claim terms, or should the Board adopt a particular construction.

“physical object of a predetermined type” (claims 1 and 13)

The term “physical object of a predetermined type” should be construed as “something of a predetermined type which exists in the real (physical) world and which can be visually recognized as such by a human being when depicted in a digital image, and which excludes virtual or abstract objects and concepts such as pixels, data, and image characteristics and parameters.” Such a construction is consistent with the ’132 patent, which explains that:

The term “physical object” as used herein is to be understood in contrast with non-physical, virtual or abstract objects and concepts, such as pixels, data, and image characteristics and parameters. A physical object is something that exists in the real (physical) world and which can be visually recognized as such by a human being when depicted in a digital image.

APPLE-1001, 2:27-33. As examples, the ’132 patent specification discloses that predetermined types of physical objects can include faces represented in a digital

image. *Id.*, 2:65-3:1. Based on my knowledge and experience in this field, I believe a POSITA would have understood that this interpretation is consistent with the '132 patent.

III. Legal Standards for Prior Art

22. In view that I am not an attorney, my understanding of the legal standards throughout this section are based on information provided to me by plaintiff's counsel and experience in prior patent cases.

23. I understand that a patent or other publication must first qualify as prior art before it can be used to invalidate a patent claim.

24. I understand that a U.S. or foreign patent qualifies as prior art to an asserted patent if the date of issuance of the patent is prior to the invention of the asserted patent. I further understand that a printed publication, such as an article published in a journal, magazine or trade publication, qualifies as prior art to an asserted patent if the date of publication is prior to the invention of the asserted patent.

25. I understand that a U.S. or foreign patent also qualifies as prior art to an asserted patent if the date of issuance of the patent is more than one year before the filing date of the asserted patent. I further understand that a printed publication, such as an article published in a magazine or trade publication, constitutes prior art to an asserted patent if the publication occurs more than one

year before the filing date of the asserted patent.

26. I understand that a U.S. patent qualifies as prior art to the asserted patent if the application for that patent was filed in the United States before the invention of the asserted patent.

A. Legal Standards for Anticipation

27. I understand that patents or printed publications that qualify as prior art can be used to invalidate a patent claim as anticipated.

28. I understand that, once the claims of a patent have been properly construed, the second step in determining anticipation of a patent claim requires a comparison of the properly construed claim language to the prior art on a limitation-by-limitation basis.

29. I understand that a prior art reference “anticipates” an asserted claim, and thus renders the claim invalid, if all limitations of the claim are disclosed in that prior art reference, either explicitly or inherently (i.e., necessarily present).

30. I understand that anticipation in an *inter partes* review must be proven by a preponderance of the evidence.

B. Legal Standards for Obviousness

31. I understand that even if a patent is not anticipated, it is still invalid if the differences between the claimed subject matter and the prior art are such that the subject matter as a whole would have been obvious at the time the invention

was made to a POSITA.

32. I understand that a POSITA provides a reference point from which the prior art and claimed invention should be viewed. This reference point is applied instead of someone using his or her own insight or hindsight in deciding whether a claim is obvious.

33. I also understand that an obviousness determination includes the consideration of various factors such as: (1) the scope and content of the prior art, (2) the differences between the prior art and the asserted claims, (3) the level of ordinary skill in the pertinent art, and (4) the existence of secondary considerations such as commercial success, long-felt but unresolved needs, failure of others, etc.

34. I understand that an obviousness evaluation can be based on a combination of multiple prior art references. I understand that the prior art references themselves may provide a suggestion, motivation, or reason to combine, but other times the linkage between two or more prior art references is common sense. I further understand that obviousness analysis recognizes that market demand, rather than scientific literature, often drives innovation, and that a motivation to combine references may be supplied by the direction of the marketplace.

35. I understand that if a technique has been used to improve one device, and a POSITA would recognize that it would improve similar devices in the same

way, using the technique is obvious unless its actual application is beyond his or her skill.

36. I also understand that practical and common sense considerations should guide a proper obviousness analysis, because familiar items may have obvious uses beyond their primary purposes. I further understand that a POSITA looking to overcome a problem through invention will often be able to fit together the teachings of multiple publications. I understand that obviousness analysis therefore takes into account the inferences and creative steps that a POSITA would employ under the circumstances.

37. I understand that a particular combination may be proven obvious merely by showing that it was obvious to try the combination. For example, when there is a design need or market pressure to solve a problem and there are a finite number of identified, predictable solutions, a POSITA has good reason to pursue the known options within his or her technical grasp because the result is likely the product not of innovation but of ordinary skill and common sense.

38. The combination of familiar elements according to known methods is likely to be obvious when it does no more than yield predictable results. When a work is available in one field of endeavor, design incentives and other market forces can prompt variations of it, either in the same field or a different one. If a POSITA can implement a predictable variation, the patent claim is likely obvious.

39. It is further my understanding that a proper obviousness analysis focuses on what was known or obvious to a POSITA, not just the patentee. Accordingly, I understand that any need or problem known to those of ordinary skill in the field of endeavor at the time of invention and addressed by the patent can provide a reason for combining the elements in the manner claimed.

40. I understand that a claim can be obvious in light of a single reference, without the need to combine references, if the elements of the claim that are not found explicitly or inherently in the reference can be supplied by the common sense of one of ordinary skill in the art.

41. I understand that secondary indicia of non-obviousness may include (1) a long felt but unmet need in the prior art that was satisfied by the invention of the patent; (2) commercial success of processes covered by the patent; (3) unexpected results achieved by the invention; (4) praise of the invention by others skilled in the art; (5) taking of licenses under the patent by others; (6) deliberate copying of the invention; (7) failure of others to find a solution to the long felt need; and (8) skepticism by experts. I understand that evidence of secondary indicia of non-obviousness, if available, should be considered as part of the obviousness analysis.

42. I also understand that there must be a relationship between any such secondary considerations and the invention. I further understand that

contemporaneous and independent invention by others is a secondary consideration supporting an obviousness determination.

43. In sum, my understanding is that prior art teachings are properly combined where a POSITA having the understanding and knowledge reflected in the prior art and motivated by the general problem facing the inventor, would have been led to make the combination of elements recited in the claims. Under this analysis, the prior art references themselves, or any need or problem known in the field of endeavor at the time of the invention, can provide a reason for combining the elements of multiple prior art references in the claimed manner.

44. I understand that obviousness in an *inter partes* review must be proven by a preponderance of the evidence.

IV. U.S. Publication No. 2002/0181801 to Needham et al. ("Needham")

45. Needham describes all of the elements of claims 1 and 5-7 of the '132 Patent. Needham, titled "Feature-based Image Correction," relates to "content based digital image processing." Ex. 1004, [0001]. Needham describes a computing device, such as a personal computer, a laptop, a hand held device, or a camera, having an automated feature-based image correction mechanism 120 (shown in Fig. 2 reproduced below) that performs feature-based image correction operations on a digital image 110, which contains digital image data composed of

pixels. *Id.*, [0001], [0003], [0015]. The correction can include enhancing image feature characteristics for technical or aesthetic purposes. *Id.*, [0017], [0020].

46. The correction mechanism 120 includes a correction specification unit 210 that provides configuration parameters for performing feature-based image correction. *Id.*, [0024]. The configuration parameters specify feature types 220, feature weights 230, and correction parameters 240. *Id.*, [0024], Fig. 2 (items 215, 220, 230, 240). A correction parameter 240 defines the correction operation and the operational parameter used during the correction operation. *Id.*, [0019]-[0020], [0024], [0031]-[0032], Fig. 7. The correction operations can include contrast, brightness, and dynamic range adjustments. *Id.*, [0018]-[0022], [0031]-[0032].

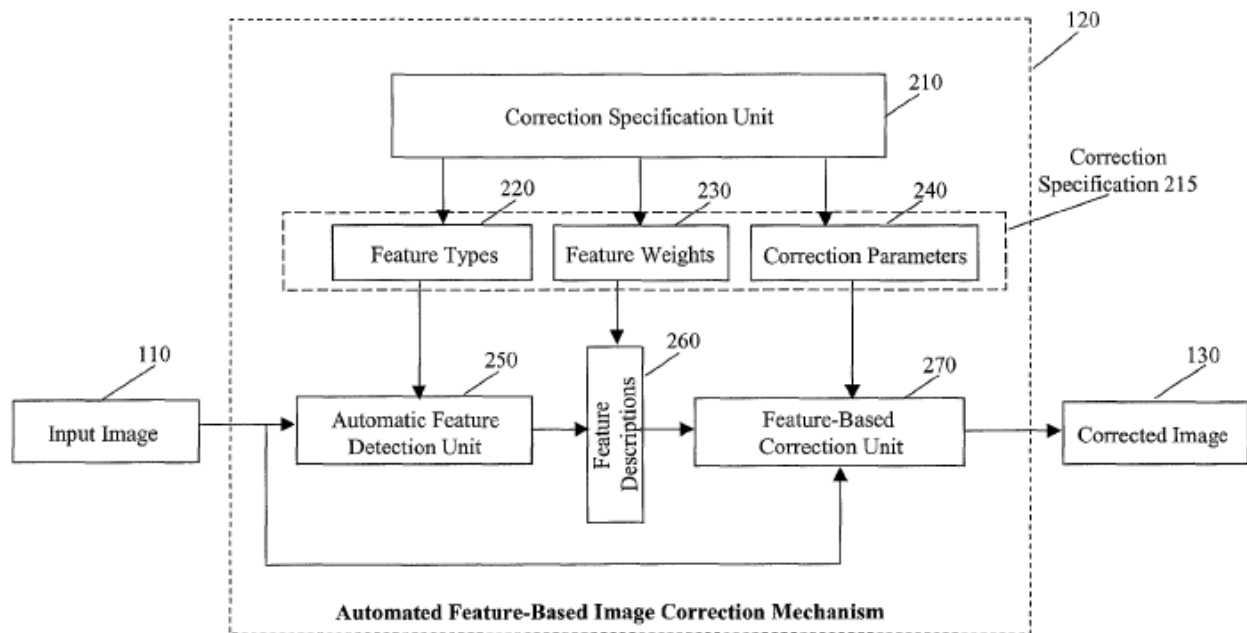


Fig. 2

47. The correction mechanism 120 includes an automatic feature detection unit 250 that detects, from the digital image 110, predetermined types of image features specified by feature types 220 using any technique or algorithm for detecting features in an image. *Id.*, [0024], [0026]. A specified image feature may correspond to a human face, a person, a car, a building, an animal, the sky, etc. *Id.*, [0017], [0020], [0028], Figs. 3, 4. An image feature corresponds to an area in the image. *Id.*, [0030]. The detection unit 250 can detect different types of image features (e.g., a human face and a building) in a single digital image. *Id.*, [0017], [0020], [0022].

48. For each detected image feature, the feature detection unit 250 constructs a corresponding feature description 260 that includes the feature type, the location, the size, the shape descriptor, and the statistical properties (e.g., average, minimum, or maximum intensity values) of the detected image feature. *Id.*, [0026], [0030], Fig. 6. Such feature descriptions 260 are used to determine where and how to apply the correction operations. *Id.*, [0030].

49. The correction mechanism 120 includes a feature-based correction unit 270. *Id.*, [0024]. The correction unit 270 receives the feature description 206 for the detected image feature and retrieves the corresponding correction parameters 240. *Id.*, [0035]. In accordance with the retrieved correction parameters 240, the correction unit 270 performs a correction operation (e.g.,

enhancing the brightness or contrast) on the detected image feature according to the feature description and an operational parameter (e.g., an intensity upper bound or dynamic range) that may be defined as a function of statistical properties of the detected image feature. *Id.*, [0029], [0032].

50. The correction unit 270 can perform the correction operation by changing the intensity values of the pixels of the digital image by re-scaling, or applying a gain to, the intensity values of the pixels. *Id.*, [0002]-[0003]. For example, Needham explains that a digital photo that has very low contrast, which corresponds to a small dynamic range, “can be enhanced through digitally increasing the contrast of the digital photo,” which “can be achieved by re-scaling the intensity value of every single pixel throughout the entire digital photo based on a larger intensity dynamic range.” *Id.*, [0003].

51. The correction unit 270 can apply different types of correction operations to different image features. *Id.*, [0020], [0028]. “For example, maximizing the intensity dynamic range (i.e., enhance the contrast) may be performed on a human face image feature and a different correction operation that increases the brightness may be applied to the image feature that represents the sky.” *Id.*, [0020].

52. The correction unit 270 can also apply different amounts of a correction to different image features. *Id.*, [0022]. Weights can be assigned to

different image features to specify their relative importance and used to control the amount of the correction parameter when applying the correction operation to the image features. *Id.*, [0022], [0027], [0035]. “For instance, if the correction operation of maximizing intensity dynamic range is applied to both human faces and buildings and a human face feature has a higher weight than a building feature, the intensity dynamic range used for correcting human faces in an image may be larger (corresponding to higher contrast) than that used for correcting buildings in an image.” *Id.*, [0022]. Needham explains that “[i]n this way, the human faces may be corrected so that they become more visible than buildings.” *Id.*, [0022].

V. U.S. Publication No. 2008/0007634 to Nonaka et al. (“Nonaka”)

53. Nonaka describes a camera 10 (shown in Fig. 1 reproduced below) that corrects a digital image of a backlight scene to improve visibility of a person in the image. Ex. 1005, [0003], [0005], [0009]. An example of a backlight scene includes a scene with a person in a dark room and a bright outdoor landscape. *Id.*, [0043], Figs. 2A-2C. A backlight scene can have a large luminance difference between the person in the foreground and the background. *Id.*, [0003]. Because the dynamic range of an image pickup device 3 is limited, the image pickup device 3 produces an image with the person appearing dark. *Id.*, [0043]-[0047].

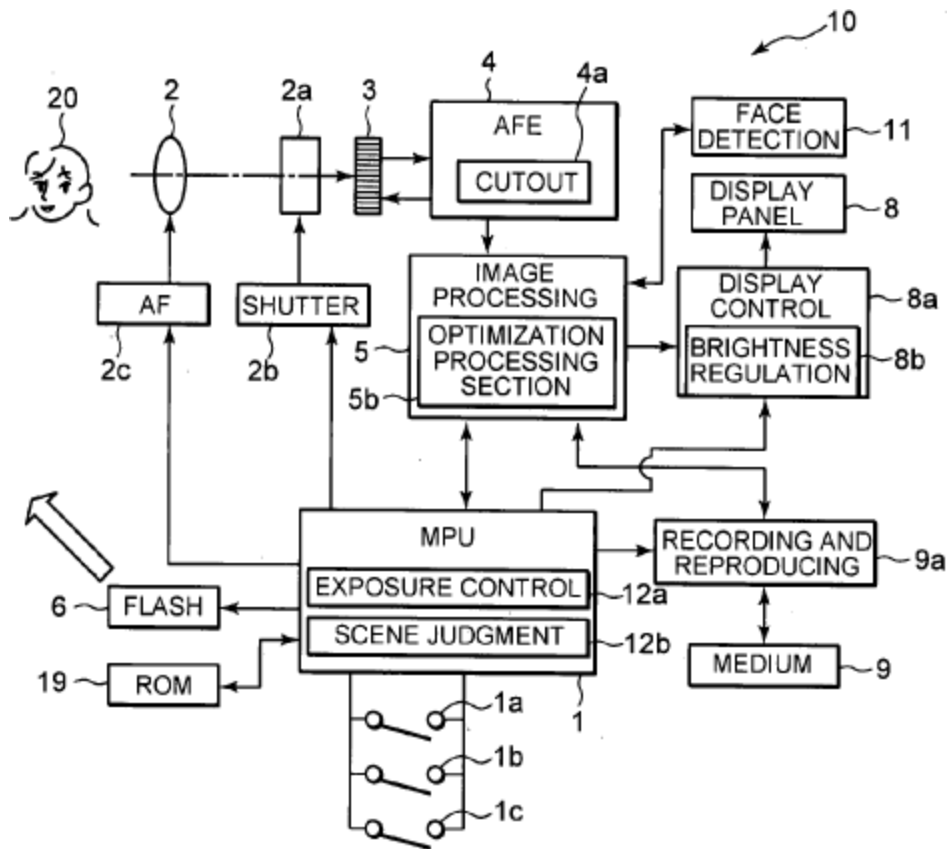


Fig. 1

54. The camera 10 includes an analog front end (AFE) section 4 that converts an analog image signal output from the image pickup device 3 into digital image data composed of pixels. *Id.*, [0026]-[0027]. The digital image data is provided to an image processing section 5 which includes an optimization processing section 5b and to a face detecting section 11. *Id.*, [0028]-[0029], [0042].

55. The face detecting section 11 detects, from the digital image data, whether or not a human face exists in the image. *Id.*, [0042]. Nonaka discloses

that various means for detecting a face can be used, including detecting whether there is a facial pattern in the image by comparing portions of the image to a reference pattern to determine which portions of the image include or do not include a face. *Id.*, [0059]-[0060]. The results of the face detection indicates whether a person exists in the image. *Id.*, [0059]. When a face is detected, the face detecting section 11 outputs a size and a position of the face in the image. *Id.*, [0042].

56. If no face is detected in the image, the optimization processing section 5b does not perform any corrections. *Id.*, [0058]. If a face is detected in a dark portion of the image, the optimization processing section 5b performs corrections, such as luminance amplification or contrast emphasis, on the digital image data to correct the brightness and emphasize the contrast of the face portion and the person. *Id.*, [0003], [0029], [0058], [0064]-[0066], Fig. 8 (steps S11, S17). The optimization processing section 5b appropriately corrects bright and dark regions of the image based on the luminance value of each region “to earn a wide dynamic range of brightness ... so that both of a dark portion and a bright portion can easily be seen.” *Id.*, [0006], [0029], [0033]. Thus, the luminance amplification and contrast emphasis are performed to correct the dynamic range of the image.

57. Because the image has a large luminance difference between the person in the foreground and the landscape in the background, the amounts of

luminance amplification and contrast emphasis applied to the landscape portion of the image can be different than the amounts of luminance amplification and contrast emphasis applied to the person portion of the image. *Id.*, [0047]-[0051]. For example, Nonaka explains with reference to Fig. 4A (reproduced below) that the optimization processing section 5b performs amplifying correction of the landscape portion of the image with a “gain 1,” which raises the luminance of the landscape from E0 to E1. *Id.*, [0048]. Because the “gain 1” cannot secure sufficient visibility of the person (including the face) without saturating the landscape, the optimization processing section 5b performs the correction processing of the person with a “gain 2,” which is “a correction value larger than that of the gain 1,” to raise the luminance of the person from F0 to F2. *Id.*, [0049]-[0050]. Applying gain 2 to the person results in the person being brighter than if gain 1 were applied to both the person and the landscape of the digital image data.

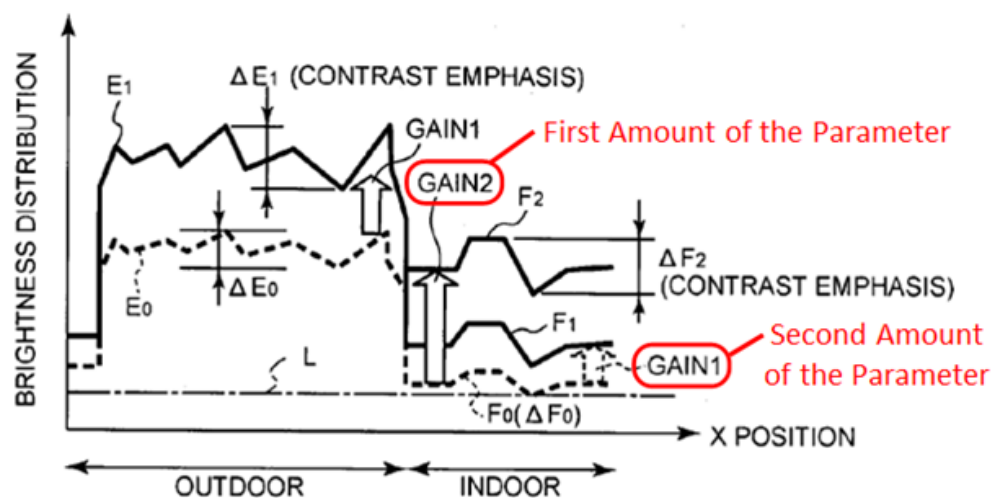


Fig. 4A (Nonaka)

Id., Fig. 4A (annotated)

VI. Combination of Needham and Nonaka

58. The combination of Needham and Nonaka describes all of the elements of claims 1 and 5-7 of the '132 Patent. Of particular importance, the combination of Needham and Nonaka describes “applying a first amount of the correction to the first portion of the digital image data” and “applying a second amount of the correction to a second portion of the digital image data, wherein the first amount differs from the second amount, and wherein the first amount corresponds to a physical object of the predetermined type,” which are features that were added to independent claim 1 during prosecution that led to the allowance of claim 1 and its dependent claims. *See* Ex. 1002, 122, 129-131.

