

Declaration of Chandrajit Bajaj, Ph.D. in Support of
Petition for *Inter Partes* Review of
U.S. Patent No. 8,982,109 B2

UNITED STATES PATENT AND TRADEMARK OFFICE

BEFORE THE PATENT TRIAL AND APPEAL BOARD

META PLATFORMS, INC., INSTAGRAM, LLC, WHATSAPP INC.,
Petitioners

v.

EYESMATCH LTD., MEMOMI LABS INC.,
Patent Owners

Case IPR2022-00489
U.S. Patent No. 8,982,109 B2
Issue Date: March 17, 2015

Title: Devices, Systems and Methods of Capturing and
Displaying Appearances

DECLARATION OF CHANDRAJIT BAJAJ, PH.D.

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I, Chandrajit Bajaj, Ph.D., declare as follows:

I. INTRODUCTION AND QUALIFICATIONS

A. Qualifications and Experience

1. I am currently employed as a Professor of Computer Science at the University of Texas at Austin (“UT Austin”). I hold the Computational Applied Mathematics endowed Chair in Visualization. I am also the Director of the Computational Visualization Center at UT Austin, which has been funded by the National Institutes of Health, the National Science Foundation, the Department of Energy, and the Department of Defense. The center’s personnel include twelve researchers, scientists, post-graduate students, and staff.

2. My curriculum vitae (“CV”), a copy of which is included as **Exhibit A** hereto, provides details on my education, experience, publications, and other qualifications. It includes a list of all publications I have authored in the previous 37 years.

3. I have a Bachelor of Technology degree in Electrical Engineering, which I obtained from the Indian Institute of Technology in Delhi (IITD) in 1980. I also have a Master of Science degree and a doctorate in Computer Science from Cornell University in 1983 and 1984, respectively.

4. Prior to my employment at the University of Texas (UT), I was an

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assistant professor, associate professor, and finally professor of Computer Sciences at Purdue University (Purdue) from 1984 until I resigned in 1997 and transferred to UT. During this time, I was also the Director of the Image Analysis and Visualization Center at Purdue University. I was a visiting associate professor of Computer Science at Cornell University from 1990-1991. I have also been invited for collaborative visits by several academic institutions and have presented numerous keynote presentations worldwide. I have been an editorial member of the SIAM Journal on Imaging Sciences and the ACM Transactions on Graphics, and I continue my editorial role for ACM Computing Surveys and the International Journal of Computational Geometry and Applications.

5. I have spent the better part of my career, both at Purdue and UT Austin, researching, designing, teaching, and using computer systems to model, simulate, search, and visualize natural and synthetic objects, combining computational image and geometry processing. I am knowledgeable about and have much experience in both the hardware and software, including algorithms, used for capturing, analyzing, and displaying imagery in real-time permitting user interaction.

6. In the 1970s, I majored in Electrical Engineering at the Indian Institute of Technology, with a minor in Computer Sciences. There, I was intimately involved in the design and fabrication of microprocessor-controlled circuits

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including the development of microprocessor controller software. In the 1980s, while at Cornell University, these past experiences from my time at Indiana Institute of Technology led to research in computational geometry, processing, and optimization. In the early 1990s, I created 3D collaborative multimedia software environments which were fully searchable, navigable for multi-person computer gaming and simulation. In 1994, I co-authored a technical paper entitled “Shastra: Multimedia Collaborative Design Environment,” Vinod Anupam and Chandrajit L. Bajaj, IEEE Multimedia 1.2 (1994) 39, 39–49.