59. For instance, Needham describes image correction operations (i.e., a method) that includes detecting types of image features (e.g., a human face and a building) in a digital image (i.e., determining whether a first portion of digital image data represents a physical object of a predetermined type). Ex. 1004, [0015], [0017], [0026], [0028], [0029], [0030], [0033], Figs. 5, 8. Needham also discloses determining and applying a weight assigned to human face features (i.e., a first amount of the dynamic range correction corresponding to the physical object of the predetermined type) when correcting the dynamic range of a human face, and determining and applying a lower weight assigned to building features (i.e., a

second, different amount of the dynamic range correction) when correcting the dynamic range of buildings. *Id.*, [0022].

60. Similarly, Nonaka describes a method that includes detecting whether or not a human face exists in digital image data (i.e., determining whether a first portion of digital image data represents a physical object of a predetermined type). Ex. 1005, [0010], [0036], [0042], [0059], [0063], Figs. 1, 7A, 7B, 8 (step S10-S12). Nonaka's method further includes performing (which includes determining and applying) amplifying correction of the landscape portion of the image with a "gain 1" (i.e., a second amount of the correction) and amplifying correction of the person with a "gain 2" (i.e., a first amount of the correction corresponding to the physical object of the predetermined type), which is "a correction value larger than that of the gain 1." *Id.*, [0048]-[0050], Fig. 4A. Nonaka also describes applying different amounts of contrast emphasis to the landscape and person portions of the image. *Id.*, [0048]-[0050], Fig. 4A.

61. Thus, if Needham's teachings regarding applying weights to control correction parameters do not satisfy the claimed features that led to allowance, i.e., "applying a first amount of the correction to the first portion of the digital image data" and "applying a second amount of the correction to a second portion of the digital image data, wherein the first amount differs from the second amount, and wherein the first amount corresponds to a physical object of the predetermined

type,” such features were commonly known in similar prior art digital image processing systems such as those shown by Nonaka. For example, Nonaka explicitly discloses that the correction parameter for dynamic range correction is a gain. Ex. 1005, [0048]-[0050]. Nonaka teaches applying a “gain 2” (i.e., a first amount of the correction) to the face portion (i.e., the first portion) of the digital image data and applying a “gain 1” (i.e., a second, different amount of the correction) to the landscape portion (i.e., a second portion) of the digital image data, where the “gain 2” (i.e., the first amount) corresponds to backlit faces. *Id.*, [0048]-[0050], Fig. 4A. Nonaka’s camera applies a “gain 2” to the face portion because the “gain 1” applied to the landscape cannot secure sufficient visibility of the person (including the face) in the backlit region without saturating the landscape. *Id.*, [0049]-[0050]. Applying gain 2 to the backlit region including the face results in the face being brighter than if gain 1 were applied to both the face and the landscape of the digital image data (i.e., resulting in a first portion of a digital image that corresponds to the first portion of digital image data being brighter than if the second amount of the parameter were applied to both the first portion and the second portion of the digital image data). *Id.*, Fig. 4A.

62. Incorporation of Nonaka’s teachings improves Needham’s system by providing functionality for improving visibility of a person in a backlit scene. APPLE-1005, [0003], [0005], [0008]-[0009], [0043]-[0044]. A POSITA would

have been led by Nonaka to modify Needham to apply amplifying correction and contrast emphasis (i.e., dynamic range correction), enabling both the person and landscape portions of an image to be more easily distinguished and perceived. A POSITA would have recognized that the predictable combination of Needham and Nonaka would have included using gain as a correction parameter for dynamic range correction and applying different amounts of gain to different image features so that the more important image features become sufficiently visible. A POSITA would have been prompted to combine the features of Nonaka with the teachings of Needham because they both relate to digital image processing, and specifically to dynamic range correction of digital image data. Ex. 1004, [0001], [0019]-[0022]; Ex. 1005, [0006], [0029], [0033]. In addition, Needham expressly states that its system may include a camera, and Nonaka describes a camera and a method of controlling a camera. Ex. 1004, [0015]; Ex. 1005, [0010].

63. Design incentives would also have prompted a POSITA to look to Nonaka to improve the camera of Needham. Nonaka describes processing image data at a high speed so that the image signal from an image pickup device is substantially displayed in real time, and processing image data to improve the visibility of the subject during the display of the image for monitoring while the user is shooting the image. Ex. 1005, [0027], [0032]-[0033]. A POSITA would have found it desirable to implement these features in a digital camera, and Nonaka

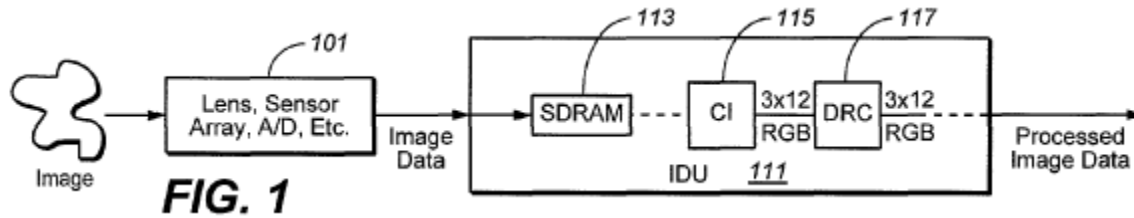
describes well-known components and techniques for doing so. Combining Nonaka's camera and method of controlling a camera with the teachings of Needham produces no more than expected results and is within the capability of a POSITA. Thus, a POSITA implementing a camera based on the teachings of Needham would have been motivated to look to Nonaka and would have understood that Nonaka's features could be combined with Needham.

VII. U.S. Publication No. 2008/0291287 to Dvir ("Dvir")

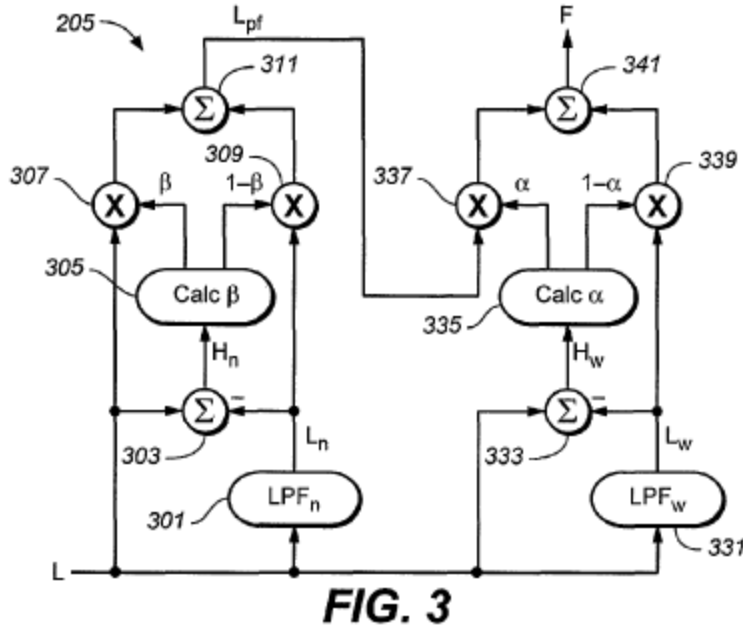
64. Dvir, entitled "Dynamic Range Compensation by Filter Cascade," describes dynamic range enhancement using a cascade of nonlinear edge preserving filters and nonlinear pixel point operations. Ex. 1007, [0001], [0005]-[0006]. Dvir's description of its embodiments is very similar to, and in some instances exactly the same as, the '132 Patent's description of the filtering and non-linear combining block 205 and other components of the DRC unit 117 shown in Figs. 2-4. *Compare* Ex. 1007, [0012]-[0036], Figs. 2-4 *with* Ex. 1001, 3:28-58, 3:65-4:50, 5:15-51, 6:45-9:53, Figs. 3, 4.

65. Dvir describes an image processing unit (IPU) 111 that includes a "DRC (Digital Range Compensation) 117 as shown in Fig. 1 reproduced below. Ex. 1007, [0015]. The DRC 117 computes a gain (or attenuation), $G(s)$, for each sensor pixel of the image data. *Id.*, [0016]. The DRC 117 uses "the current pixel in conjunction with a plurality of signals derived from one or more successively

widening neighborhoods to refine the estimate of the enhancement gain for the current pixel.” *Id.*, [0014].



66. In particular, the DRC 117 includes a filtering and non-linear combining block 205 where low pass filtering and non-linear combining are performed to produce a filtered image. *Id.*, [0018]. Block 205 receives image data $L(s)$ indicating the measure of image strength. *Id.*, [0018]. In the basic embodiment, block 205 includes two cascaded 2-dimensional low-pass filters, as shown in Fig. 3 reproduced below, using narrow and wide neighborhoods of the pixel being treated. *Id.*, [0019]. The first stage of the filter filters the image by a narrow window low pass filter. *Id.*, [0020]. The second stage of the filter is constructed similarly to the first stage but having a wide window. *Id.*, [0020].



67. The filter thresholds and weighting factors α , β can be made adaptive and responsive to image characteristics such as the minimum, maximum, mean, median, standard deviation, or other statistical measures taken from a histogram of the whole image or within a sub-image block. *Id.*, [0023], [0027]-[0032]. In addition, block 205 can include one or more additional cascaded stages between the initial stage with the narrowest window and the last stage with the widest window to obtain finer edge preserving transition. *Id.*, [0026]. The window sizes may be dependent on the content of the image. *Id.*, [0026]. The number of stages and the particular stages to be used can be adaptively selected using measurements from the whole image or from a sub-image block, and the local contrast can be controlled by selectively using various stages in cascade. *Id.*, [0033]-[0036]. User

preference for the amount of local contrast can also be used to adaptively determine the number of cascaded stages of the filters. *Id.*, [0034].

68. The output of the filter is a filtered image $F(s)$ that is the linear combination of the output of the first stage and the low-pass filtered signal of the second stage. *Id.*, [0020]. The filtered image $F(s)$ is an edge preserving low-pass filtered version of the image $L(s)$ that carries information on the intensity of the pixels. *Id.*, [0025]. The filtered image $F(s)$ is applied to a gain look-up table 207 to determine the gain values $G(s)$. *Id.*, [0018], [0025]. Each color component (C_{in}) of the input RGB image (R_{in} , G_{in} , B_{in}) is multiplied by $G(s)$ to produce the output color component for that pixel $C_o(s)$, as shown in Fig. 2 reproduced below. *Id.*, [0016].

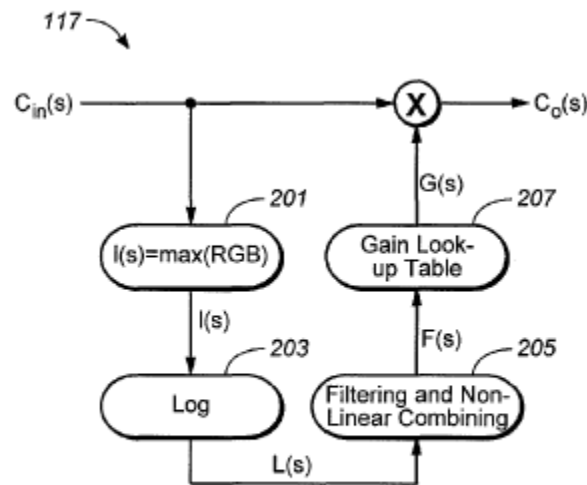


FIG. 2

VIII. Combinations of Needham and Dvir and Needham, Nonaka, and Dvir

69. The combinations of Needham and Dvir and Needham, Nonaka, and Dvir describe all of the elements of claim 8 of the '132 Patent. As discussed above, Needham alone and/or Needham in view of Nonaka describe determining the amount of gain to apply to the first portion of the digital image data, but do not describe maintaining local contrast. Dvir teaches such features.

70. For instance, Dvir describes dynamic range modification “us[ing] the current pixel in conjunction with a plurality of signals derived from one or more successively widening neighborhoods to refine the estimate of the enhancement gain for the current pixel.” EX. 1007, [0014]. Dvir performs the dynamic range modification using cascaded two-dimensional low-pass filters that use narrow (to determine the first intermediate value) and wide (to determine the second intermediate value) neighborhoods of the pixel being treated. *Id.*, [0005]-[0006], [0012]-[0013], [0019]-[0026], Figs. 3, 4. Dvir discloses that the number of cascaded stages of the filters can be adaptively selected depending on the image content to control local contrast of the image. *Id.*, [0033]-[0036]. In addition, Dvir discloses that user preference for the amount of local contrast can also be used to adaptively determine the number of cascaded stages of the filters. *Id.*, [0034].

71. Based on the disclosures of Dvir, a POSITA would have been motivated to adaptively select the number of cascaded stages of the filters based on

the image content and user preference so as to maintain local contrast of the first portion of the digital image data. Moreover, to maintain local contrast of the first portion of the digital image data, a POSITA would have corrected dynamic range by employing Dvir's cascaded two-dimensional low-pass filters from which the number of stages can be adaptively selected. *Id.* In these ways, a POSITA would have expected success and improvement through the integration of these features of Dvir into Needham alone, or into the Needham-Nonaka combination.

72. The combinations of Needham and Dvir and Needham, Nonaka, and Dvir corrects dynamic range using a cascade of nonlinear edge preserving filters and nonlinear pixel point operations to calculate the pixel gain. EX. 1007, [0006], [0012]. Incorporation of Dvir's teachings further improves Needham's system (and thus, the combination of Needham and Nonaka) by providing functionality for refining the estimate of the enhancement gain for the current pixel. EX. 1007, [0014]. A POSITA would have recognized that the predictable modification to Needham alone and the combined system of Needham and Nonaka would have included determining the gain for dynamic range correction using a cascade of nonlinear edge preserving filters and nonlinear pixel point operations in order to achieve superior image quality.

73. Additional reasons that would have prompted a POSITA to combine the features of Dvir with Needham and Needham in view of Nonaka include

Needham, Nonaka, and Dvir all being related to digital image processing, and specifically to dynamic range correction of digital image data. EX. 1004, [0001], [0019]-[0022]; EX. 1005, [0006], [0029], [0033]; EX. 1007, [0001], [0005].

Needham and the combination of Needham and Nonaka provide a system for dynamic range correction of an image, but does not explain in detail any particular technique for determining the amount of gain to apply. Dvir describes a technique for dynamic range correction that uses a cascade of nonlinear edge preserving filters and nonlinear pixel point operations to calculate the pixel gain. EX. 1007, [0006], [0012]. In addition, Needham, Nonaka, and Dvir all describe systems for digital cameras. EX. 1004, [0015]; EX. 1005, [0010]; EX. 1007, [0015].

74. Design incentives would also have prompted a POSITA to look to Dvir to improve Needham and/or the combined system of Needham and Nonaka. Dvir describes techniques for correcting a digital image that use the current pixel in conjunction with a plurality of signals derived from one or more successively widening neighborhoods to refine the estimate of the enhancement gain for the current pixel. EX. 1007, [0014]. A POSITA would have found it desirable to refine the estimate of the enhancement gain for a pixel in order to achieve superior image quality, and Dvir describes well-known components and techniques for doing so. EX. 1007, [0005]. Combining Dvir's dynamic range correction technique with Needham, alone and/or in combination with Nonaka, produces no

more than expected results and is within the capability of a POSITA. Thus, a POSITA implementing Needham, alone and/or in combination with Nonaka, would have been motivated to look to Dvir.

IX. U.S. Patent 6,891,977 to Gallagher (“Gallagher”)

75. Gallagher describes processing a digital image based on semantic information in the image. Ex. 1006, 1:6-13, 3:39-48. According to Gallagher, a digital image includes one or more two-dimensional arrays of numbers. *Id.*, 3:23-24. A monochrome digital image includes one array of pixel values corresponding to light intensities. *Id.*, 3:26-28. A color digital image includes three arrays representing red, green, and blue pixel values respectively. *Id.*, 3:24-26.

76. In Gallagher, a digital image is processed by a gain map generator 2, which is shown in Fig. 5 reproduced below. The gain map generator 2 creates a gain map $\beta(x,y)$. *Id.*, 6:25-30. The gain map $\beta(x,y)$ is a control signal used to determine the level of correction to apply on a pixel-by-pixel basis and indicates the gain of a correction operation, e.g., a sharpening operation, on a pixel-by-pixel or region-by-region basis based on semantic labels derived from pattern recognition. *Id.*, 6:25-30. The semantic content of a region can represent an object such as a human face, a building, a cloud, or the sky. *Id.*, 3:47-48.

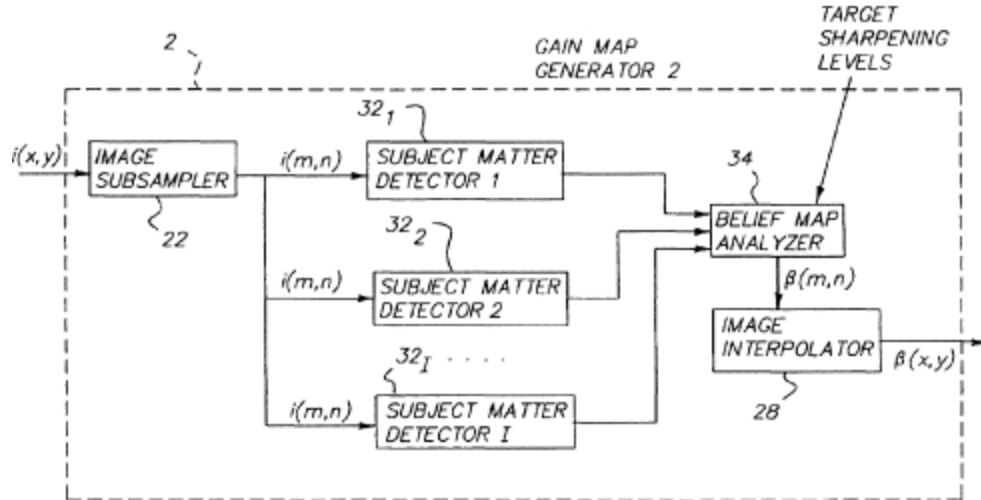


FIG. 5

77. The gain map generator 2 includes a subject matter detector 32₁ that creates a belief map $M_1(x,y)$ specifying the probability that a pixel or region in an image represents a target subject matter such as human flesh. *Id.*, 6:38-40, 6:55-58. A pixel value of 1 in the belief map can represent the belief that the pixel represents the target subject matter, and a pixel value of 0 can represent the belief that the pixel does not represent the target subject matter. *Id.*, 6:46-49.

78. A belief map analyzer 34 then combines the belief map $M_1(x,y)$ with a target correction level T_1 for the subject matter to produce a gain map for the subject matter. *Id.*, 6:58-61. The value of the gain map at any particular pixel (x,y) represents the gain parameter of the correction and is related to the subject matter detected at the corresponding image location. *Id.*, 6:31-7:33.

79. As shown by equation (4), the value of the gain map at a pixel that represents the target subject matter is a combination of a gain value T_0 for a pure

background image independent of the subject matter and a gain value T_1 for the detected subject matter. *Id.*, 6:55-7:20. Also, as apparent from equation (4), the gain map $\beta(x,y)$ can be generated by modifying a gain map T_0 for a pure background image based on the subject matter belief map $M_1(x,y)$ and the target correction amount T_1 for the detected subject matter. *Id.*, 6:55-7:20. After generating the gain map $\beta(x,y)$, the image is corrected according to the gain map. *Id.*, 8:22-24.

X. Combinations of Needham and Gallagher and Needham, Nonaka, and Gallagher

80. The combinations of Needham and Gallagher and/or Needham, Nonaka, and Gallagher describes all of the elements of claim 13 of the '132 Patent. For example, with respect to Needham, a POSITA would have recognized that applying the first amount of correction to the human face feature (i.e., the first portion) would include applying the feature weight corresponding to the human face feature (i.e., a first gain that is based on the determination that the first portion represents a human face) and the same correction operation (including a second gain that is independent of the detected human face) to both the human face and the buildings. Gallagher expressly teaches that this was a known feature. Gallagher's system generates a gain map for a correction operation by combining a gain map T_0 for a pure background image and a target correction amount T_1 for the

detected subject matter (e.g., human flesh) based on a subject matter belief map $M_1(x,y)$. Ex. 1006, 6:55-7:20, Fig. 5.

81. The combinations of Needham and Gallagher and Needham, Nonaka, and Gallagher use a gain map T_0 for a pure background image as an operational parameter for dynamic range correction and combining/modifying the gain map T_0 with the weight or target correction amount T_1 assigned to the image feature based on the feature description specifying the location of the image feature.

Incorporation of Gallagher's teachings further improves the Needham's system (and thus, the combination of Needham and Nonaka) by providing functionality for applying a correction operation on a pixel-by-pixel or region-by-region basis based on semantic information in the image. Ex. 1006, 6:25-30. A POSITA would have recognized that the predictable modification to Needham and the combined system of Needham and Nonaka would have included generating a gain map for dynamic range correction and using the gain map to correct the image as suggested by the teachings of Gallagher.

82. In addition, a POSITA would have been prompted to combine the features of Gallagher with Needham, alone and/or in view of Nonaka, because Needham, Nonaka, and Gallagher all relate to digital image processing. Ex. 1004, [0001]; EX. 1005, [0033]; Ex. 1006, 1:6-7. In addition, the processing techniques described in Needham, Nonaka, and Gallagher all include feature detection and

gain adjustments. EX. 1004, [0002]-[0003], [0017], [0026], [0028], [0029], [0030], Figs. 2-5; EX. 1005, [0036], [0042], [0049]-[0050], [0059], [0063], Figs. 1, 4A, 7A, 7B, 8 (step S10-S12); EX. 1006, 2:37-40, 3:45-48, 6:25-7:33, 8:22-24, Fig. 5.

83. Design incentives would also have prompted a POSITA to look to Gallagher to improve Needham and/or the combined system of Needham and Nonaka. Gallagher describes techniques for correcting a digital image without amplifying noise. EX. 1006, 2:21-24. Increasing the visibility of features in an image may also increase the visibility of noise in the image. Ex. 1009, 159 (“As often is the case with histogram equalization of smooth, noisy regions, this image shows significant enhancement of the noise.”), 192 (“Bringing out detail of this nature by expanding the dynamic range of the intensity levels also enhanced noise”). A POSITA would have found it desirable to adjust the amount of correction of digital image data based on both the content of the image and the amount of noise in the image, and Gallagher describes well-known components and techniques for doing so. Combining Gallagher’s image correction technique with Needham and Needham in view of Nonaka produces no more than expected results and is within the capability of a POSITA. Thus, a POSITA implementing Needham, alone and/or in combination with Nonaka, would have been motivated to look to Gallagher.

XI. Conclusion

84. I currently hold the opinions expressed in this declaration. But my analysis may continue, and I may acquire additional information and/or attain supplemental insights that may result in added observations.

85. I hereby declare that all statements made of my own knowledge are true and that all statements made on information and belief are believed to be true. I further declare that these statements were made with the knowledge that willful false statements and the like so made are punishable by fine or imprisonment, or both, under Section 1001 of the Title 18 of the United States Code and that such willful false statements may jeopardize the validity of the application or any patents issued thereon.

Dated: March 18, 2019

By: 

Alan C. Bovik, Ph.D., P.E

**CURRICULUM VITAE
PROFESSOR ALAN CONRAD BOVIK**



Biographical Sketch

Al Bovik was born in Kirkwood, MO on June 25, 1958. He received the B.S. degree in Computer Engineering in 1980 and the M.S. and Ph.D. degrees in Electrical and Computer Engineering in 1982 and 1984, all from the University of Illinois, Urbana-Champaign.

He holds the Ernest J. Cockrell Endowed Chair in Engineering at The University of Texas at Austin, where he is a Professor in the Department of Electrical and Computer Engineering and The Institute for Neurosciences, and Director of the Laboratory for Image and Video Engineering (LIVE). During the Spring of 1992, he held a visiting position in the Division of Applied Sciences, Harvard University, Cambridge, Massachusetts.

He is well known as the inventor or co-inventor of Order Statistic Filters; the Gabor Texture Model; the Image Modulation Model; the Structural Similarity (SSIM) and Visual Information Fidelity (VIF) Indices for image quality assessment, the MOtion-based Video Integrity Evaluation (MOVIE) index for video quality assessment, the BRISQUE, BLIINDS and NIQE blind image and video quality models, the LIVE Image and Video Quality Databases (downloaded thousands of times), and SIVA - the Signal, Image and Video Audiovisual Demonstration Gallery (used by more than 1000 sites around the world), as well as many other contributions to the fields of digital television, image and video processing, computational vision, and modeling of visual perception.

Professor Bovik has frequently been featured or quoted in the media including *The Wall Street Journal*, *The Hollywood Reporter*, *Austin American-Statesman*, *Emmy Magazine*, and *Sound and Picture*. He has published more than 800 technical articles and U.S. patents in these areas. His publications have been cited more than 80,000 times in the literature, his current H-index is above 100, and he is listed as a **Highly-Cited Researcher** by Thompson Reuters/Clarivate Analytics, indicating one of the top 1% of most-cited researchers within the field of Engineering. He is the

author of the widely-adopted *The Handbook of Image and Video Processing*, Second Edition (Elsevier Academic Press, 2005), *Modern Image Quality Assessment* (Morgan & Claypool, 2006), and *The Essential Guides to Image and Video Processing* (Elsevier Academic Press, 2009).

Dr. Bovik received Television's highest honor, an individual **Primetime Emmy Award for Outstanding Achievement in Engineering Development** from the Academy of Television Arts and Sciences (The Television Academy) in October 2015, for his work on the development of video quality prediction models that have become standard tools in broadcast and post-production houses throughout the television industry. He received the **2019 IEEE Fourier Award** "For seminal contributions and high-impact innovations to the theory and application of perception-based image and video processing." He was also the recipient of the **2017 Edwin H. Land Medal** from The Optical Society and the Society for Imaging Science and Technology, "For substantially shaping the direction and advancement of modern perceptual picture quality theory, and for energetically engaging industry to transform his ideas into global practice."

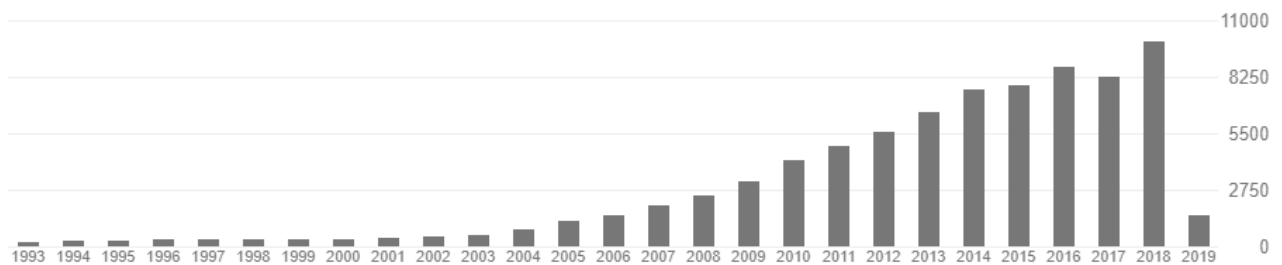
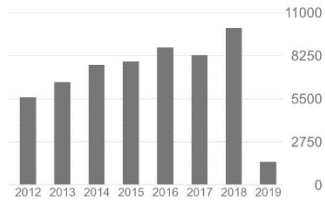
He has also received all of the major awards from the IEEE Signal Processing Society, including: the **Norbert Wiener Society Award** (2013); the **Claude Shannon/Harry Nyquist Technical Achievement Award** (2005); the **Best Paper Award** (2009); the **Signal Processing Magazine Best Paper Award** (2013); the **Karl Friedrich Gauss Education Award** (2007); the **Distinguished Lecturer Award** (2000); the **Leo L. Beranek Meritorious Service Award** (1998); the **Sustained Impact Paper Award** (2017); the **Signal Processing Letters Best Paper Award** (2017); and (co-author) the **Young Author Best Paper Award** (2013).

He is the author of two **2017 Google Scholar Classic Papers** recognizing highly-cited papers that have stood the test of time, and are among the ten most-cited articles in their area of research published ten years earlier. He also received the **EURASIP Best Paper Award** (2018), the **Picture Coding Symposium Best Paper Award** (2018), and the **IEEE Circuits and Systems for Video Technology Best Paper Award** (2016). He also was named recipient of the **Honorary Member Award** of the Society for Imaging Science and Technology for 2013, received the **SPIE Technology Achievement Award** for 2012, and was the **IS&T/SPIE Imaging Scientist of the Year** for 2011.

He is also a recipient of the **Joe J. King Professional Engineering Achievement Award** (2015) and the **Hocott Award for Distinguished Engineering Research** (2008), both from the Cockrell School of Engineering at The University of Texas at Austin, the **Distinguished Alumni Award** from the University of Illinois at Champaign-Urbana (2008), the **IEEE Third Millennium Medal** (2000) and two journal paper awards from the Pattern Recognition Society.

He is a Fellow of the IEEE, a Fellow of the Optical Society of America (OSA), a Fellow of the Society of Photo-Optical and Instrumentation Engineers (SPIE), and is a member of the Society of Motion Picture and Television Engineers (SMPTE) and a member of both The Television Academy (ATAS) and the National Academy of Television Arts and Sciences (NATAS). He is also a member of the Royal Society of Photography.

Professor Bovik has been involved in numerous professional society activities, including: Board of Governors, IEEE Signal Processing Society, 1996-1998; Editor-in-Chief, *IEEE Transactions on Image Processing*, 1996-2002; Overview Editor, *IEEE Transactions on Image Processing*, 2009-present; Editorial Board, *The Proceedings of the IEEE*, 1998-2004; Senior Editorial Board, *IEEE Journal on Special Topics in Signal Processing*, 2005-2009; Series Editor for Image, Video, and Multimedia Processing, Morgan and Claypool Publishing Company, 2003-present; and Founding General Chair, *First IEEE International Conference on Image Processing*, held in Austin, Texas, in November, 1994. He was also the General Chair of the 2014 *Texas Wireless Symposium*, held in Austin in November of 2014. Dr. Bovik is also a busy and much sought-after consultant to industry.



This image is a Word Cloud formed from the titles of the journal papers in this document, roughly illustrating the topical frequency of Professor Bovik's research work:



Honors and Awards



1. Elected to Honor Society of Phi Kappa Phi, 1981.
2. Stark Centennial Endowed Fellow in Engineering, University of Texas, Austin, 1987-1991.
3. Listed in *Men of Achievement*, 1988.
4. Honorable Mention, Thirteenth Annual Pattern Recognition Society Award for the paper "Nonparametric tests for edge detection in noise," *Pattern Recognition* (1988).
5. Registered Professional Engineer in the State of Texas (License # 114706).
6. Elevated to Senior Member of the IEEE, November 1989.
7. Supervised PhD Dissertation "On Using Chromatic Information in Stereo Correspondence" (John R. Jordan III), selected winner of the University of Texas all-campus Outstanding Dissertation Award, 1990.

8. Supervised winner of 1990 MCC Awards for Excellence in Computer Science and Electrical & Computer Engineering student paper award winner for the paper (Dapang Chen and A.C. Bovik) "Visual Pattern Image Coding," *IEEE Transactions on Communications*, vol. COM-38, no. 12, December 1990.
9. National Finalist, 1990 Eta Kappa Nu Outstanding Young Electrical Engineer Award. There were 7 Finalists in this U.S. competition.
10. William H. Hartwig Endowed Fellow in Engineering, The University of Texas at Austin, 1991-present.
11. Recipient of University of Texas **Engineering Foundation Faculty Excellence Award**, 1991.
12. Associate Director, Center for Vision and Image Sciences, The University of Texas at Austin, 1994-2000.
13. Honorable Mention, Nineteenth Annual Pattern Recognition Society Award for the paper "Using Chromatic Information in Dense Stereo Correspondence," *Pattern Recognition*, 1993.
14. Elected **Fellow of the Institute of Electrical and Electronics Engineers (IEEE)** "For Contributions to Nonlinear Image Processing," December 1995.
15. General Dynamics Endowed Fellow in Engineering, The University of Texas at Austin, 1996-2000.
16. Recipient of the IEEE Signal Processing Society **1998 Leo L. Beranek Meritorious Service Award Meritorious Service Award** in 1998. This is the highest service honor given by the Society. Citation: "For Broad and Extensive Service Contributions to the Society, and in Particular for the Creation of the IEEE International Conference on Image Processing."
17. Recipient of the **IEEE Third Millennium Medal**, 2000.
18. Recipient of the **IEEE Signal Processing Distinguished Lecturer Award** in 2000.
19. **Plenary Speaker**, *International Conference on Multimedia Processing and Systems*, Madras, India, August 14, 2000.
20. Named Robert Parker, Sr. Centennial Professor in Engineering, The University of Texas at Austin, September 2000-August 2003.
21. Named a Dean's Fellow in the College of Engineering in the Year 2002.
22. Named The Cullen Trust for Higher Education Endowed Professor, The University of Texas at Austin, September 2003-August 2005.
23. **Plenary Address**, *IEEE Southwest Symposium on Image Analysis and Interpretation*, Lake Tahoe, Nevada, March 28-30, 2004.
24. **Plenary Address**, *National Instruments NI Week*, Austin, Texas, June 2004.
25. Named the **Keys and Joan Curry/Cullen Trust Endowed Chair in Engineering**, The University of Texas at Austin, September 2005-2014.
26. Recipient of the IEEE Signal Processing Society **Claude Shannon / Harry Nyquist Technical Achievement Award**, 2005. This is the highest technical honor given by the Society. Citation: "For Broad and Lasting Contributions to the Field of Digital Image Processing."
27. **Keynote Address**, *Twelfth Annual Worldwide Virtual Instrumentation Conference and Exhibition*, Austin Convention Center, Austin, Texas, August 2006.
28. Elected **Fellow of the Optical Society of America**, "For fundamental research contributions to and technical leadership in digital image and video processing," November 2006.
29. **Keynote Address**, *SPIE Human Vision and Electronic Imaging Conference*, San Jose, California, January 29, 2007.
30. **Plenary Address**, *IEEE Signal Processing Society International Workshop on Multimedia Signal Processing*, Chania, Crete, Greece, October 2007.

31. **Plenary Address**, *Texas Wireless Symposium*, Austin, Texas, October 2007.
32. **Plenary Address**, *IEEE Southwest Symposium on Image Analysis and Interpretation*, Santa Fe, New Mexico, March 2008.
33. Recipient of the IEEE Signal Processing Society **Karl Friedrich Gauss Education Award** in 2008. This is the highest education honor given by the Society. Citation: “*For Broad and Lasting Contributions to Image Processing, including popular and important image processing books, innovative on-line courseware, and for the creation of the leading research and educational journal and conference in the image processing field.*”
34. Elected **Fellow of the Society of Photo-Optical and Instrumentation Engineers (SPIE)** “*For pioneering technical, leadership, and educational contributions to the field of image processing,*” December 2007.
35. **Plenary Address**, *IEEE Region 10 Conference*, Hyderabad, India, November 2008.
36. **Plenary Address**, *First IEEE International Workshop on IP Multimedia Communications*, Virgin Islands, USA, August 4, 2008.
37. **Plenary Address**, *IEEE International Conference on Image Processing*, San Diego, California, October 2008.
38. Recipient of the **Distinguished Alumni Award of the University of Illinois**, Champaign-Urbana “*For fundamental and enduring technical, educational and service contributions to the field of digital image and video processing,*” September 2008.
39. Recipient of the **Billy and Claude R. Hocott Award** for Distinguished Engineering Research, The University of Texas at Austin. This is the highest engineering research award given annually to one member of the faculty of the Cockrell School of Engineering, October 2008.
40. Panelist, “Tools, Targets and Trends,” *First International Workshop on Quality of Multimedia Experience*, San Diego, California, July 30, 2009.
41. Winner, **IEEE Signal Processing Society Best Paper Award** for 2009, for the paper “Image Quality Assessment: From Error Visibility to Structural Similarity,” published in the *IEEE Transactions on Image Processing*, volume 13, number 4, pages 600-612, April 2004. This is the highest paper award given by the Society, and is retrospective over the five years leading up to the award.
42. **Plenary Address**, *IEEE Southwest Symposium on Image Analysis and Interpretation*, Austin, Texas, May 2010.
43. **Plenary Address**, *Optical Society of America Topical Meeting on Digital Image Processing and Analysis (DIPA)*, Tucson, AZ, June 2010.
44. **Keynote Address**, *National Instruments NI Week Vision Summit*, August 2010.
45. Elected **Fellow of the American Institute for Medical and Biological Engineering (AIMBE)**, October 2010.
46. **Plenary Address**, *IS&T / SPIE Electronic Imaging Symposium*, San Francisco, California, January 2011.
47. Recipient of the **IS&T / SPIE Imaging Scientist of the Year Award**, 2011. This is the highest technical honor collaboratively given by these two Societies. Citation: “*For his seminal contributions to the computational aspects of biological visual perception, specifically in the areas of image and video quality.*”
48. **Keynote Address**, *European Workshop on Visual Information Processing*, Paris, July 2011.
49. **Keynote Address**, *IEEE Southwest Symposium on Image Analysis and Interpretation*, Santa Fe, New Mexico, April 2012.
50. **Plenary Address**, *Optical Society of America Meeting on Computational Optical Sensing and*

- Imaging*, Monterrey, California, June 25, 2012.
51. **Plenary Address**, *Workshop on Digital Video Analytics and Processing*, IIT-Chennai, Chennai, India, December 2012.
 52. **Keynote Address**, *International Workshop on Video Processing and Quality Metrics for Consumer Electronics*, Scottsdale, Arizona, January 30, 2013.
 53. Recipient of the **SPIE Technology Achievement Award**, 2012. This is the highest technical honor given by the 17,000 member Society for Photo-Optical and Instrumentation Engineers. Citation: “*For Broad and Lasting Contributions to the Field of Perception-Based Image Processing.*”
 54. **Keynote Address**, *IEEE Signal Processing Society Workshop on Image, Video, and Multidimensional Signal Processing*, Seoul, Korea, June 2013.
 55. Recipient of the **Honorary Member Award** of the Society for Imaging Science and Technology, 2014. This is the highest award of any kind given by IS&T. Citation: “*For his impact in shaping the direction and advancement of the field of perceptual image processing.*”
 56. **Keynote Address**, *SPIE Conference on Image Quality and System Performance*, San Francisco, California, January 2014.
 57. Recipient of the **Norbert Wiener Society Award of the IEEE Signal Processing Society**, 2013. This is the highest award of any kind given by the IEEE SPS. Citation: “*For fundamental contributions to digital image processing theory, technology, leadership and education.*”
 58. Recipient of the **IEEE Signal Processing Magazine Best Paper Award** of the IEEE Signal Processing Society for 2013, for the paper “Mean Squared Error: Love it or Leave it? — A New Look at Signal Fidelity Measures,” *IEEE Signal Processing Magazine*, vol. 26, no. 1, pp. 98-117, January 2009. This is the highest survey paper award given by the Society, and is retrospective over the five years leading up to the award.
 59. Co-author of the **IEEE Signal Processing Society Young Author Best Paper Award** (with K. Seshadrinathan) for 2013, for the paper “Motion Tuned Spatio-Temporal Quality Assessment of Natural Videos,” *IEEE Transactions on Image Processing*, vol. 19, no. 2, pp. 335-350, February 2010. This is the highest young author paper award given by the Society, and is retrospective over the five years leading up to the award.
 60. **Plenary Address**, *IEEE Southwest Symposium on Image Analysis and Interpretation*, San Diego, California, April 2014.
 61. **Keynote Address**, *Second IEEE Global Conference on Signal and Information Processing*, Atlanta, Georgia, December 2014.
 62. **Highly-Cited Researcher for 2014**, according to Thompson Reuters, indicating one of the top 1% of most-cited researchers within the field of Engineering, August 2014.
 63. Named Holder of the **Ernest J. Cockrell Endowed Chair in Engineering (#3)**, The University of Texas at Austin, September 2014-present.
 64. Recipient of the **ICIP Top 10% Paper Award** for the paper “Assessment of Video Quality Using Time-Frequency Statistics,” presented at the *IEEE International Conference on Image Processing*, Paris, France, October 27-30, 2014 (with A. Mittal and M. Saad).
 65. **Keynote Address**, *Eighth International Conference on Image and Graphics (ICIG)*, Tianjin, China, August 2015.
 66. Recipient of the **Joe J. King Professional Engineering Achievement Award**, The University of Texas at Austin. This is the highest engineering award honoring professional achievement and leadership given annually to one member of the faculty of the Cockrell School of Engineering, September 2015.