7. The increasing need for real-time computer graphics display realism without sacrificing interactivity led me also to explore fast and efficient image processing techniques such as feature selection, segmentation, detection, texture mapping with data compression, such as described in my publications “Image Segmentation Using Gradient Vector Diffusion and Region Merging,” “Detecting Circular and Rectangular Particles Based on Geometric Feature Detection in Electron Micrographs,” “Compression-Based 3D Texture Mapping for Real-Time Rendering,” and “3D RGB Image Compression for Interactive Applications.” During this time, I was also intimately involved with the development of a new synthetic-natural hybrid data compression MPEG (Motion Pictures Expert Group) standard. Additionally, I applied and received a joint patent “Encoding Images of

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3-D Objects with Improved Rendering Time and Transmission Process,” August 2002, U.S. Patent No. 6,438,266.

8. My work with encoding, transmission and reconstructing 3-D objects led me to explore image processing and geometric modeling techniques such as surface reconstruction from CT scans, point clouds, segmentation, and texture mapping with data compression, such as those described in my publications: “Multi-Component Heart Reconstruction from Volumetric Imaging,” and “Automatic Reconstruction of Surfaces and Scalar Fields from 3D Scans.”

9. In the mid-2000s, I began to create spatially-realistic 3D graphical environments of natural molecules and cells with a combination of different types of acquired and reconstructed imagery within which a user may explore, query, and learn. My publication titled “From Voxel Maps to Models,” that appeared in an Oxford University Press book titled *Imaging Life: Biological Systems from Atoms to Tissues*, c. 15 (Gary C. Howard, William E. Brown & Manfred Auer eds.) (2014), is an example of my research in computational imaging.

10. Over the course of my career, I have participated in the design and use of several computer systems, spanning handhelds, laptops, and graphics workstations to PC/Linux clusters, as well as very large memory supercomputers for capturing, modeling, processing and displaying acquire and simulated data of

diverse scientific phenomena. My experience with computer modeling, imaging, computer graphics, and scientific visualization encompasses the use of interactive technologies, such as 3D pointers and mice, smart IR touch-screens, motion detection and gesture-based user interfaces, and multi-display walls, in many different fields and industrial settings, such as interactive games, medicine (e.g., molecular, biomedical, and industrial diagnostics), oil and gas exploration, geology, cosmology, and military industries.

11. During this time at UT Austin, I also designed and implemented scalable solutions for inverse problems in microscopy, spectroscopy, biomedical imaging, constructing spatially realistic and hierarchical 3D models, development of search/scoring engines for predicting energetically favorable multi-molecular and cellular complexes, and statistical analysis and interrogative visualization of neuronal form-function.

12. I have courtesy appointments and supervise M.S. and Ph.D. students from several UT Austin departments, including biomedical and electrical engineering, neurobiology, and mathematics. I currently serve on the editorial boards for the International Journal of Computational Geometry and Applications and the ACM Computing Surveys. Much of my work involves issues relating to interactive image processing, feature extraction, 3D modeling, bio-informatics,

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computer graphics, and computational visualization. Examples of my publications, including peer-reviewed publications on these sub-areas are listed in my CV.

13. As set forth in my CV, I have authored approximately 167 peer-reviewed journal articles, 34 book chapters (which were also peer reviewed), and 154 peer-reviewed conference publications.

14. I currently serve on the editorial boards for the International Journal of Computational Geometry and Applications and the ACM Computing Surveys.

15. I have written and edited four books on topics ranging from image processing, geometric modeling, and visualization techniques to algebraic geometry and its applications. I have given 165 invited speaker keynote presentations. I am a Fellow of the American Association for the Advancement of Science, a Fellow of the Institute of Electrical and Electronics Engineers (IEEE), a Fellow of the Society of Industrial and Applied Mathematics (SIAM), and also a Fellow of the Association of Computing Machinery (also known as ACM), which is the world's largest education and scientific computing society. The ACM Fellow is ACM's most prestigious member grade and recognizes the top 1% of ACM members for their outstanding accomplishments in computing and information technology and/or outstanding service to ACM and the larger computing community.