67. **Plenary Address**, *IEEE Southwest Symposium on Image Analysis and Interpretation*, Santa Fe, New Mexico, March 2016.
68. Recipient of Television's highest honor, an individual **Primetime Emmy Award for Outstanding Achievement in Engineering Development** from the Academy of Television Arts and Sciences in October 2015, for the invention of "Structural Similarity (SSIM) Video Quality Measurement." The award recognizes his work on the development of video quality prediction models which have become standard tools in broadcast and post-production houses throughout the television industry. A Primetime Emmy Award is Television's highest honor. Individual Emmy Awards are rare, and individual awards to academics are exceedingly rare.
69. **Highly-Cited Researcher for 2015**, according to Thompson Reuters, indicating one of the top 1% of most-cited researchers within the field of Engineering.
70. Recipient of the **IEEE Circuits and Systems for Video Technology Best Paper Award** of the IEEE Circuits and Systems Society for 2016, for the paper "Video Quality Assessment by Reduced Reference Spatio-Temporal Entropic Differencing," *IEEE Transactions on Circuits and Systems for Video Technology*, vol. 23, no. 4, pp. 684 – 694, April 2013. Retrospective over the three years leading up to the award.
71. **Keynote Address**, Thomas Huang Symposium, The Beckman Institute, The University of Illinois, Urbana, Illinois, October 1, 2016.
72. **Keynote Address**, *IEEE International Workshop on Signal Processing Systems*, Dallas, Texas, October 26-28, 2016.
73. **Highly-Cited Researcher for 2016**, according to Thompson Reuters, indicating one of the top 1% of most-cited researchers within the field of Engineering.
74. Recipient of the **IEEE Signal Processing Society Sustained Impact Paper Award for 2017**, for the paper "Image Quality Assessment: From Error Visibility to Structural Similarity," published in the *IEEE Transactions on Image Processing*, volume 13, number 4, pages 600-612, April 2004. This award is required to be limited to papers published in an IEEE Signal Processing Society journal at least ten years prior to the award, thereby recognizing sustained impact over many years on a subject related to the Society's technical scope. Notably, this is the most-cited paper ever published in any IEEE Signal Processing Society transactions, journal, magazine, express letters, or conference proceedings.
75. **Keynote Address**, *International Conference on Computer Analysis of Images and Patterns*, Ystad, Sweden, August 2017.
76. Recipient of the **Edwin H. Land Medal** for 2017 from The Optical Society and the Society for Imaging Science and Technology. Citation: *For substantially shaping the direction and advancement of modern perceptual picture quality theory, and for energetically engaging industry to transform his ideas into global practice.*
77. **2017 Google Scholar Classic Paper Award** (for Computer Vision and Pattern Recognition): "Image information and visual quality," *IEEE Transactions on Image Processing*, vol. 15, no. 2, pp. 430-444, February 2006. Google Scholar Classic Papers are highly-cited papers that have stood the test of time, and are among the ten most-cited articles in their area of research published ten years earlier. The main algorithm developed in the paper, called the Visual Information Fidelity (VIF) Index, is a core picture quality prediction engine used to quality-assess all encodes streamed globally by Netflix.
78. **2017 Google Scholar Classic Paper Award** (for Signal Processing): "An evaluation of recent full reference image quality assessment algorithms," *IEEE Transactions on Image Processing*, vol. 15, no. 11, pp. 3440-3451, November 2006. Google Scholar Classic Papers are highly-

cited papers that have stood the test of time, and are among the ten most-cited articles in their area of research published ten years earlier. The picture quality database and human study described in the paper, the LIVE Image Quality Database, has been the standard development tool for picture quality research since its first introduction in 2003.

79. **Highly-Cited Researcher for 2017**, according to Clarivate Analytics, indicating one of the top 1% of most-cited researchers within the field of Engineering.
80. Recipient of the **IEEE Signal Processing Letters Best Paper Award** of the IEEE Signal Processing Society for 2018, for the paper “Making a ‘Completely Blind’ Image Quality Analyzer,” *IEEE Signal Processing Letters*, vol. 21, no. 3, pp. 209-212, March 2013. This ‘high-impact’ Letters paper award is retrospective over the five years leading up to the award.
81. **Plenary Address**, *IEEE Southwest Symposium on Image Analysis and Interpretation*, Las Vegas, Nevada, April 2018.
82. **Keynote Address**, *Picture Quality Symposium*, San Francisco, California, June 2018.
83. **Keynote Address**, *European Workshop on Visual Information Processing (EUVIP)*, Tampere, Finland, November 2018.
84. **Keynote Address**, *SPIE Conference on Image Quality and System Performance*, San Francisco, California, January 2019.
85. Recipient of the **EURASIP Best Paper Award** of the European Association for Signal Processing for 2018, for the paper “Full-Reference Quality Assessment of Stereopairs Accounting for Rivalry,” *Signal Processing: Image Communication*, vol. 28, no. 10, pp. 1143-1155, October 2013. Retrospective over the five years leading up to the award.
86. Recipient of the **Best Paper Award** of the *Picture Coding Symposium* for the paper, “Detecting Source Video Artifacts with Supervised Sparse Filters,” June 2018.
87. Recipient of the **IEEE Fourier Award for Signal Processing** for 2019. This major honor is an IEEE-level Technical Field Award. Citation: *For seminal contributions and high-impact innovations to the theory and application of perception-based image and video processing*.
88. **Highly-Cited Researcher for 2018**, according to Clarivate Analytics, indicating one of the top 1% of most-cited researchers within the field of Engineering.

Professional Society Activities

Editorships and Publication Boards

1. Textbook reviewer for McGraw-Hill, West Educational, Academic Press, Prentice-Hall, and The MIT Press.
2. Editorial Board, *Pattern Recognition*, 1988 - present.
3. Associate Editor, *IEEE Transactions on Signal Processing*, 1989 - 1993.
4. Publications Board, IEEE Signal Processing Society, 1989 - 2002.
5. Guest Editor, Special Issue on “Three-Dimensional Microscopy,” *Machine Vision and Applications*, volume 4, no. 4, November 1991.
6. Steering Committee, *IEEE Transactions on Image Processing*, 1991 - 1995.
7. Editorial Board, *Journal of Visual Communication and Image Representation*, 1992 - 1995.
8. Associate Editor, *IEEE Signal Processing Letters*, 1993 - 1995.
9. Area Editor, *Graphical Models and Image Processing*, 1995 - 1998.
10. Editor-in-Chief, *IEEE Transactions on Image Processing*, 1996 - 2002.
11. Editorial Board, *Pattern Analysis and Applications*, 1997-1998.
12. Editorial Board, *The Proceedings of the IEEE*, 1998 - 2002.
13. Editorial Board, *Real-Time Imaging*, 2000 - 2004.

14. Series Editor for Image, Video, and Multimedia Processing, Morgan and Claypool Publishing Company, 2003 - present.
15. Editorial Board of the *Encyclopedia of Multimedia*, Kluwer Academic Publishing, 2005.
16. Senior Editorial Board, *IEEE Journal on Special Topics in Signal Processing*, 2006-present.
17. Editorial Board of the *Encyclopedia of Wireless and Mobile Communications*, 2006.
18. Overview Editor, *IEEE Transactions on Image Processing*, 2009-present.
19. Guest Editor, *IEEE Journal of Selected Topics in Signal Processing*, Special Issue on Special Issue on Perception Inspired Video Processing, 2013.
20. Senior Editorial Board, *IEEE Journal of Selected Topics in Signal Processing*, 2015-present.

Conference Chairmanships

1. Local Arrangements Chairman, *IEEE Computer Society Workshop on the Interpretation of 3-D Scenes*, Austin, Texas, November 24-27, 1989.
2. Program Chairman, SPIE Program on Image Processing, *SPIE/SPSE Symposium on Electronic Imaging*, Santa Clara, California, February 11-16, 1990.
3. Conference Chairman and Organizer, *SPIE Conference on Biomedical Image Processing*, Santa Clara, California, February 11-16, 1990.
4. Conference Chairman and Organizer, *SPIE Conference on Biomedical Image Processing II*, San Jose, California, February 24 - March 1, 1991.
5. Conference Co-Chairman, *SPIE Conference on Wavelet Applications in Signal and Image Processing*, San Diego, California, July 12-13, 1993.
6. General Chairman, *First IEEE International Conference on Image Processing*, Austin, Texas, November 14-16, 1994.
9. General Chair, *Texas Wireless Symposium*, Austin, Texas, November 2014.
7. Honorary General Chair, *IEEE Southwest Symposium on Image Analysis and Interpretation*, Las Vegas, Nevada, April 2018.

Other Conference Technical Committees and Program Committees

1. Technical Program Committee, *Tenth International Conference on Pattern Recognition*, Atlantic City, New Jersey, June 1990.
2. Technical Program Committee, *IEEE Computer Society Conference on Computer Vision and Pattern Recognition*, Maui, Hawaii, June 1991.
3. Technical Program Committee, *SPIE Symposium on Visual Communications and Image Processing*, Boston, Massachusetts, November 1992.
4. Technical Program Committee, *IEEE Computer Society Conference on Computer Vision and Pattern Recognition*, New York, New York, June 1993.
5. Conference Board, IEEE Signal Processing Society, 1992 - 1995.
6. Technical Program Committee, *Twelfth International Conference on Pattern Recognition*, Jerusalem, Israel, October 1994.
7. Technical Program Committee, *IEEE Workshop on Biomedical Image Analysis*, Seattle, Washington, June 1994.
8. Technical Program Committee, *IEEE Workshop on Nonlinear Signal and Image Processing*, Neos Marmaras-Halkidiki, Greece, June 1995.
10. Technical Program Committee, *IEEE International Conference on Image Processing*, Washington, DC, October 1995.
11. U.S. Liason, *IEEE International Conference on Image Processing*, Lausanne, Switzerland,

- November 1996.
12. Technical Program Committee, *IEEE International Conference on Image Processing*, Santa Barbara, CA, October 1997.
 13. Scientific Committee, *European Signal Processing Conference (EUSIPCO)*, Rhodes, Greece, September 1998.
 14. Technical Program Committee, *IEEE International Conference on Image Processing*, Chicago, IL, October 1998.
 15. Technical Program Committee, *IEEE Computer Society Conference on Computer Vision and Pattern Recognition*, Santa Barbara, California, June 1998.
 16. Technical Program Committee, *IEEE International Conference on Image Processing*, Vancouver, British Columbia, September 2000.
 17. Technical Program Committee, *IEEE International Conference on Image Processing*, Thessaloniki, Greece, October 2001.
 18. Organizing Committee, *IASTED International Conference on Signal and Image Processing - SIP 2002*, Kauai, Hawaii, August 12-14, 2002.
 19. Technical Program Committee, *IEEE International Conference on Image Processing*, Rochester, New York, September 2002.
 20. Technical Program Committee, *IEEE International Conference on Image Processing*, Barcelona, Spain, September 2003.
 21. Technical Program Committee, *SPIE Symposium on Visual Communications and Image Processing*, Lugano, Switzerland, November 2003.
 22. Technical Program Committee, *IEEE International Conference on Image Processing*, Singapore, October 2004.
 23. Technical Program Committee, *SPIE Symposium on Visual Communications and Image Processing*, San Jose, California, November 2004.
 24. Technical Program Committee, *IEEE International Conference on Image Processing*, Genoa, Italy, September 2005.
 25. Technical Program Committee, *SPIE Symposium on Visual Communications and Image Processing*, Beijing, China, November 2005.
 26. Technical Program Committee, *First International Workshop on Video Processing and Quality Metrics for Consumer Electronics*, Scottsdale, Arizona, January 2005.
 27. Technical Program Committee, *SPIE Symposium on Visual Communications and Image Processing*, San Jose, California, January 2006.
 28. Technical Program Committee, *Second International Workshop on Video Processing and Quality Metrics for Consumer Electronics*, Scottsdale, Arizona, January 2006.
 29. International Program Committee, *IASTED International Conference on Signal and Image Processing* Honolulu, Hawaii, August 2006.
 30. Technical Program Committee, *Southwest Symposium on Image Analysis and Interpretation*, Denver, Colorado, March 2006.
 31. Technical Program Committee, *IEEE International Conference on Image Processing*, Atlanta, Georgia, October 2006.
 32. Technical Program Committee, *Third International Workshop on Video Processing and Quality Metrics for Consumer Electronics*, Scottsdale, Arizona, January 26-26, 2007.
 33. Technical Program Committee, *SPIE Symposium on Visual Communications and Image Processing*, San Jose, California, January 2007.
 34. Technical Program Committee, *IEEE International Conference on Image Processing*, San

- Antonio, Texas, September 2007.
35. Technical Program Committee, *SPIE Symposium on Visual Communications and Image Processing*, San Jose, California, January 2008.
 36. Technical Program Committee, *IEEE International Conference on Image Processing*, San Diego, California, October 2008.
 37. International Technical Program Committee, *Sixth Indian Conference on Computer Vision, Graphics, and Image Processing*, Bhubaneswar, India, December 2008.
 38. Advisory Committee and Technical Program Committee, *First International Workshop on Quality of Multimedia Experience*, San Diego, California, July 2009.
 39. Technical Program Committee, *IEEE International Conference on Image Processing*, Cairo, Egypt, November 2009.
 40. Steering Committee, *Second International Workshop on Quality of Multimedia Experience*, Trondheim, Norway, June 2010.
 41. Technical Program Committee, *IEEE International Conference on Image Processing*, Hong Kong, September 2010.
 42. Steering Committee, *Third International Workshop on Quality of Multimedia Experience*, Mechelen, Belgium, September 2011.
 43. Technical Program Committee, *IEEE International Conference on Image Processing*, Brussels, Belgium, September 2011.
 44. Technical Program Committee, *IAPR/IEEE International Joint Conference on Biometrics*, Brussels, Belgium, October 2011.
 45. Steering Committee, *Fourth International Workshop on Quality of Multimedia Experience*, Yarra Valley, Australia, July 2012.
 46. Technical Program Committee, *IEEE International Conference on Image Processing*, Orlando, Florida, October 2012.
 47. Technical Program Committee, *European Workshop on Visual Information Processing*, Paris, France, June 2013.
 48. Steering Committee, *Fifth International Workshop on Quality of Multimedia Experience*, Klagenfurt am Wörthersee, Austria, July 2013.
 49. Technical Program Committee, *IEEE International Conference on Image Processing*, Melbourne, Australia, September 2013.
 50. Technical Program Committee, *International Symposium on Image and Signal Processing and Analysis*, Trieste, Italy, September 2013.
 51. Technical Program Committee, *IEEE International Conference on Image Processing*, Paris, France, October 2014.
 52. Technical Program Committee, *IEEE Global Conference on Signal and Information Processing (GlobalSIP)*, Atlanta, Georgia, December 2014.
 53. Technical Program Committee, *ACM Workshop on Perception Inspired Video Processing*, Orlando, Florida, November 2014.
 54. Technical Program Committee, *IEEE International Conference on Image Processing*, Quebec, Canada, October 2015.
 55. Program Committee, *Third Workshop on Quality of Multimedia Services (QUAMUS)*, Naples, Italy, November 2016.
 56. Technical Program Committee, *IEEE International Conference on Image Processing*, Phoenix, Arizona, September 2016.

Standing Society Committees

1. IEEE Computer Society Pattern Analysis and Machine Intelligence Technical Committee, 1988 - present.
2. Image and Multidimensional Digital Signal Processing Technical Committee of the IEEE Signal Processing Society, 1989 - 2002.
3. Member-at-Large, Board of Governors, IEEE Signal Processing Society, 1996 - 2002.
4. Awards Board, IEEE Signal Processing Society, 2004 - 2007.
5. IEEE Communication Society Multimedia Communications Technical Committee, 2010-present.

Government Panels

1. Review Panelist, National Science Foundation, Instrumentation, Sensing, and Measurement Small Business Innovation Research Program, September 1987.
2. Review Panelist, National Science Foundation, Computer Research Equipment Program, November 1987.
3. Review Panelist, National Science Foundation, Research Initiation Awards, March 1993.
4. Review Panelist, National Science Foundation, CAREER Awards, November 2004.
5. Review Panelist, National Science Foundation, Information and Intelligent Systems Awards, November 2004.
6. Review Panelist, National Science Foundation, Science and Technology Centers (STC), September 2015.

Other Panels and Boards

1. Advisory Board, International Center for Signal Processing, Tampere, Finland, 1996 - present.
2. Faculty Advisory Committee, Center for Advanced Studies in the Arts, The University of Texas at Austin, 1997 - 2000.

Journal Citation Highlights

- 1983: #2 cited paper of *IEEE Transactions on Acoustics, Speech and Signal Processing*
- 1987: #7 cited paper of *Pattern Recognition Letters*
- 1989: #12 cited paper of *Pattern Recognition*
- 1990: #4 cited paper of *IEEE Transactions on Pattern Analysis and Machine Intelligence*
- 1996: #9 cited paper of *IEEE Transactions on Speech and Audio Processing*
- 2002: #1 cited paper of *IEEE Signal Processing Letters* (**#1 cited ever of >1000**)
#10 cited paper of *IEEE Transactions on Multimedia*
- 2004: #1 cited paper of *IEEE Transactions on Image Processing* (**#1 cited ever of >1000**)
#1 cited paper of *EURASIP Journal on Signal Processing: Image Communication* (**#1 cited ever of >1000**)
- 2005: #7 cited paper of *IEEE Transactions on Image Processing*
#11 cited paper of *IEEE Transactions on Image Processing*
- 2006: #3 cited paper of *IEEE Transactions on Image Processing*
#4 cited paper of *IEEE Transactions on Image Processing*
- 2009: #1 cited paper of *IEEE Selected Topics in Signal Processing*
#1 cited paper of *IEEE Signal Processing Magazine*
- 2010: #1 cited paper of *IEEE Signal Processing Letters*
#2 cited paper of *IEEE Signal Processing Letters*

- #3 cited paper of *EURASIP Journal on Signal Processing: Image Communication*
#4 cited paper of *IEEE Transactions on Circuits and Systems for Video Technology*
#5 cited paper of *IEEE Transactions on Image Processing*
#10 cited paper of *IEEE Transactions on Image Processing*
 2011: #6 cited paper of *IEEE Transactions on Image Processing*
#6 cited paper of *EURASIP Journal on Signal Processing: Image Communication*
 2012: #1 cited paper of *IEEE Transactions on Image Processing*
#3 cited paper of *IEEE Transactions on Image Processing*
#3 cited paper of *IEEE Journal on Selected Topics in Signal Processing*
#4 cited paper of *IEEE Signal Processing Letters*
 2013: #1 cited paper of *IEEE Signal Processing Letters*
#3 cited paper of *IEEE Transactions on Circuits and Systems for Video Technology*
#1 cited paper of *EURASIP Journal on Signal Processing: Image Communication*
#2 cited paper of *EURASIP Journal on Signal Processing: Image Communication*
 2014: #1 cited paper of *IEEE Transactions on Image Processing*
#9 cited paper of *IEEE Transactions on Image Processing*
#1 cited paper of *EURASIP Journal on Signal Processing: Image Communication*
#4 cited paper of *EURASIP Journal on Signal Processing: Image Communication*
#7 cited paper of *EURASIP Journal on Signal Processing: Image Communication*
 2015: #3 cited paper of *IEEE Journal on Selected Topics in Signal Processing*
#5 cited paper of *IEEE Transactions on Image Processing*
 2016: #6 cited paper of *IEEE Transactions on Image Processing*

Journal Publications

1. A.C. Bovik, T.S. Huang and D.C. Munson, "A generalization of median filtering using linear combinations of order statistics," *IEEE Transactions on Acoustics, Speech, and Signal Processing*, vol. ASSP-31, no. 6, pp. 1342-1350, December 1983.
2. A.C. Bovik, T.S. Huang and D.C. Munson, "Edge-sensitive image restoration using order-constrained least-squares methods," *IEEE Transactions on Acoustics, Speech, and Signal Processing*, vol. ASSP-33, no. 4, pp. 1253-1263, October 1985.
3. A.C. Bovik and D.C. Munson, "Edge detection using median comparisons," *Computer Vision, Graphics, and Image Processing*, vol. 33, pp. 377-389, March 1986.
4. A.C. Bovik, T.S. Huang and D.C. Munson, "Nonparametric tests for edge detection in noise," *Pattern Recognition*, vol. 19, No. 3, pp. 209-219, 1986.
5. A.C. Bovik and D.C. Munson, "Optimal detection of object boundaries in uncorrelated speckle," *Optical Engineering*, vol. 25, no. 11, pp. 1246-1252, November 1986.
6. J.K. Aggarwal, K.R. Diller and A.C. Bovik, "Computer vision and image processing research at the University of Texas at Austin," *Image and Vision Computing*, vol. 4, no. 4, pp. 219-222, November 1986.
7. A.C. Bovik, T.S. Huang and D.C. Munson, "The effect of median filtering on edge estimation and detection," *IEEE Transactions on Pattern Analysis and Machine Intelligence*, vol. PAMI-9, no. 2, pp. 181-194, March 1987.
8. A.C. Bovik, "Streaking in median filtered images," *IEEE Transactions on Acoustics, Speech, and Signal Processing*, vol. ASSP-35, no. 4, pp. 493-503, April 1987.
9. N.H. Kim, A.B. Wysocki, A.C. Bovik and K.R. Diller, "A microcomputer-based vision system for area measurement," *Computers in Biology and Medicine*, vol. 17, no. 3, pp. 173-183, June

- 1987.
10. A.C. Bovik and A. Restrepo, "Spectral properties of moving L-estimates of independent data sequences," *Journal of the Franklin Institute*, vol. 324, no. 1, pp. 125-137, 1987.
11. M. Clark, A.C. Bovik and W.S. Geisler, "Texture segmentation using Gabor modulation/demodulation," *Pattern Recognition Letters*, vol. 6, pp. 261-267, September 1987.
12. J.R. Jordan and A.C. Bovik, "Computational stereo using color," Cover Paper of Special Issue on Machine Vision and Image Understanding, *IEEE Control Systems Magazine*, vol. 8, no. 3, pp. 31-36, June 1988.
13. F. Macías-Garza, A.C. Bovik and K.R. Diller, "Missing cone of frequencies and low-pass distortion in 3-D microscopic images," *Optical Engineering*, vol. 27, no. 6, pp. 461-465, June 1988.
14. S.H. Kim, K.T. Park and A.C. Bovik, "Recognition of Korean isolated digits using a pole-zero model," *Journal of the Korean Acoustical Society*, vol. 25, no. 4, pp. 356-365, June 1988.
15. F. Macías-Garza, A.C. Bovik, K.R. Diller, S.J. Aggarwal and J.K. Aggarwal, "Digital reconstruction of three-dimensional serially sectioned optical images," *IEEE Transactions on Acoustics, Speech, and Signal Processing*, vol. ASSP-36, no. 7, pp. 1067-1075, July 1988.
16. A. Restrepo, and A.C. Bovik, "On the generation of random numbers from heavy-tailed distributions," *Proceedings of the IEEE*, vol. 76, no. 7, pp. 838-840, July 1988.
17. A. Restrepo and A.C. Bovik, "Adaptive trimmed mean filters for image restoration," *IEEE Transactions on Acoustics, Speech, and Signal Processing*, vol. ASSP-36, no. 8, pp. 1326-1337, August 1988.
18. C.-C. Chu and A.C. Bovik, "Visible surface reconstruction via local minimax approximation," *Pattern Recognition*, vol. 21, no. 4, pp. 303-312, 1988.
19. A.C. Bovik, "On detecting edges in speckle imagery," *IEEE Transactions on Acoustics, Speech, and Signal Processing*, vol. ASSP-36, no. 10, pp. 1618-1627, October 1988.
20. N.H. Kim and A.C. Bovik, "A contour-based stereo matching algorithm using disparity continuity," *Pattern Recognition*, vol. 21, no. 5, pp. 505-514, 1988.
21. D.D. Kerrick and A.C. Bovik, "Microprocessor-based recognition of handprinted characters from a tablet input," *Pattern Recognition*, vol. 21, no. 5, pp. 525-537, 1988.
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 417. D. Kundu, D. Ghadiyaram, A.C. Bovik and B.L. Evans, "No-reference image quality assessment for high dynamic range images," *Fiftieth Annual Asilomar Conference on Signals, Systems, and Computers*, Monterey, California, November 6-9, 2016.
 418. C. Ancuti, C. Ancuti, C. Devleeschouwer, R. Garcia and A.C. Bovik, "Multi-scale underwater descattering," *23rd International Conference on Pattern Recognition*, Cancun, Mexico, December 4-8, 2016.
 419. D.E. Moreno-Villamarín, H.D. Benítez-Restrepo and A.C. Bovik, "Statistics of natural fused image distortions," *IEEE International Conference on Acoustics, Speech, and Signal Processing*, New Orleans, Louisiana, March 5-9, 2017.
 420. D. Ghadiyaram, J. Pan, A.C. Bovik, A. Moorthy, P. Panda and K.-C. Yang, "Subjective and objective quality assessment of mobile videos with in-capture distortions," *IEEE International Conference on Acoustics, Speech, and Signal Processing*, New Orleans, Louisiana, March 5-9, 2017.
 421. P. Gupta, J.L. Glover, N.G. Paulter Jr. and A.C. Bovik, "Statistical modelling of x-ray images," *ASTM International Symposium on the Technologies and Metrology of Checkpoint Screening Equipment*, Toronto, Ontario, Canada, April 12-13, 2017.
 422. A.C. Bovik, C. Bampis and T.R. Goodall, "Perceptual issues of streaming video," Invited Paper, *Society for Information Display International Symposium*, Los Angeles, California, May 21-26, 2017.
 423. C. Bampis and A.C. Bovik, "Temporal and behavioral aspects of subjective video quality perception," *Seventeenth Annual Meeting of the Vision Sciences Society*, St. Petersburg, Florida, May 19-24, 2017.
 424. C. Bampis, Z. Sinno and A.C. Bovik, "Localizing and correcting exposure-saturated regions using a natural image statistics model," *Seventeenth Annual Meeting of the Vision Sciences Society*, St. Petersburg, Florida, May 19-24, 2017.
 425. T.R. Goodall and A.C. Bovik, "Upscaling and comb artifact prediction on motion pictures using convolution networks," *Seventeenth Annual Meeting of the Vision Sciences Society*, St. Petersburg, Florida, May 19-24, 2017.
 426. C.G. Rodriguez -Pulicio, H.D. Benítez-Restrepo and A.C. Bovik, "Image quality assessment to enhance infrared face recognition," *IEEE International Conference on Image Processing*, Beijing, China, September 17-20, 2017.
 427. C. Bampis, C. Rusu, H. Hajj and A.C. Bovik, "Robust matrix factorization for collaborative filtering in recommender systems," *Fifty-First Annual Asilomar Conference on Signals, Systems, and Computers*, Monterey, California, October 29 - November 1, 2017.
 428. T.M. Jarriel, F. Isikdogan, P. Passalacqua, and A.C. Bovik, "Ganges-Brahmaputra-Meghna delta connectivity analysis using new tools for the automatic extraction of channel networks from remotely sensed imagery," *American Geophysical Union Fall Meeting*, New Orleans, Louisiana, December 11-15, 2017.

429. Z. Sinno, C. Caramanis and A.C. Bovik, "Second order natural scene statistics model of blind image quality assessment," *IEEE International Conference on Acoustics, Speech, and Signal Processing*, Calgary, British Columbia, Canada, April 15-20, 2018.
430. Z. Sinno and A.C. Bovik, "On the natural statistics of chromatic images," *IEEE Southwest Symposium on Image Analysis and Interpretation*, Las Vegas, Nevada, April 9-11, 2018.
431. T. Goodall and A.C. Bovik, "Artifact detection maps learned using shallow convolutional networks," *IEEE Southwest Symposium on Image Analysis and Interpretation*, Las Vegas, Nevada, April 9-11, 2018.
432. P. Gupta, C. Bampis, Y. Jin and A.C. Bovik, "Natural scene statistics for noise estimation," *IEEE Southwest Symposium on Image Analysis and Interpretation*, Las Vegas, Nevada, April 9-11, 2018.
433. S. Kwon, S. Kim, H.S. Lee, J.Y. Park, K.J. Kim, M.K. Markey, A.C. Bovik, S. Bang, S.W. Park, S.Y. Song, J.B. Chung and M.J. Chung, "Survival analysis based on relationship between lewis antigen and carbohydrate antigen 19-9 in 1115 patients with pancreatic cancer in 1115 asian population," *Digestive Disease Week*, Washington DC, June 2-5, 2018.
434. S. Kim, S. Kwon, H.S. Lee, K.J. Kim, M.K. Markey, A.C. Bovik, J.Y. Park, S. Bang, S.W. Park, S.Y. Song, J.B. Chung and M.J. Chung, "CA19-9 nadir within the first 12 weeks of chemotherapy predicts overall survival in patients with advanced pancreatic cancer," *Digestive Disease Week*, Washington DC, June 2-5, 2018.
435. P. Gupta, C. Bampis, Y. Ji and A.C. Bovik, "Natural scene statistics for noise estimation," *IEEE Southwest Symposium on Image Analysis and Interpretation*, Las Vegas, Nevada, April 8-10, 2018.
436. T.R. Goodall and A.C. Bovik, "Artifact detection maps learned using shallow convolutional networks," *IEEE Southwest Symposium on Image Analysis and Interpretation*, Las Vegas, Nevada, April 8-10, 2018.
437. Z. Sinno and A.C. Bovik, "On the natural statistics of chromatic images," *IEEE Southwest Symposium on Image Analysis and Interpretation*, Las Vegas, Nevada, April 8-10, 2018.
438. C. Bampis, Z. Li and A.C. Bovik, "A simple prediction fusion improves data-driven full-reference video quality assessment models," *Picture Coding Symposium*, San Francisco, California, June 24-27, 2018.
439. T. Goodall and A.C. Bovik, "Detecting source video artifacts with supervised sparse filters," *Picture Coding Symposium*, San Francisco, California, June 24-27, 2018 (**Best Paper Award**).
440. Z. Sinno, A.K. Moorthy, J. De Cock, Z. Li, and A.C. Bovik, "Quality assessment of thumbnail and billboard images on mobile devices," *Picture Coding Symposium*, San Francisco, California, June 24-27, 2018.
441. X. Yu, C.G. Bampis, P. Gupta and A.C. Bovik, "Predicting the quality of images compressed after distortion in two steps," *SPIE Conference on Applications of Digital Image Processing*, San Diego, California, August 19-23, 2018.
442. Z. Sinno and A.C. Bovik, "Predicting 3D visual discomfort using natural scene statistics and a binocular model," *SPIE Conference on Applications of Digital Image Processing*, San Diego, California, August 19-23, 2018.
443. S. Kim, S. Kwon, M.K. Markey, A.C. Bovik, S.H. Hong, J. Kim, B. Joung and J. Park, "Paroxysmal versus persistent atrial fibrillation: cross-institutional validation of predictive benefit of surface 12-lead electrocardiography," *European Society of Cardiology Congress*, Munich, Germany, August 25-29, 2018.
444. S. Kwon, S. Kim, A.C. Bovik, M.K. Markey, H. Lee, G. Joo, B. Joung, H. Im, and J. Park,

- “Risk of mortality depends on the temporal sequence of atrial fibrillation and ischemic stroke,” *European Society of Cardiology Congress*, Munich, Germany, August 25-29, 2018.
445. S. Kwon, S. Kim, A.C. Bovik, M.K. Markey, H. Lee, B. Joung, H. Im, and J. Park, “Sex differences in influence of atrial fibrillation upon mortality of patients with ischemic stroke,” *European Society of Cardiology Congress*, Munich, Germany, August 25-29, 2018.
 446. J. Pan, M. Mueller, T. Lahlou and A.C. Bovik, “Orthogonally-divergent fisheye stereo,” *Advanced Concepts for Intelligent Vision Systems Conference*, Poitiers, France, September 24-27, 2018.
 447. H. Zeng, L. Zhang and A.C. Bovik, “Blind image quality assessment with a probabilistic quality representation,” *IEEE International Conference on Image Processing*, Athens, Greece, October 7-10, 2018.
 448. C. Bampis, Z. Li and A.C. Bovik, “Enhancing temporal quality measurements in a globally deployed streaming video quality predictor,” *IEEE International Conference on Image Processing*, Athens, Greece, October 7-10, 2018.
 449. Z. Sinno and A.C. Bovik, “Large scale subjective video quality study,” *IEEE International Conference on Image Processing*, Athens, Greece, October 7-10, 2018.
 450. P. Gupta, C. Bampis and A.C. Bovik, “Multivariate statistics for blind image quality applications,” *IEEE International Conference on Image Processing*, Athens, Greece, October 7-10, 2018.
 451. C. Zhang, J. Zhou, X. Gu, S. Zhu and A.C. Bovik, “Eye movement pattern modeling and visual comfort viewing S3D images,” *IEEE International Conference on Visual Communications and Image Processing*, Taichung, Taiwan, December 9-12, 2018.
 452. S. Kwon, S. Kim, H. Im, A.C. Bovik, B. Joung and J. Park, “Gamma glutamyl transferase predicts new onset atrial fibrillation,” *American Heart Association Scientific Sessions*, Chicago, Illinois, November 10-12, 2018.
 453. P. Gupta, C. Bampis, J. Glover, N. Paulter and A.C. Bovik, “Multivariate statistical modeling for image quality prediction,” *SPIE Conference on Image Quality and System Performance*, Burlingame, California, January 13-17, 2019.
 454. C. Bampis, Z. Li, I. Katsavounidas, T.Y. Huang, C. Ekanadhan and A.C. Bovik, “Subjective analysis of an end-to-end streaming system,” *SPIE Conference on Image Quality and System Performance*, Burlingame, California, January 13-17, 2019.
 455. J. Berón, H.D.B. Restrepo and A.C. Bovik, “Optimal feature selection for blind super-resolution image quality evaluation,” *IEEE International Conference on Acoustics, Speech, and Signal Processing*, Brighton, England, May 12-17, 2019.

Patents

1. A.C. Bovik and D. Chen, “Method and apparatus for visual pattern image coding,” U.S. Patent Number 5,144,688, September 1, 1992.
2. A.C. Bovik, D. Chen and P.L. Silsbee, “Method and apparatus for coding both still and moving visual pattern images,” U.S. Patent Number 5,282,255, January 25, 1994.
3. M.S. Sampat, A.C. Bovik and M.K. Markey, “Method and apparatus for detecting spiculated masses in mammography,” U.S. Patent Number 8,164,039, April 24, 2012.
4. S. Jahanbin, A.C. Bovik, E. Perez and D. Nair, “Detection of textural defects using a one class support vector machine,” U.S. Patent Number 8,457,414, June 4, 2013.
5. A.K. Moorthy and A.C. Bovik, “Method and apparatus for assessing a quality of an image or video using a distortion classifier,” U.S. Patent 8,660,372, February 25, 2014.

6. A.K. Moorthy and A.C. Bovik, "Maximizing perceptual quality and naturalness of captured images," U.S. Patent 9,277,148, March 1, 2016.
7. A.K. Moorthy and A.C. Bovik, "Determining quality of an image or video using a distortion classifier," U.S. Patent 9,595,090, March 14, 2017.
8. D. Ghadiyaram, J. Pan and A.C. Bovik, "Predicting a viewer's quality of experience," U.S. Patent 10,182,097, January 15, 2019.
9. A.K. Moorthy and A.C. Bovik, "Method and Apparatus for Assessing and Correcting the quality of an image or a video using a distortion classifier," U.S. Patent pending, 2017.
10. T.R. Goodall and A.C. Bovik, "Visible-infrared image discerner," U.S. Patent pending, 2017.
11. T.R. Goodall and A.C. Bovik, "Perceptual non-uniformity index" U.S. Patent pending, 2017.
12. A.C. Bovik, C. Hunger, Z. Li, M. Crooks, M. Meserve, M. Mora and M. Webb, "Detecting and correcting whiteboard images while enabling the removal of the speaker," U.S. Patent pending, 2017.
13. A.C. Bovik, "Conditional image or video quality assessment," U.S. Patent pending, 2017.
14. A.C. Bovik, S. Kim, J.S. Park, C.G. Bampis and G.A. Dimakis, "Adversarial Video compression guided by soft edge detection," U.S. Patent pending, 2019.

Book Reviews and Other Articles

1. B.K.P. Horn, *Robot Vision*. MIT Press, Cambridge, MA, 1986 (book jacket).
2. T.J. Terrell, *Introduction to Digital Filters*. Wiley, New York, 1988, in *IEEE Circuits and Devices Magazine*, vol. 6, no. 5, p. 59, September 1990.
3. Professor Bovik was the subject of the article "Algorithm assesses image and video quality," by Andrew Wilson, *Vision Systems Design* October 2006, available online: http://vsd.pennnet.com/Articles/Article_Display.cfm?Section=ARTCL&ARTICLE_ID=274253&VERSION_NUM=2&p=19.
4. Professor Bovik's research on video quality was the subject of the article "HPC for your visual library: How algorithms and supercomputers assess video quality," *International Science Grid this Week*, July 2015, online: <http://www.isgtw.org/feature/hpc-your-visual-library-how-algorithms-and-supercomputers-assess-video-quality>.

Thesis and Dissertation

1. A.C. Bovik, "Nonlinear filtering using linear combinations of order statistics," Coordinated Science Laboratory Report R-935, University of Illinois, Urbana, IL, January 1982 (also M.S. Thesis).
2. A.C. Bovik, "Noise-robust methods for image restoration and edge detection," Ph.D. dissertation, University of Illinois, Urbana, IL, May 1984.

Keynote Addresses, Plenary Addresses, Distinguished Lectures, and Other Invited Talks

1. Invited Talk, "L-filters," 1985 College of Engineering Annual Research Review, The University of Texas at Austin, May 1985.
2. Invited Talk, "Detection of Object Boundaries in Synthetic Aperture Radar Imagery," University of Illinois Coordinated Science Laboratory, Urbana, Illinois, June 1985.
3. Invited Talk, "On the Information Content of Handprinted Characters," Texas Instruments Invited Presentation, Dallas, Texas, March 1986.
4. Invited Talk, "A Microcomputer-based Stereo Computer Vision System," 1986 College of Engineering Annual Research Review, The University of Texas at Austin, May 1986.

5. Invited Talk, "Efficient Recognition of Handprinted Characters," Texas Instruments Invited Presentation, Dallas, Texas, July 1986.
6. Invited Talk, "Three-dimensional Computer Vision: Goals and Methods," Central Texas IEEE Section and ASSP-COMSOC Chapter Invited Presentation, Austin, Texas, October 9, 1986.
7. Invited Talk, "A Microprocessor-based Handprinted Character Recognition System," Texas Instruments Invited Presentation, Dallas, Texas, February 1987.
8. Invited Talk, "An Image Processing and Computer Vision Instructional Laboratory," IBM Corporation, Austin, Texas, May 1987.
9. Invited Talk, "Recognition of D'Nealian Script," Texas Instruments Invited Presentation, Dallas, Texas, August 1987.
10. Invited Talk, "Image Processing and Computer Vision Research," Motorola SABA Spring Meeting, Austin, Texas, April 1988.
11. Invited Talk, "Computational Texture Analysis Using Localized Spatial Filtering," Brooks Air Force Base, San Antonio, Texas, June 1988.
12. Invited Talk, "Computer Vision," University of Texas Electrical & Computer Engineering Visiting Committee, Austin, Texas, April 1989.
13. Invited Talk, "Three-dimensional Computer Vision," Texas Instruments Invited Presentation, Dallas, Texas, June 1989.
14. Invited Talk, "CCD Image Processing," Texas Instruments Invited Presentation, Dallas, Texas, February 1990.
15. Invited Talk, "Digital Image Processing - A Personal Overview," IBM Seminar, Austin, Texas, April 1990.
16. Invited Talk, "Computer Vision for Three-dimensional Microscopy," University of Liverpool, Quantitative Microscopy Group, Liverpool, England, February 1991.
17. Invited Talk, "Visual Pattern Image Sequence Coding," NASA Johnson Space Center, Houston, Texas, May 1991.
18. Invited Talk, "Machine Vision Research in the Laboratory for Vision Systems," Motorola Semiconductor, Phoenix, Arizona, July 1991.
19. Invited Talk, "Wavelet-based Image and Video Coding," IBM Corporation, Austin, Texas, November 1991.
20. Invited Talk, "Local analysis of image frequencies," Division of Applied Sciences, Harvard University, Cambridge, Massachusetts, April 1992.
21. Invited Talk, "Modulation Models for Image Processing and Multi-band Image Demodulation," Texas Instruments Invited Presentation, Dallas, Texas, April 1993.
22. Invited Talk, "Active Vision Technology for a Semi-autonomous Rover," NASA Johnson Space Center, Houston, Texas, May 1993.
23. Invited Talk, "The Practical Application of Active Focus Control for Depth Recovery," NASA Johnson Space Center, Houston, Texas, April 1994.
24. Invited Talk, "FOVEA: A Foveated Vergent Active Stereo System," Center for Vision and Image Sciences, The University of Texas at Austin, Austin, Texas, May 1996.
25. Invited Talk, "An Algebraic Approach to Multi-frame Blind Image Deconvolution," Phillips Research Laboratory, Kirtland Air Force Base, Albuquerque, New Mexico, November 19, 1996.
26. Invited Talk, "AM-FM Image Models," Phillips Research Laboratory, Kirtland Air Force Base, Albuquerque, New Mexico, November 19, 1996.
27. Invited Talk, "AM-FM Image Analysis," US Army Research Office First Annual Center for