16. I have been retained by counsel for Petitioners to provide my expert

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opinion in connection with the above-captioned proceeding as set forth herein. I am being compensated for my time working on this matter at my standard hourly rate. I do not have any personal or financial stake or interest in the outcome of the present proceeding, and the compensation is not dependent on the outcome of this IPR and in no way affects the substance of my statements in this Declaration.

B. Materials Considered

17. The analysis that I provide in this Declaration is based on my education, research, and experience, as well as the documents I have considered. In forming my opinions, I have read and considered U.S. Patent No. 8,982,109 B2 (“109 patent”) [Ex. 1001] and its prosecution history. I have cited to the following documents in my analysis below:

Exhibit No.	Description of Document
1001	U.S. Patent No. 8,982,109 B2 to Nissi Vilcovsky and Ofer Saban (filed March 15, 2013, issued March 17, 2015) (“109” or “109 patent”)
1003	U.S. Patent App. Pub. No. US 2007/0040033 A1 to Louis B. Rosenberg (filed September 26, 2006, published February 22, 2007) (“Rosenberg”)
1004	Excerpts from 2003 International Conference on Multimedia and Expo, ICME '03 Proceedings, including Alexandre R.J. Francois et al., <i>A Handheld Mirror Simulation</i> (2003) (“Francois”)

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Exhibit No.	Description of Document
1005	U.S. Patent No. 8,587,653 B1 to Joseph Vidunas et al. (filed April 30, 2010, issued November 19, 2013) (“Vidunas”)
1006	U.S. Patent No. 6,512,541 B2 to Randy R. Dunton et al. (filed December 8, 1997, issued January 28, 2003) (“Dunton”)
1007	U.S. Patent No. 8,264,587 B2 Sinhung Yong et al. (filed January 15, 2009, issued September 11, 2012) (“Yong”)
1008	U.S. Patent No. 8,264,573 B2 to Toshihiko Suzuki (filed May 11, 2010, issuing September 11, 2012) (“Suzuki”)
1009	U.S. Patent Application Ser. No. 13/088,369 to Nissi Vilcovsky (filed April 17, 2011, issuing as U.S. Patent No. 8,624,883)
1010	U.S. Patent Application Ser. No. 11/817,411 to Nissi Vilcovsky (PCT filed March 1, 2006, issuing as U.S. Patent No. 7,948,481)
1011	Redline comparison of U.S. Patent Application Ser. No. 13/088,369 to Nissi Vilcovsky (Ex. 1009) with written description of ’109 patent
1012	Excerpts from <i>Joint Claim Construction Chart</i> filed on November 16, 2021 in <i>EyesMatch Ltd. et al., v. Facebook, Inc. et al.</i> , No. 1:21-cv-00111 RGA (JLH) (D. Del.)
1013	Excerpts from <i>Microsoft Computer Dictionary</i> (5th ed. 2002)
1014	Excerpts from Julie Adair King et al., <i>Digital Photography for Dummies</i> (6th ed. 2009)
1015	Excerpts from Brad Hansen, <i>Dictionary of Multimedia</i> (1998)

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Exhibit No.	Description of Document
1016	Excerpts from Dick Pountain, <i>New Penguin Dictionary of Computing</i> (2001)
1027	U.S. Patent No. 6,811,492 B1 to Minoru Arakawa et al. (filed November 28, 2000, issued November 2, 2004) (“Arakawa”)

II. PERSON OF ORDINARY SKILL IN THE ART

18. I understand that an assessment of claims of a patent filed before the America Invents Act (“AIA”) of 2011 took effect (“pre-AIA”) should be undertaken from the perspective of a person of ordinary skill in the art as of the earliest claimed priority date (i.e., the “time the invention was made”). I am informed that patent applications filed before March 16, 2013 are governed by pre-AIA law. In this case, the ’109 patent states on its face that it issued from U.S. Patent Application No. 13/843,001, filed March 15, 2013, which purports to be a continuation-in-part (CIP) of U.S. Patent Application No. 13/088,369 filed on April 17, 2011 (issuing as U.S. Patent No. 8,624,883), which in turn purports to be continuation of U.S. Patent No. Application No. 11/817,411 filed on March 1, 2006 (issuing as U.S. Patent No. 7,948,481). I am informed that a patent owner normally has the burden of proving that a CIP application is entitled to the filing date of an earlier application, and as applied to this case, that means that Patent Owner would bear the burden to show that the challenged claims are entitled to a priority date based on the April 17, 2011