- Imaging Science Review, Washington University, St. Louis, Missouri, January 17, 1997.
28. Invited Talk, "Image Analysis Research at UT-Austin," Phillips Research Laboratory, Kirtland Air Force Base, Albuquerque, New Mexico, June 26, 1997.
 29. Invited Talk, "AM-FM Image Models and Applications," CICSIR Distinguished Lecture Series, The University of British Columbia, Vancouver, March 18, 1999.
 30. Invited Talk, "AM-FM Image Models and Applications," Signal and Image Processing Seminar Series, The University of Texas, Austin, April 23, 1999.
 31. Invited Talk, "Observations on Video Compression and a Demonstration of Video Quality Assessment," Video Services Forum, Bell Atlantic Corporation, New York City, May 5, 1999.
 32. Invited Talk, "Teaching Digital Image and Video Processing Using Labview," National Instruments Labview Conference, Austin, Texas, August 1999.
 33. Invited Talk, "Foveated Visual Communications," Department of Electrical and Computer Engineering Visiting Committee, The University of Texas at Austin, November 1999.
 34. Invited Talk, "AM-FM Models: New Image Representations for Multimedia Applications," The American College, Madurai, India, August 2000.
 35. **Plenary Speaker**, "AM-FM Models: New Image Representations for Multimedia Applications," *International Conference on Multimedia Processing and Systems*, Madras, India, August 14, 2000.
 36. **Texas A&M Distinguished Lecture Series**, "AM-FM Models: New Image Representations," Texas A&M University, College Station, Texas, November 10, 2000.
 37. **IEEE Signal Processing Society Distinguished Lecture**: "AM-FM Models: New Image Representations," Howard University, Washington, DC, March 30, 2001.
 38. **IEEE Signal Processing Society Distinguished Lecture**: "AM-FM Models: New Image Representations," Washington State University, Pullman, Washington, April 6, 2001.
 39. **IEEE Signal Processing Society Distinguished Lecture**: "AM-FM Models: New Image Representations," Rochester Institute of Technology, Rochester, NY, June 14, 2001.
 40. **Distinguished Lecture**: "AM-FM Models: New Image Representations," Rose-Hulman Institute of Technology, Terre-Haute, Indiana, March 23, 2002.
 41. Invited Lecture: "Using Visual Attention in Video Processing and Communication," The Colorado School of Mines, Golden, Colorado, July 2002.
 42. Invited Lecture: "Using Visual Attention in Video Processing and Communication," The Indian Institute of Technology, Chennai, Tamilnadu, India, January 2003.
 43. Invited Lecture: "Image Quality Assessment: From Error Measurement to Structural Similarity," The Indian Institute of Technology, Chennai, Tamilnadu, India, January 2003.
 44. Invited Talk, Quality Monitoring for Video Services over Networks, Time-Warner Corporation, Austin, Texas, March 2003.
 44. Invited Lecture: "Using Visual Attention in Video Processing and Communication," The University of Virginia, Charlottesville, Virginia, April 2003.
 45. **Plenary Speaker**, "Attention-Grabbing Image Processing," *IEEE Southwest Symposium on Image Analysis and Interpretation*, Lake Tahoe, Nevada, March 28-30, 2004.
 52. **Plenary Speaker**, "Teaching Image and Video Processing Using Labview," *National Instruments NI Week*, Austin, Texas, June 2004.
 54. Invited Lecture, "Gabor Spiculation Filters for the Detection of Spiculated Masses in Digital Mammograms," *Annual Conference, UT Center for Biomedical Engineering and UT Department for Biomedical Engineering*, Houston, Texas, December 6-7, 2004.
 55. Guest Lecturer, "Digital Image and Video Processing," *UT Honors Colloquium*, Austin, Texas,

- July 22, 2005.
56. Keynote Speaker, "New Measures for Image and Video Quality Assessment," *Twelfth Annual Worldwide Virtual Instrumentation Conference and Exhibition*, Austin Convention Center, Austin, Texas, August 9, 2006.
 57. **Distinguished Lecture**, "Evidence-Based Detection of Spiculated Lesions," Distinguished Lecturers Seminar, Computer Science Department, The University of Houston, Houston, Texas, September 29, 2006.
 58. Invited Talk, "Next Generation Video Coding and Image/Video Quality Assessment Algorithms," *AT&T Labs University Collaboration Symposium*, Shannon Laboratory, Florham Park, New Jersey, August 3-4, 2006.
 59. Invited Talk, "Towards Video Surveillance," *Freescale Semiconductor Corporation*, Austin, Texas, January 26, 2007.
 60. **Keynote Speaker**, "New Vistas in Image and Video Quality," *SPIE Human Vision and Electronic Imaging Conference*, San Jose, California, January 29-February 1, 2007.
 61. Invited Talk, "On Image Quality Assessment," *National Instruments Corporation*, Austin, Texas, February 7, 2007.
 62. Invited Talk, "State of the Art of Image and Video Quality Assessment," *Freescale Semiconductor Corporation*, Austin, Texas, May 15, 2007.
 64. Invited Talk, "Wireless Video Surveillance," *Freescale Semiconductor Corporation*, Austin, Texas, June, 2007.
 65. Invited Talk, "Object Tracking in Video Surveillance," *Freescale Semiconductor Corporation*, Austin, Texas, August 7, 2007.
 66. **Plenary Talk**, "New Directions in Image and Video Quality Assessment," *IEEE Signal Processing Society International Workshop on Multimedia Signal Processing*, Chania, Crete, Greece, October 1-3, 2007.
 67. **Plenary Talk**, "Image and Video Quality on Wireless Networks," *Texas Wireless Symposium*, Austin, Texas October 18, 2007.
 68. **Plenary Talk**, "Analyzing Image Quality," *IEEE Southwest Symposium on Image Analysis and Interpretation*, Santa Fe, New Mexico, March 24-27, 2008.
 69. Invited Talk, "Assessment of Range Image Quality by Structural Similarity," *21st Century Technology*, Austin, Texas, October 23, 2007.
 70. **Plenary Talk**, "Video Quality and Video Databases," *First IEEE International Workshop on IP Multimedia Communications*, Virgin Islands, USA, August 4-7, 2008.
 71. **Beckman Institute Distinguished Lecture**, "Light on Video Quality," The University of Illinois, September 5, 2008.
 72. **Azriel Rosenfeld Distinguished Lecture**, "MOVIE Index for Video Quality Assessment," The University of Maryland, October 3, 2008.
 73. **Plenary Talk**, "Quality is in the Eye of the Beholder," *IEEE International Conference on Image Processing*, San Diego, California, October 15, 2008.
 74. **Plenary Talk**, "Video Quality Assessment," *IEEE Region 10 Conference (TENCON)*, Hyderabad, India, November 18-21, 2008.
 75. Invited Talk, "Video Quality Metrics and their Applications," *Texas Instruments, Inc.*, Dallas, Texas, February 9, 2009.
 76. **Distinguished Lecture**, "Quality is in the Eye of the Beholder," Center for Perceptual Systems, The University of Texas at Austin, March 9, 2009.
 77. Invited Lecture, "Quality is in the Eye of the Beholder," *Video Services Forum*, Montreal,

- Canada, May 6, 2009.
78. Panelist, "Tools, Targets and Trends," *First International Workshop on Quality of Multimedia Experience*, San Diego, California, July 30, 2009.
 79. Invited Talk, "Visual Quality Assessment: Past, Present, and Future," *Siemens Corporate Research*, Princeton, New Jersey, May 2010.
 80. **Plenary Address**, "Visual Quality: Seeing the Future," *IEEE Southwest Symposium on Image Analysis and Interpretation*, Austin, Texas, May 2010.
 81. **Inaugural Plenary Address**, "Blind Image Quality Assessment is Not Impossible," *First Optical Society of America Topical Meeting on Digital Image Processing and Analysis (DIPA)*, Tucson, AZ, June 2010.
 82. Invited Talk, "Visual Quality Assessment: Seeing the Future," *Texas Instruments, Inc.*, Dallas, Texas, June 2010.
 83. **Keynote Address**, "Similarity Measurements for Space Time and 3D Visual Quality Assessment and Inspection," *National Instruments NI Week Vision Summit*, August 2010.
 84. Invited Talk, "Automatic Video Quality Agents for Digital Video Network Monitoring," *Advanced Micro Devices, Inc.*, August 2010.
 85. Invited Talk, "Automatic Video Quality Agents for Digital Video Network Monitoring," *Cisco Systems, Inc.*, September 2010.
 86. Invited Talk, "Automatic Monitoring of Video Networks by Blind Video Quality Agents," *3M Corporation*, October 2010.
 87. **Plenary Address**, "New Dimensions in Visual Quality," *IS&T/SPIE Symposium on Electronic Imaging*, January 2011.
 88. **Keynote Address**, "Perceiving Distortions in Visual Signals," *European Workshop on Visual Computing*, Paris, France, July 2011.
 89. Invited Talk, "Review of Recent Results on VQA," Cisco Corporation, San Jose, California, October 2011.
 90. **Keynote Address**, "Blind Visual Quality Estimation Models: Flavors, Assumptions and Performance," *IEEE Southwest Symposium on Image Analysis and Interpretation*, Santa Fe, New Mexico, April 2012.
 91. Invited Talk, "Visual Quality Estimation: How Blind is Blind?," Texas Instruments, Inc., Dallas, Texas, April 2012.
 92. **Plenary Address**, "Image Quality Assessment: How Blind is Blind?," *Optical Society of America Meeting on Computational Optical Sensing and Imaging*, Monterrey, California, June 25, 2012.
 93. **Keynote Address**, "Natural Scene Statistics and the Perception of Visual Distortion," *Workshop on Digital Video Analytics and Processing*, IIT-Chennai, Chennai, India, December 2012.
 94. Invited Talk, "Video Quality Assessment Research," Intel and Cisco Corporations, via Webex, July 2012.
 95. **Keynote Address**, "Quality Assessment of Mobile Video," *International Workshop on Video Processing and Quality Metrics for Consumer Electronics*, Scottsdale, Arizona, January, 2013.
 96. Invited Talk, "Natural Scene Statistics, the Perception of Visual Distortion, and Visual Tasking," National Institute for Standards and Technology (NIST), October, 2012.
 97. **Distinguished Lecture**, "Perceptual Monitoring of Wireless Video Networks," Northwestern University, Evanston, Illinois, April 2013.
 98. **Keynote Address**, "Perspectives on Natural 3D Statistics," *IEEE Signal Processing Society*

- Workshop on Image, Video, and Multidimensional Signal Processing*, Seoul, Korea, June 2013.
99. **Distinguished Lecture**, “Natural Scene Statistics and the Perception of Visual Distortion,” Chung-Ang University, Seoul, Korea, June 2013.
 100. Invited Talk, “Perceptual Monitoring of Wireless Video Networks,” Qualcomm Corp, San Diego, California, August 2013.
 101. **Keynote Address**, “Perceptual Tools for Quality-Aware Video Networks,” *SPIE Conference on Image Quality and System Performance*, San Francisco, California, January 2014.
 102. Invited Talk, “Wireless Video Quality Assessment,” *Cisco Corporation*, via Webex, January 2014.
 103. Invited Talk, “Three Years of Wireless Video Quality Research,” *Intel Corporation*, Santa Clara, California, January 2014.
 104. **Plenary Address**, “Tasking on Natural 3D Statistics,” IEEE Southwest Symposium on Image Analysis and Interpretation, San Diego, California, April 2014.
 105. Eminent Speaker, “Natural Scene Statistics and the Perception of Visual Distortion,” University of Virginia, Charlottesville, Virginia, April 2014.
 106. **Keynote Address**, “Tasking on Natural Image and Video Statistics,” *Second IEEE Global Conference on Signal and Information Processing*, Atlanta, Georgia, December 2014.
 107. **Keynote Address**, “Tasking on the Natural Statistics of Pictures and Videos,” *Eighth International Conference on Image and Graphics (ICIG)*, Tianjin, China, August 2015.
 108. **Plenary Address**, “Behavior and Video Quality,” *IEEE Southwest Symposium on Image Analysis and Interpretation*, Santa Fe, New Mexico, March 2016.
 109. Invited Talk, “Tasking on the Natural Statistics of Pictures and Videos,” Department of Engineering, Beijing University of Technology, Beijing, China, August 2015.
 110. **Distinguished Lecture**, “Natural Scene Statistics and the Perception of Visual Distortion,” Department of Electrical and Computer Engineering, The University of Texas at Austin, August 2015.
 111. **Plenary Address**, “New Challenges for Image Quality: A New Database and a New Modality,” *IEEE Southwest Symposium on Image Analysis and Interpretation*, Santa Fe, New Mexico, March 2016.
 112. Invited Talk, “Don’t Mess with My Picture Statistics,” *Peli Fest, a Festschrift in honor of Eli Peli*, Scherpens Eye Institute, Boston, Massachusetts, June 17, 2016.
 113. **Keynote Address**, “Leave my Picture Statistics Alone,” Thomas Huang Symposium, The Beckman Institute, Urbana, Illinois, October 1, 2016.
 114. **Keynote Address**, “Advances in Picture Quality: Vision Science and Algorithms,” *IEEE International Workshop on Signal Processing Systems*, Dallas, Texas, October 26-28, 2016.
 115. Invited Talk, “Perceptual Issues of Streaming Video (and How to Solve Them),” Huawei Strategy and Technology Workshop, Shenzhen, China, May 16, 2017.
 116. Invited Talk, “Perceptual Issues of Streaming Video,” SID Display Week, Los Angeles, California, May 26, 2017.
 117. **Keynote Address**, “Perceptual Issues of Streaming Video (and How to Solve Them),” *International Conference on Computer Analysis of Images and Patterns*, Ystad, Sweden, August 2017.
 118. Distinguished Lecture, “Natural Scene Statistics and the Perception of Visual Distortion,” Linköping University, Linköping, Sweden, August 2017.

119. Invited Talk, “Natural Scene Statistics and the Perception of Visual Distortion,” Department of Statistics, The University of Texas at Austin, Austin Texas, October 2017.
120. Invited Talk, “Picture Quality: Neuroscience Meets Video Engineering,” Department of Neuroscience, The University of Texas at Austin, Austin Texas, November 2017.
121. **Plenary Address**, “The ‘Ins’ and ‘Outs’ of Perceptual Streaming Video,” *IEEE Southwest Symposium on Image Analysis and Interpretation*, Las Vegas, Nevada, April 2018.
122. Invited Talk, “Peculiarities of a Picture Quality Predictor,” *Chellappa 65 Symposium*, June 4, 2018.
123. **Keynote Address**, “Perception is Everything,” *Picture Quality Symposium*, San Francisco, California, June 2018.
124. **Keynote Address**, “Consciousness of Stream: Perceptually Optimizing Global Video Quality,” *European Workshop on Visual Information Processing (EUVIP)*, Tampere, Finland, November 2018.
125. Distinguished Lecture, “The Beginning and the End of Streaming (Quality),” The University of California at Riverside, Riverside, California, January 2019.
126. **Keynote Address**, “Consciousness of Streaming (Quality),” *SPIE Conference on Image Quality and System Performance*, San Francisco, California, January 2019.
127. Invited Talk, “Towards Blind Video Quality Prediction,” Facebook Research, Menlo Park, California, January 2019.
128. Invited Talk, “Predicting UGC Video Quality,” YouTube, Mountain View, California, January 2019.
129. Invited Talk, “Blind Streaming Video Quality,” U.S. Army Night Vision Laboratory, Austin, Texas, January 2019.

Forty-four Plenary Addresses, Keynote Addresses, or Distinguished Lectures at international conferences, symposia, workshops, or universities.

Short Courses

1. “Digital Image Processing - A First Course,” IBM Corporation, Austin, Texas, September 10-21, 1990.
2. “Machine Vision in Manufacturing,” Instituto Tecnológico de Monterrey, Mexico City, January 5-9, 1992.
3. “Digital Image Processing,” IBM Corporation, Austin, Texas, Fall 1992.
4. “Digital Image Processing,” IBM Corporation, Austin, Texas, Fall 1994.
5. “Introduction to Digital Image Processing,” Texas Instruments, Inc., Dallas, Texas, Winter 1995.
6. “Introduction to Digital Image Processing,” Texas Instruments, Inc., Dallas, Texas, Spring 1995.
7. “Introduction to Digital Image Processing,” Texas Instruments, Inc., Dallas, Texas, Summer 1995.
8. “Introduction to Digital Image Processing,” Texas Instruments, Inc., Dallas, Texas, Fall 1995.
9. “Digital Signal Processing Theory,” Texas Instruments, Inc., Dallas, Texas, Fall 1995.
10. “Digital Signal Processing Theory,” Texas Instruments, Inc., Dallas, Texas, Winter 1996.
11. “Digital Image and Video Processing,” Texas Instruments, Inc., Dallas, Texas, Spring 1996.
12. “Digital Image and Video Processing,” Texas Instruments, Inc., Dallas, Texas, Summer 1996.
13. “Digital Signal Processing Theory,” Texas Instruments, Inc., Dallas, Texas, Fall 1996.

14. "Digital Image and Video Processing," Texas Instruments, Inc., Dallas, Texas, Fall 1996.
15. "Digital Image and Video Processing," Texas Instruments, Inc., Dallas, Texas, Spring 1997.
16. "Digital Image and Video Processing," Texas Instruments, Inc., Dallas, Texas, Spring 1997.
17. "Digital Signal Processing Theory," Texas Instruments, Inc., Dallas, Texas, Spring 1997.
18. "Digital Signal Processing Theory," Raytheon Systems, Dallas, Texas, Fall 1997.
19. "Digital Image and Video Processing," Raytheon Systems, Dallas, Texas, Fall 1997.
20. "Digital Image and Video Processing," Raytheon Systems, Dallas, Texas, Spring 1998.
21. Tutorial: "Image and Video Compression," *International Conference on Multimedia Processing and Systems*, Madras, India, August 13-15, 2000.
22. "Digital Image and Video Processing," Xilinx Corporation, San Jose, California, Fall 2005.
23. Tutorial: "Visual Perception and Image Processing," *IEEE Region 10 Conference (TENCON)*, Hyderabad, India, November 18-21, 2008.
24. Tutorial: "Image Quality Assessment: Not So SSIMple," *NIP: International Conference on Digital Printing Technologies*, Austin Texas, September 19-23, 2010.

Grants and Contracts Received

State and Federal Grants

1. "Analysis and reconstruction of three-dimensional microscopic images," National Science Foundation, \$264,000 (Co-Principal Investigator), 1986-1988.
2. "Computer research into multiprocessing systems via hypercube architecture," National Science Foundation, \$70,000 (Investigator), 1986-1987.
3. "Research into three-dimensional computer vision and sensor integration: Texture, color, and stereopsis," Texas Advanced Research Program, \$293,603 (Principal Investigator), 1988-1990.
4. "Laser scanning microscope for three-dimensional microscopy," National Science Foundation, \$75,000 (Co-Principal Investigator), 1989-1990.
5. "Animated computer vision technology," Texas Advanced Technology Program, \$102,720 (Principal Investigator), 1989-1991.
6. "Very fast high-compression image sequence coding using simple spatio-temporal image patterns," National Aeronautics and Space Administration (NASA), \$57,407 (Principal Investigator), 1990-1991.
7. "Numerical instrumentation for shape and shape change analysis via three-dimensional microscopy," National Science Foundation, \$450,000 (Co-Principal Investigator), 1991-1994.
8. "Local spatio-temporal analysis in vision systems," Air Force Office of Scientific Research, \$3,200,000 (Co-Principal Investigator), 1993-1996.
9. "Animated computer vision technology for a semi-autonomous rover," National Aeronautics and Space Administration (NASA), \$64,108 (Principal Investigator), 1993-1994.
10. "High speed video coding and communication," Texas Advanced Technology Program, \$189,026 (Principal Investigator), 1993-1995.
11. "Multiresolution information archival and analysis system," National Aeronautics and Space Administration (NASA), \$750,000 (Co-Principal Investigator), 1994-1997.
12. "Scalable processing of multi-sensor and multi-spectral imagery," Phillips Air Force Base, \$60,000 (Co-Principal Investigator), 1994-1995.
13. "A research center in the scientific foundations of image representation and analysis," Army Research Office, \$650,000 (UT-Austin portion of \$4.5 Million divided among the Army Center for Imaging Science: Washington University, Harvard University, MIT and UT-Austin)

- (Investigator), 1995-2000.
14. "3-D analysis of microvessel angiogenesis via laser scanning confocal microscopy," Texas Advanced Research Program, \$201,250 (Co-Principal Investigator), 1995-1997.
 15. "Image processing and data compression tools for satellite imaging," Phillips Air Force Base by subcontract through Schafer Associates, \$69,969 (Co-Principal Investigator), 1996-1997.
 16. "AM-FM analysis of images and video," Air Force Office of Scientific Research, \$114,351 (Principal Investigator), 1997-2000.
 17. "Foveated wireless video communication," Texas Advanced Technology Program, \$198,700 (Principal Investigator), 1999-2001.
 18. "Computer vision systems for automatic target recognition and automatic recognition of human activities," Army Research Office (2/3) and UT-Austin matching funds (1/3), \$150,000 (Co-Principal Investigator), 2000-2001.
 19. "New models of low-level visual search and applications to robotic vision, detection, and data mining," Texas Advanced Research Program, \$143,950 (Co-Principal Investigator), 2001-2003.
 20. "Active stereoscopic visual search driven by natural scene statistics," National Science Foundation, \$250,000 (Principal Investigator), 2002-2005.
 21. "Gabor spiculation filters for the detection of spiculated masses in digital mammograms," The Whitaker Foundation, \$20,000 (Principal Investigator), 2002-2003.
 22. "Blind image and video quality assessment using natural scene statistics," National Science Foundation, \$250,000 (Principal Investigator), 2003-2006.
 23. "High-speed multimedia transmission for space-time communication systems," Texas Advanced Technology Program, \$145,000 (Co-Principal Investigator), 2004-2005.
 24. "Detection of spiculated masses and architectural distortions in digitized mammograms," Department of Defense US Army Medical Research and Materiel Command, \$90,000 (Principal Investigator), 2004-2007.
 25. "Foundations of Visual Search," National Science Foundation, \$1,200,000 (Principal Investigator), 2004-2010.
 26. "Vehicle Structure Recovery from a Moving Air Platform," Air Force Office of Strategic Research, Subcontract from 21 Technologies, Inc, \$32,000 (Principal Investigator), 2005-2006.
 27. "Passive Optical Modeling," Air Force Office of Strategic Research, Subcontract from 21 Technologies, Inc, \$292,000 (Co-Principal Investigator), 2006-2008.
 28. "Quality Assessment of Natural Videos," National Science Foundation, \$272,764 (Principal Investigator), 2007-2010.
 29. "High-Definition and Immersive Acquisition, Processing, and Display Equipment for Video Processing and Vision Science Research and Education," National Science Foundation, \$205,912 (Principal Investigator), 2009-2011.
 30. "Statistical Measurement, Modeling, and Inference on Natural 3D Scenes," National Science Foundation, \$496,614 (Co-Principal Investigator), 2009-2012.
 31. "RFCODE: Robust Foveated Encoding," Air Force Office of Strategic Research, Subcontract from 21 Technologies, Inc, \$255,460 (Co-Principal Investigator), 2010-2012.
 32. "Computer-Aided Detection of Breast Cancer," Texas Ignition Fund, \$50,000 (Co-Principal Investigator, ACB = \$25,000), 2010.
 33. "Foveated Compression, Tracking and Search in Very Large Format Videos," Lawrence Livermore National Laboratory, \$60,000 (Principal Investigator, ACB = \$60,000), 2011.

34. "Intelligent Autonomous Video Quality Agents," National Science Foundation, \$499,944 (Principal Investigator, ACB = \$249,972), 2011-2014.
35. "Foveated Compression, Tracking and Search in Very Large Format Videos II," Lawrence Livermore National Laboratory, \$60,000 (Principal Investigator, ACB = \$60,000), 2012.
36. "Enhancement of Foggy Images," Korea Association of Industry, Academy, and Research Institute (KAIARI), subcontract via Hongik University, \$78,000 (Principal Investigator, ACB = \$78,000), 2012-2014.
37. "Objective Evaluation of the Effect of Image Quality on Visual Tasks," National Institute of Standards and Technologies (NIST), \$50,000 (Principal Investigator, ACB = \$50,000), 2012-2013.
38. "Objective Evaluation of the Effect of Image Quality on Visual Tasks, Phase 2" National Institute of Standards and Technologies (NIST), \$75,000 (Principal Investigator, ACB = \$75,000), 2013-2014.
39. "Objective Evaluation of the Effect of Image Quality on Visual Tasks, Phase 3" National Institute of Standards and Technologies (NIST), \$80,000 (Principal Investigator, ACB = \$80,000), 2014-2015.
40. "Tasking on Natural Image Statistics: 2D and 3D Object and Category Detection in the Wild," National Science Foundation, \$441,933 (Principal Investigator, ACB = \$441,933), 2015-2018.
41. "Perception-Driven Technical Performance Evaluation of the Capabilities of Imagers," National Institute of Standards and Technologies (NIST), \$596,610 (Principal Investigator, ACB = \$596,610), 2015-2020.

Industrial Grants

1. "A Stereo Computer Vision Laboratory," IBM Corporation, 2 IBM PC/AT personal computers, peripheral equipment, and software, \$50,000 commercial value (Principal Investigator), 1984.
2. "Handprinted Character Recognition," Texas Instruments Research Grant, \$20,000 (Principal Investigator), 1985-1986.
3. "A Stereo Computer Vision Laboratory - Update," IBM Corporation, 2 IBM RT PC personal computers, peripheral equipment, and software, \$125,000 commercial value (Principal Investigator), 1986-1987.
4. "Handprinted Character Recognition II," Texas Instruments Research Grant, \$35,000 (Principal Investigator), 1986-1987.
5. "An Image Processing and Computer Vision Instructional Laboratory," IBM Corporation, 8 IBM RT PC personal computers, peripheral equipment, and software, \$400,000 commercial value (Principal Investigator), 1986-1987.
6. "Computer Equipment for Handprinted Character Recognition," TI Personal Computer, software, and peripherals, Texas Instruments, retail value \$6616, (Principal Investigator), 1987-1988.
7. "Handprinted Character Recognition III," Texas Instruments Research Grant, \$50,000 (Principal Investigator), 1987-1988.
8. "Three-dimensional Computer Vision," Texas Instruments Research Grant, \$45,000 (Principal Investigator), 1988-1989.
9. "CCD Image Processing," Texas Instruments Research Grant, \$40,000 (Principal Investigator), 1989-1990.
10. "Computing Shape Changes in Three-Dimensional Confocal Microscope Images," Cray

- Research Incorporated University Research & Development Grant Program, \$42,000, (Principal Investigator) 1990-1991.
11. "Automated 3-D Inspection of RF Power Transistor Assemblies," Motorola University Partnerships in Research Program, \$24,700 (Principal Investigator), 1990-1991.
 12. "CCD image processing II," Texas Instruments Research Grant, \$45,000 (Principal Investigator), 1990-1991.
 13. "Automated 3-D Inspection of RF Power Transistor Assemblies II," Motorola University Partnerships in Research Program, \$25,000 (Principal Investigator), 1991-1992.
 14. "Integrating Visual and Acoustic Cues for Automatic Speech Recognition," Motorola DSP University Support Program, equipment, retail value \$6,204 (Principal Investigator), 1991-1992.
 15. "Integrating Visual and Acoustic Cues for Automatic Speech Recognition," Motorola DSP University Support Program, equipment, retail value \$4,604 (Principal Investigator), 1991-1992.
 16. "Automated 3-D Inspection of RF Power Transistor Assemblies III," Motorola University Partnerships in Research Program, \$25,000 (Principal Investigator), 1992-1993.
 17. "Wavelet-based Image/video Coding and Code Conversion," IBM Corporation, \$70,000 (Principal Investigator), 1992-1993.
 18. "Wavelets and Applications to Multiscale Signal Analysis," Texas Instruments Research Grant, \$18,000 (Principal Investigator), 1992-1993.
 19. "Automated 3-D Inspection of RF Power Transistor Assemblies IV," Motorola University Partnerships in Research Program, \$12,000 (Principal Investigator), 1993-1994.
 20. "High Performance Compression Technologies for High-Speed Workstation-To-Workstation Video Transmission," IBM Corporation, 1 IBM RS/6000 Power PC engineering workstation, peripheral equipment and software, \$20,000 commercial value (Principal Investigator), 1994-1995.
 21. "Digital Signal and Image Processing," Unrestricted Research Grant, Schlumberger Austin Research, \$25,000 (Principal Investigator), 1994-1995.
 22. "Digital Image Processing for FLIR," Unrestricted Research Grant, Texas Instruments, Inc., \$35,000 (Principal Investigator), 1995-1996.
 23. "Use of a Macintosh and Quicktake Camera for Image Processing in the Classroom to Aid Student Understanding," Apple Computer Corporation, one PowerMac 7200 engineering workstation, peripheral equipment, and software, \$15,000 commercial value (Principal Investigator), 1996
 24. "Digital Image Analysis," Unrestricted Research Grant, Texas Instruments, Inc., \$45,000 (Principal Investigator), 1996-1997.
 25. "Digital Video Quality Assessment," Unrestricted Research Grant, Southwestern Bell Telephone Company, \$35,000 (Principal Investigator), 1996-1997.
 26. "Digital Image Analysis," Unrestricted Research Grant, Texas Instruments, Inc., \$20,000 (Principal Investigator), 1997-1998.
 27. "Digital Video Telecommunications Research and Teaching in the Laboratory for Image and Video Engineering (LIVE)," Intel Corporation, Equipment grant, cluster of Pentium NT workstations, \$250,000 (Principal Investigator), 1997-2000.
 28. "Image Halftoning Research," Unrestricted Research Grant, Hewlett-Packard Laboratories, Palo Alto, CA, \$15,000 (Co-Principal Investigator), 1997-1998.
 29. "Digital Video Quality Assessment II," Unrestricted Research Grant, Southwestern Bell

- Telephone Company, \$30,000 (Principal Investigator), 1997-1998.
30. "Wireless Video on the HomeBus," Motorola Semiconductor Products Sector, \$35,000 (Principal Investigator), 1997-1998.
 31. "Digital Image Analysis," Unrestricted Research Grant, Raytheon Systems, \$38,000 (Principal Investigator), 1998-1999.
 32. "Digital Image Analysis," Unrestricted Research Grant, Raytheon Systems, \$23,000 (Principal Investigator), 1999-2000.
 33. "Objective Quality Assessment for High Quality Digital Video," Unrestricted Research Grant, Southwestern Bell Telephone Company, \$30,000 (Principal Investigator), 1998-1999.
 34. "Automatic Assessment of Compressed Digital Video Quality Using Human Visual Criteria," Dell Computer Corporation, \$38,320 (Principal Investigator), 1999-2000.
 35. "Wireless Video Coding," Lucent Technologies, \$30,000 (Principal Investigator), 1999-2000.
 36. "Web-based Instruction of Digital Signal, Image and Video Processing," TxTEC Consortium Curriculum Grant, \$11,700 (Principal Investigator), 1999-2000.
 37. "Web-based Instruction of Digital Signal, Image and Video Processing," TxTEC Consortium Faculty Incentive Grant, \$4,000 (Principal Investigator), 1999-2000.
 38. "Standards-compliant High-Quality Low-Bitrate Video Communications Using the TMS320C62x Processor," Texas Instruments, Incorporated, \$198,712 (Principal Investigator), 1999-2001.
 39. "Equipment for Web-Based Video Instruction," TxTEC Consortium Curriculum Grant, \$2,700 (Principal Investigator), 2000-2001.
 40. "Biomedical Image Analysis I," Perceptive Scientific Instruments, \$10,000 (Co-Principal Investigator), 2000-2001.
 41. "Image Processing Research," Raytheon Corporation, \$15,000 (Principal Investigator), 2000-2001.
 42. "Digital Video Telecommunications Research and Teaching in the Laboratory for Image and Video Engineering (LIVE)," Intel Corporation, Equipment grant, cluster of Pentium III NT workstations, \$50,000 (Principal Investigator), 2000-2001.
 43. "Live Video Demonstrations for Teaching Digital Image and Video Processing," TxTEC Consortium Curriculum Grant, \$14,000 (Principal Investigator), 2001-2002.
 44. "Video Networking I," Unrestricted Research Grant, Southwestern Bell Telephone Company, \$42,000 (Principal Investigator), 2001-2002.
 45. "Biomedical Image Analysis II," Perceptive Scientific Instruments, \$7,500 (Principal Investigator), 2001.
 46. "Digital video processing equipment grant," Texas Instruments DSC21 EVM Video Processing Equipment, Texas Instruments, Inc., \$15,000 commercial value (Principal Investigator), 2001.
 47. "Biomedical Image Analysis III," Perceptive Scientific Instruments, \$7,500 (Principal Investigator), 2002.
 48. "Video Networking II," Unrestricted Research Grant, Southwestern Bell Telephone Company, \$10,000 (Principal Investigator), 2002.
 49. "Biomedical Image Analysis IV," Perceptive Scientific Instruments, \$20,000 (Principal Investigator), 2002-2003.
 50. "Video Networking III," Unrestricted Research Grant, Southwestern Bell Telephone Company, \$40,000 (Principal Investigator), 2002-2003.
 51. "Video Communication Research," Unrestricted Research Grant, WNCG Industrial Affiliates

- Program, \$2,500 (Principal Investigator), 2002-2003.
52. "Biomedical Image Analysis V," Perceptive Scientific Instruments, \$20,000 (Principal Investigator), 2003.
 53. "Flourescence Microscopy," Advanced Digital Imaging Research, \$10,000 (Principal Investigator), 2003.
 54. "Biomedical Image Processing in Labview," National Instruments, Inc., \$10,000 (Principal Investigator), 2003.
 55. "Video Networking IV," Unrestricted Research Grant, Southwestern Bell Telephone Company, \$40,000 (Principal Investigator), 2003-2004.
 56. "Video Communication Research," Unrestricted Research Grant, WNCG Industrial Affiliates Program, \$2,500 (Principal Investigator), 2003-2004.
 57. "Digital Light Display Projector," Dell 3200MP Projector, Texas Instruments, Inc., commercial value \$1,839 (Principal Investigator), 2004.
 58. "Video Networking V," Unrestricted Research Grant, Southwestern Bell Telephone Company, \$40,000 (Principal Investigator), 2004-2005.
 59. "Flourescence Microscopy," Advanced Digital Imaging Research, \$12,752 (Principal Investigator), 2004-2005.
 60. "Face Recognition," Advanced Digital Imaging Research, \$25,504 (Principal Investigator), 2004-2005.
 61. "Face Recognition," Advanced Digital Imaging Research, \$25,504 (Principal Investigator), 2004-2005.
 62. "Video Communication Research," Unrestricted Research Grant, WNCG Industrial Affiliates Program, \$2,500 (Principal Investigator), 2004-2005.
 63. "Video Communication Research," Unrestricted Research Grant, WNCG Industrial Affiliates Program, \$5,000 (Principal Investigator), 2005.
 64. "Video Communication Research," Unrestricted Research Grant, WNCG Industrial Affiliates Program, \$10,000 (Principal Investigator), 2005-2006.
 65. "Flourescence Microscopy," Advanced Digital Imaging Research, \$25,504 (Principal Investigator), 2005-2006.
 66. "Face Recognition," Advanced Digital Imaging Research, \$51,008 (Principal Investigator), 2004-2005.
 67. "Video Networking VI," Unrestricted Research Grant, Southwestern Bell Telephone Company, \$40,000 (Principal Investigator), 2006.
 68. "Image Quality for Postal Systems," Unrestricted Research Grant, U.S. Postal Service by Subcontract to Autim, Inc., \$30,000 (Principal Investigator), 2006.
 69. "Image Quality for the U.S. Mint," Unrestricted Research Grant, U.S. Mint by Subcontract to Autim, Inc., \$10,000 (Principal Investigator), 2006.
 70. "Wireless Video Surveillance I," Unrestricted Research Grant, Freescale Semiconductor, \$25,000 (Co-Principal Investigator), 2006.
 71. "Semiconductor Inspection," Unrestricted Research Grant, KLA-Tencor, \$30,000 (Principal Investigator), 2006-2007.
 72. "Video communication research," Unrestricted Research Grant, WNCG Industrial Affiliates Program, \$10,000 (Principal Investigator), 2006-2007.
 73. "Visual inspection," Unrestricted Research Grant, National Instruments, \$40,000 (Principal Investigator), 2006-2007.
 74. "Video networking VII," Unrestricted Research Grant, Southwestern Bell Telephone

- Company, \$40,000 (Principal Investigator), 2007.
75. "Wireless Video Surveillance II," Unrestricted Research Grant, Freescale Semiconductor, \$20,000 (Principal Investigator), 2007.
 76. "Semiconductor Inspection II," Unrestricted Research Grant, KLA-Tencor, \$30,000 (Principal Investigator), 2007-2008.
 77. "Wireless Video Surveillance III," Unrestricted Research Grant, Freescale Semiconductor, \$20,000 (Principal Investigator), 2007.
 78. "Video Communication Research," Unrestricted Research Grant, WNCG Industrial Affiliates Program, \$10,000 (Principal Investigator), 2007-2008.
 79. "Objective Video Quality Measurement," Unrestricted Research Grant, AT&T, \$40,000 (Principal Investigator) 2008.
 80. "Advanced Perceptual Video Quality Measurement," Unrestricted Research Grant, Texas Instruments, \$35,000 (Principal Investigator), 2008.
 81. "Video Quality Assessment for In-Flight Entertainment Systems," Boeing, \$99,000 (Co-Principal Investigator), 2008.
 82. "Video Quality Assessment," Agilent, \$39,640 (Principal Investigator), 2008.
 83. "Video Communication Research," Unrestricted Research Grant, WNCG Industrial Affiliates Program, \$15,000 (Principal Investigator), 2008-2009.
 84. "Objective Video Quality Measurement," Unrestricted Research Grant, AT&T, \$49,000 (Principal Investigator), 2009.
 85. "Blind Image Quality Assessment," Unrestricted Research Grant, Videoclarity, Inc., \$18,000 (Principal Investigator), 2009.
 86. "Delivery and Assessment of High Quality Video over UDP/IP Networks," Boeing, \$100,000 (Principal Investigator), 2009.
 87. "Advanced Perceptual Rate Control," Unrestricted Research Grant, Texas Instruments, \$35,000 (Principal Investigator), 2009.
 88. "Spinal Imaging," Orthokinematics, \$50,000 (Principal Investigator), 2009.
 89. "Video Communication Research," Unrestricted Research Grant, WNCG Industrial Affiliates Program, \$10,000 (Principal Investigator), 2009-2010.
 90. "Blind Video Quality Algorithms," Unrestricted Research Grant, AT&T, \$49,000 (Principal Investigator), 2010.
 91. "Advanced Perceptual Rate Control II," Unrestricted Research Grant, Texas Instruments, \$35,000 (Principal Investigator), 2010.
 92. "Perceptual Optimization of Wireless Video Networks," Unrestricted Research Grant, Intel Corporation and Cisco Corporation, \$900,000, (Co-Principal Investigator), 2010-2012.
 93. "Wireless Video Research," Unrestricted Research Grant, WNCG Industrial Affiliates Program, \$10,000 (Principal Investigator), 2010-2011.
 94. "Objective Measurement of Stereoscopic Visual Quality," Unrestricted Research Grant, Cisco Corporation, \$99,438, (Principal Investigator), 2011.
 95. "Blind Video Quality Algorithms II," Unrestricted Research Grant, AT&T, \$49,000 (Principal Investigator), 2011.
 96. "Objective Quality Assessment of Stereo Videos," Unrestricted Research Grant, Texas Instruments, \$35,000 (Principal Investigator), 2011.
 97. "Wireless Video Research," Unrestricted Research Grant, WNCG Industrial Affiliates Program, \$20,000 (Principal Investigator), 2011-2012.
 98. "Objective Quality Assessment of Stereo Videos II," Unrestricted Research Grant, Texas

- Instruments, \$35,000 (Principal Investigator), 2012.
99. "Objective Measurement of Stereoscopic Visual Quality II," Unrestricted Research Grant, Cisco Corporation, \$99,348, (Principal Investigator), 2012.
 100. Equipment Grant, Intel, Inc. 8 Intel Xeon and I6 Processors, \$24,000, (Principal Investigator), 2012.
 101. "Blind Video Quality Assessment," Video Clarity, Inc., \$17,000 (Principal Investigator), 2012.
 102. Equipment Grant, Intel Inc., RAID Servers and RAID memory units, \$15,000 (Principal Investigator), 2012.
 103. "Wireless Video Research," Unrestricted Research Grant, WNCG Industrial Affiliates Program, \$17,000 (Principal Investigator), 2012-2013.
 104. "Study on Subjective Perception of Video Rebuffering Events," Avvasi, Inc., Unrestricted Research Grant, \$18,000 (Principal Investigator), 2013.
 105. "Wireless Video Research," Unrestricted Research Grant, WNCG Industrial Affiliates Program, \$15,000 (Principal Investigator), 2013-2014.
 106. "Perceptual Quality of Automotive Surround View Projection Systems," Unrestricted Research Grant, Texas Instruments, \$35,000 (Principal Investigator), 2013.
 107. "Spinal Image Analysis," St. David's Texas Neuroscience Institute, Unrestricted Research Grant, \$37,500 (Co-Principal Investigator), 2013-2014.
 108. "Study on Subjective Perception of Video Rebuffering Events II," Avvasi, Inc., Unrestricted Research Grant, \$18,000 (Principal Investigator), 2014.
 109. "Perceptual Quality of Automotive Surround View Projection Systems II," Unrestricted Research Grant, Texas Instruments, \$35,000 (Principal Investigator), 2014.
 110. "Wireless Video Research," Unrestricted Research Grant, WNCG Industrial Affiliates Program, \$14,000 (Principal Investigator), 2014-2015.
 111. "Spinal Image Analysis II," St. David's Texas Neuroscience Institute, Unrestricted Research Grant, \$15,952 (Co-Principal Investigator), Spring 2015.
 112. "Blind Video Quality Algorithms III," Unrestricted Research Grant, AT&T, \$49,000 (Principal Investigator), 2015.
 113. "Perceptual Quality of Automotive Surround View Projection Systems III," Unrestricted Research Grant, Texas Instruments, \$35,000 (Principal Investigator), 2015.
 114. "Subjective Study of In-capture Video Distortions," Qualcomm, Inc., \$45,000 (Principal Investigator), 2015-2016.
 115. "Perceptual Prediction of Streaming Video Artifacts," Netflix, Inc., \$85,000 (Principal Investigator), 2015-2016.
 116. "Wireless Video Research," Unrestricted Research Grant, WNCG Industrial Affiliates Program, \$19,000 (Principal Investigator), 2015-2016.
 117. "Tesla K-40 GPU Board for 3D Computer Vision Research," Nvidia Corporation, Stated Value \$906 (Principal Investigator), 2016.
 118. "Perceptual Prediction of Streaming Video Artifacts II," Netflix, Inc., \$90,000 (Principal Investigator), 2016-2017.
 119. "Perceptual Quality of Automotive Surround View Projection Systems III," Unrestricted Research Grant, Texas Instruments, \$35,000 (Principal Investigator), 2016.
 120. "Wireless Video Research," Unrestricted Research Grant, WNCG Industrial Affiliates Program, \$14,000 (Principal Investigator), 2016-2017.
 121. "Perceptual Issues of Streaming Video," Unrestricted Research Grant, Huawei, Inc., \$100,000 (Principal Investigator), 2017-2018.

122. "Perceptual Quality of Automotive Surround View Projection Systems IV," Unrestricted Research Grant, Texas Instruments, \$35,000 (Principal Investigator, ACB = \$35,000), 2017.
123. "Perceptual Prediction of Streaming Video Artifacts III," Netflix, Inc., \$95,000 (Principal Investigator, ACB = \$95,000), 2017-2018.
124. "Virtual Reality Research," Research Gift from Private Donor, \$15,000 (Principal Investigator, ACB = \$15,000), 2017.
125. "Wireless Video Research," Unrestricted Research Grant, WNCG Industrial Affiliates Program, \$14,000 (Principal Investigator), 2017-2018.
126. "Subjective and Objective Studies of Perceptual Issues of Viewing Virtual Reality," Oculus Research, \$192,510 (Principal Investigator), 2017-2018.
127. "Deep Learning Perceptual Video Compression," Electronics and Telecommunications Research Institute (Korea), \$121,000 (Principal Investigator), 2018.
128. "Perceptual Quality Assessment of Images and Videos," Facebook Research, \$863,921 (Principal Investigator), 2018-2021.
129. "Assessing the Quality of Encoded/Transcoded Videos with Imperfect References," YouTube, \$85,705 (Principal Investigator), 2019.
130. "Quality Assessment of User-Generated Videos," YouTube, \$52,000 (Principal Investigator), 2019.
131. "Quality Assessment of High Frame Rate Videos," YouTube, \$52,000 (Principal Investigator), 2019.
132. "Subjective and Objective Studies of Perceptual Issues of Viewing Virtual Reality II," Oculus Research / Facebook Reality Labs, \$201,292 (Principal Investigator), 2018-2019.
133. "Perceptual Prediction of Streaming Video Artifacts IV," Netflix, Inc., \$103,126 (Principal Investigator), 2018-2019.

University Grants

1. "Image Analysis using Local Statistics," Bureau of Engineering Research, The University of Texas at Austin, \$5,000 (Principal Investigator), 1984-1985.
2. "Boundary Detection in Speckle Images," University Research Institute, University of Texas, \$4,980 (Principal Investigator), 1984-1985.
3. "Development of a Stereo Computer Vision Laboratory," University Research Institute, University of Texas, \$4,980 (Principal Investigator), 1985-1986.
4. "Active Vision," University of Texas Challenge for Excellence in Computer Engineering, \$14,000 (Principal Investigator), 1990-1991.
5. "New Developments in Multi-scale Signal Processing with Application to Animated Computer Vision," University Research Institute Faculty Research Assignment, University of Texas, \$28,790 (Principal Investigator), 1991-1992.
6. "Digital Image and Video processing on the World Wide Web using National Instruments' LabVIEW," University of Texas Academic Development Funds, \$4,000 (Principal Investigator), 1997.
7. "Foveated Visual Search: from Humans to Machines," Interdisciplinary Research Initiative, University of Texas, \$100,000 (Co-Principal Investigator), 2000-2001.
8. "Using Visual Attention in Video Processing and Communication," Dean's Fellowship, College of Engineering, The University of Texas at Austin, \$56,000 (Principal Investigator), 2002.
9. Endowment Funds, Curry-Cullen Trust Endowed Chair Professorship, The University of

- Texas at Austin, \$25,000 (Principal Investigator), 2005-2006.
10. Endowment Funds, Curry-Cullen Trust Endowed Chair Professorship, The University of Texas at Austin, \$25,000 (Principal Investigator), 2006-2007.
 11. Endowment Funds, Curry-Cullen Trust Endowed Chair Professorship, The University of Texas at Austin, \$25,000 (Principal Investigator), 2007-2008.
 12. Endowment Funds, Curry-Cullen Trust Endowed Chair Professorship, The University of Texas at Austin, \$25,000 (Principal Investigator), 2008-2009.
 13. Endowment Funds, Curry-Cullen Trust Endowed Chair Professorship, The University of Texas at Austin, \$25,000 (Principal Investigator), 2009-2010.
 14. "Stereo CAD for 3D Breast Imaging," Research Grant, The University of Texas at Austin, \$6,000 (Principal Investigator), 2010.
 15. Endowment Funds, Curry-Cullen Trust Endowed Chair Professorship, The University of Texas at Austin, \$25,000 (Principal Investigator), 2010-2011.
 16. Endowment Funds, Curry-Cullen Trust Endowed Chair Professorship, The University of Texas at Austin, \$25,000 (Principal Investigator), 2011-2012.
 17. Endowment Funds, Curry-Cullen Trust Endowed Chair Professorship, The University of Texas at Austin, \$25,000 (Principal Investigator), 2012-2013.
 18. "EE 381V Digital Video," College of Engineering Academic Development Funds, \$10,587 (Principal Investigator), 2012-2013
 19. Endowment Funds, Curry-Cullen Trust Endowed Chair Professorship, The University of Texas at Austin, \$25,000 (Principal Investigator), 2013-2014.
 20. Endowment Funds, Cockrell Family Regents Endowed Chair Professorship, The University of Texas at Austin, \$80,000 (Principal Investigator), 2014-2015.
 21. Endowment Funds, Cockrell Family Regents Endowed Chair Professorship, The University of Texas at Austin, \$80,000 (Principal Investigator), 2015-2016.
 22. Endowment Funds, Cockrell Family Regents Endowed Chair Professorship, The University of Texas at Austin, \$80,000 (Principal Investigator), 2016-2017.
 23. Endowment Funds, Cockrell Family Regents Endowed Chair Professorship, The University of Texas at Austin, \$80,000 (Principal Investigator), 2017-2018.
 24. Endowment Funds, Cockrell Family Regents Endowed Chair Professorship, The University of Texas at Austin, \$80,000 (Principal Investigator), 2018-2019.

Graduate Student Supervision

Professor Bovik has graduated or is presently supervising the following students:

M.S. Completed:

Acton, Scott	Kladopoulos, K.	Sanders, Kirk
Arnow, Thomas	Krishnan, Vidhya	Schwartzkopf, Wade
Bernstein, Alan	Lacour, Patrick	Seshadrinathan, Kalpana
Brooks, Robin	Larcom, Ronald	Sharma, Shubham
Chen, Ming-Jun	Lee, Joonsoo	Shueh, Fen-Fen
Chu, Chen-Chau	Lindsey, Laurence	Sheikh, Hamid
Craevich, Danielle	Luck, Brette	Simms, Andrew
Dehel, Thomas	Malpica, William	Spires, Shannon
Emmoth, Tomas	Messerschmitt, Tina	Suriamoorthy, Kartick
	Mittal, Anish	Von Bavel, Nicholas

Floren, Andrew	Moorthy, Anush	Wehnes, Jeffrey
Ghadiyaram, Deepti	Pai, Hung-Ta	Xie, Zhengyi
Gibson, Michael	Pai, Ritha	
Gopal, Nanda	Panayi, George	
Griffin, Christopher	Rashid, Mosfeq	
Grosenbacher, Timothy	Reynolds, A-Lan	
Gupta, Praful	Restrepo, Alfredo	
Harding, David	Saad, Michele	
Jou, Jinn-Yeu	Sabir, Farooq	
Kaser, Jenny	Sampat, Mehul	
Klarquist, William		

Ph.D. Completed, Year, Dissertation Titles:

1. Longbotham, Harold (1988) "Deterministic Theory of Order Statistic Filters" (Deceased. Formerly Professor at University of Texas, San Antonio, TX)
2. Macías-Garza, Fernando (1988) "Implementation and Limitations of Scanning Light Microscopy for the Determination of Three-Dimensional Structure from Optical Serial Sections" (Currently President of Document-OS, Austin, Texas)
3. Kim, Nak (1989) "Computation of Shape from Stereo Images with Application to Biological Shape Analysis" (Currently Professor at Hankuk University of Foreign Studies, Seoul, Korea)
4. Naaman, Laith (1990) "Design of Least-Squares Order Statistic Filters"
5. Chen, Dapang (1990) "Visual Pattern Image Coding" (Currently DSP Team Leader Research Engineer at National Instruments, Austin, TX)
6. Jordan, John (1990) "On Using Chromatic Information in Stereo Correspondence" - selected winner of the University of Texas all-campus Outstanding Dissertation Award (Currently Vice President of Research at KLA-Tencor Instruments, San Jose, CA)
7. Restrepo, Alfredo (1990) "Locally Monotonic Regression and Related Techniques for Signal Smoothing and Shaping" (Currently Professor at University of the Andes in Bogota, Colombia)
8. Super, Boaz (1992) "Understanding Images of Textured Surfaces" (Currently Senior Research Engineer at Motorola, Inc., Schaumburg, Illinois)
9. Bartels, Keith (1993) "The Analysis of Biological Shape and Shape-Change from Multi-Dimensional Image Sequences" (Currently Research Engineer at Southwest

10. Silsbee, Peter (1993) Research Institute, San Antonio, TX)
 “Computer Lipreading for Improved Accuracy in Automatic Speech Recognition”
 (Currently Research Engineer at Qualcomm, Boulder, CO)
11. Acton, Scott (1993)
 “Generalized Deterministic Annealing with Application to Nonconvex Optimization Problems in Image Processing”
 FELLOW OF THE IEEE
 (Currently Professor at University of Virginia, Charlottesville, VI)
12. Chen, Tieh-Yuh (Terry) (1995)
 “Stereo Disparity from Local Image Phase: New Models for Image Modulation, Coarse-to-Fine Processing, and Disparity Channels”
 (Currently Section Chief at Chung-Shan Institute of Science and Technology, Taiwan)
13. Klarquist, William (1995)
 “FOVEA: A Foveated Vergent Active Stereo Vision System for Dynamic Three-Dimensional Scene Recovery”
 (Currently Research Engineer at SAIC, Denver, CO)
14. Yim, Changhoon (1996)
 “Multiresolution 3-D Range Segmentation Using Focus Cues”
 (Currently Professor at Konkuk University, Konkuk, South Korea)
15. Havlicek, Joseph (1996)
 “AM-FM Image Models”
 (Currently Professor at University of Oklahoma, Norman, OK)
16. Pattichis, Marios (1998)
 "AM-FM Transforms and Applications"
 (Currently Professor at The University of New Mexico, Albuquerque, NM)
17. Wei, Dong (1998)
 "Theory and Applications of Coiflet-Type Wavelets"
 (Currently Research Engineer at Huawei, Inc., Dallas, TX)
18. Kite, Thomas (1998)
 "Design and Quality Assessment of Forward and Inverse Error Diffusion Halftoning Algorithms"
 (Deceased. Formerly Vice President of Engineering at Audio Precision, Beaverton, OR)
19. Pai, Hung-Ta (1999)
 "Multichannel Blind Image Restoration"
 (Currently Professor at the National Taipei University, Taipei, Taiwan)
20. Lee, Sanghoon (2000)
 “Foveated Video Compression and Visual Communications Over Wireless and Wireline Networks”
 (Currently Professor at Yonsei University, Seoul, South Korea)

21. Barnett, Barry (2000) "Multiparty Videoconferencing Using Motion Compensated Visual Pattern Image Sequence Coding"
(Currently Consultant for International Business Machines, Inc., Austin, TX)
22. Wang, Zhou (2001) "Rate Scalable Foveated Image and Video Communications"
FELLOW OF THE IEEE
(Currently Professor at the University of Waterloo, Ontario, Canada)
23. Ling, Jian (2001) "The Development of Raman Imaging Microscopy to Visualize Drug Actions in Living Cells"
(Currently Research Engineer at Southwest Research Institute, San Antonio, TX)
24. Liu, Shizhong (2001) "DCT-Domain Video Foveation and Transcoding for Heterogeneous Video Communication"
(Currently Research Engineer for Qualcomm, San Diego, CA)
25. Swartzkopf, Wade (2002) "Maximum Likelihood Techniques for Joint Segmentation-Classification of MFISH Images"
(Currently Research Engineer at Integrity Applications Inc., Washington, DC)
26. Sheikh, Hamid Rahim (2004) "Image Quality Assessment Using Natural Scene Statistics"
(Currently Research Engineer at Samsung Research, Dallas, TX)
27. Rajashekar, Umesh (2005) "Statistical Analysis and Selection of Visual Fixations"
(Currently Post-Doctoral Research Associate at New York University, New York, NY)
28. Sabir, Muhammad Farooq (2006) "Source-Channel Distortion Modeling for Image and Video Communication"
(Currently Senior Engineer at AT&T Corporation, Dallas, TX)
29. Choi, Hyohoon (2006) "Automatic Segmentation and Classification of Multiplex-Flourescence In-Situ Hybridization Chromosome Images"
(Currently Research Engineer at Samsung Corporation, Seoul, Korea)
30. Sampat, Mehul (2006) "Evidence-Based Detection of Spiculated Lesions"
(Currently Research Fellow, Center for Neurological Imaging, Brigham and Women's Hospital & Harvard Medical School, Cambridge, MA)
31. Monaco, James Peter (2006) "Active Binocular Vision: Phase-Based Registration and Optimal Foveation"
(Currently Research Engineer at VuComp, Inc.,

32. Raj, Raghu (2007) Dallas, TX)
 “Optimal Visual Search Strategies Using Natural Scene Statistics”
 (Currently Research Engineer at The Naval Research Laboratory, Washington, DC)
33. Tavassoli, Abtine (2007)
 “Discovery and Representation of Human Strategies for Visual Search”
 (Currently Post-Doctoral Researcher at UCLA, Los Angeles, CA)
34. Channappayya, Sumohana (2007)
 “Image Communication System Design Based on the Structural Similarity Index”
 (Currently Professor at Indian Institute of Technology, Hyderabad, Andra Pradesh, India)
35. Arnow, Thomas (2008)
 “Foveated Object Recognition by Corner Search”
 (Currently Professor at Palo Alto College, San Antonio, TX)
36. Seshadrinathan, Kalpana (2008)
 “Video Quality Assessment Based on Motion Models”
 (Currently Research Engineering Manager at Intel, Inc, Santa Clara, CA)
37. Gupta, Shalini (2008)
 “Novel Algorithms for 3-D Face Recognition”
 (Currently Research Engineer at Nvidia Research, Berkeley, CA)
38. Liu, Yang (2010)
 “Scene Statistics in 3D Natural Environments”
 (Currently Post-Doctoral Researcher at Harvard Medical School and Wellesley College, Boston, MA)
39. Coffman, Thayne (2011)
 “Stochastic Methods in Computational Stereo”
 (Currently Chief Technical Officer at 21st Century Technologies, Austin, TX)
40. Jahanbin, Sina (2011)
 “Recognition of 3D Faces”
 (Currently Research Engineer at KLA-Tencor Instruments, San Jose, CA)
41. Gopinath, Ajay (2012)
 “Feature Modeling and Tomographic Reconstruction of Electron Microscopy Images”
 (Currently Research Engineer at LightLab Imaging, part of St. Jude Medical Systems)
42. Soundararajan, Rajiv (2012)
 “Information Theoretic Methods in Distributed Compression and Visual Quality Assessment”
 (Currently Professor at Indian Institute of Science, Bangalore)
43. Moorthy, Anush Krishna (2012)
 “Natural Scene Statistic Based Blind Image Quality Assessment and Repair”
 (Currently Research Engineer at Netflix, Los Gatos, CA)
44. Chen, Ming-Jun (2012)
 “Visual Perception and Quality of Distorted Stereoscopic 3-D Images”

- (Currently Research Engineer at Google, Mountain View, CA)
45. Muralidhar, Gautam (2012) “Computer-Aided Analysis and Interpretation of Breast Imaging Data”
(Currently Senior Data Scientist at Nio, Inc.)
 46. Saad, Michele (2013) “Blind Image and Video Quality Assessment Using Natural Scene and Motion Models” (Currently Research Engineer at Cognitive Scale, Austin, TX)
 47. Mittal, Anish (2013) “Natural Scene Statistics-based Blind Visual Quality Assessment in the Spatial Domain”
(Currently Research Engineering Manager at HERE, Berkeley, CA)
 48. Chen, Chao (2013) “Visual Quality-Optimized Adaptive Video Streaming over Wireless Channels,”
(Currently Research Engineer at Netflix, Los Gatos, CA)
 49. Lee, Juhun (2014) “Quantitative Analysis of Aesthetic Outcomes of Reconstructive Surgery: Disfigurement After Facial Reconstruction”
(Currently Post-Doc at UT Southwestern Medical Center University, Dallas, TX)
 50. Su, Che-Chun (2014) “Applied Statistical Modeling of Three-Dimensional Natural Scene Data”
(Currently Research Engineer at Microsoft Research, Seattle, WA)
 51. Choi, Lark-Kwon (2015) “Flicker Perception on Digital Videos”
(Currently Research Engineer at Qualcomm, San Diego, CA)
 52. Isikdogan, Furkan (2017) “Automatically Creating Spatiotemporal River Maps of the World Using Remotely Sensed Images”
(Currently Research Engineer at Intel Corp, Santa Clara, CA)
 53. Ghadiyaram, Deepti (2017) “Perceptual Quality Assessment of Real-World Images and Videos” (Currently Research Engineer at Facebook, Menlo Park, CA)
 54. Bampis, Christos (2018) “Perceptual Video Quality and Quality of Experience for Adaptive Video Streaming” (Currently Research Engineer at Netflix, Los Gatos, CA)
 55. Goodall, Todd (2018) “Inspection and Evaluation of Artifacts in Digital Video Sources” (Currently Research Engineer at Oculus Research, Seattle, WA)
 57. Sinno, Zeina (2019) “Statistical and Perceptual Properties of Images and Videos with Applications” (Currently Research Engineer at Apple, Cupertino, CA)

Ph.D. in Progress (not admitted to candidacy yet):

Chen, Li-Heng	Chen, Meixu	Madasudana, Pavan
Jin, Yize	Kim, Sungsoo	Lee, Dae Yeol
Niu, Haoran	Paul, Somdyuti	Yu, Xiangxu
Zhengqiang, Ying	Zhengzhong, Tu	

Ph.D. Admitted to Candidacy:

Gupta, Praful	Pan, Janice
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Teaching

Professor Bovik has taught the following courses at The University of Texas at Austin:

Graduate

EE 380L - Computer Vision (Fall '84, Fall '85, Fall '86, Fall '87, Fall '88, Fall '89, Fall '90)
EE 381K - Digital Signal Processing (Spring '86, Spring '87, Spring '88, Spring '93, Spring '94, Spring '95, Spring '96, Spring '97, Spring '98, Spring '99, Spring '00, Spring '01, Spring '02, Spring '03, Fall '03, Fall '04, Fall '05, Fall '06, Fall '07, Fall '10, Fall '11, Fall '12)
EE 381K - Introduction to Stochastic Processes (Spring '89)
EE 381V/381K – Digital Video (Spring '14, Spring '15, Spring '16, Spring '17)

Undergraduate

EE 351K - Probability & Random Processes (Spring '85, Fall '85, Spring '86, Fall '86, Spring '90, Spring '91)
EE 379K/371R - Digital Image Processing (Fall '91, Fall '92, Fall '93, Fall '94, Fall '95, Fall '96, Fall '97, Fall '98, Fall '99, Fall '00, Fall '01, Fall '02, Summer '03, Spring '04, Spring '05, Spring '06, Spring '07, Spring '08, Spring '10, Spring '11, Spring '12, Spring '13, Fall '13, Fall '14, Fall '15, Fall '16, Fall '17, Fall '18)