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or March 1, 2006 applications (which I understand are substantively identical). As I will explain in **Part V.B** below, although I am not aware of any attempt by Patent Owner to meet this burden, I have independently determined that the challenged claims of the '109 patent are not entitled to a priority date based on either of these earlier-filed patent applications because they do not disclose several limitations recited in claim 1 (the sole independent claim).

19. The face page of the '109 patent also identifies a provisional application (Appl. Ser. No. 61/738,957) filed December 18, 2012. I am similarly informed that a patent owner normally has the burden of proving priority to an earlier provisional application, but for purposes of my analysis, it is unnecessary for me to assess whether the challenged claims are entitled to a priority date of December 18, 2012, as all of the prior art on which I rely for the proposed grounds pre-dates that date by more than two years. I have therefore assumed, for purposes of my analysis, that the '109 patent's priority date is December 18, 2012. I am not aware of any claim by the Patent Owner to an earlier date of invention, but the opinions and analysis in this Declaration would not change if the Patent Owner were to later claim that the '109 patent was entitled to a priority date at any point between 2010-2012.

20. I have also been advised that to determine the appropriate level of a person having ordinary skill in the art, the following factors may be considered: (1)

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the types of problems encountered by those working in the field and prior art solutions thereto; (2) the sophistication of the technology in question, and the rapidity with which innovations occur in the field; (3) the educational level of active workers in the field; and (4) the educational level of the inventor.

21. The '109 patent “relates generally to imaging and display systems and, more particularly, to monitors, and interactive displays, e.g., in retail and/or service environments, medical or home situations, video conferencing, gaming, etc.” ('109, 1:26-29.) According to the patent, “[s]pecific implementations relate to making a flat panel display appear as a mirror.” ('109, 1:29-31.)

22. In my opinion, a person of ordinary skill in the art as of December 2012 would have possessed at least a bachelor's degree in electrical engineering or computer science, and two years of work experience related to image capture and processing. As part of the person's education or work experience, the person would have gained a familiarity with 3-D graphics programming and/or computer vision. A person could also have qualified as a person of ordinary skill in the art with some combination of (1) more formal education (such as a master's of science degree) and less technical experience, or (2) less formal education and more technical or professional experience in the fields listed above.

23. My opinions regarding the level of ordinary skill in the art are based

on, among other things, my approximately 40 years of experience in the field of computer science and technology, my understanding of the basic qualifications that would be relevant to an engineer or scientist tasked with investigating methods and systems in the relevant area, and my familiarity with the backgrounds of colleagues, co-workers, and employees, both past and present.

24. Although my qualifications and experience exceed those of the hypothetical person having ordinary skill in the art defined above, my analysis and opinions regarding the '109 patent have been based on the perspective of a person of ordinary skill in the art as of December 2012. As noted, my opinions and analysis in this Declaration would not change based on any point between 2010-2012.

III. STATEMENT OF LEGAL PRINCIPLES

A. Claim Construction

25. I understand that a purpose of claim construction is to determine what a person of ordinary skill in the art would have understood the claim terms to mean. Claim terms are generally given their ordinary and customary meaning, which is the meaning that the term would have to a person of ordinary skill in the art in question as of the critical date (i.e., either the earliest claimed priority date (pre-AIA) or the effective filing date (AIA)).

26. I understand that the person of ordinary skill in the art is deemed to read

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the claim term not only in the context of the particular claim in which the disputed term appears, but in the context of the entire patent, including the specification. I understand that the patent specification, under the legal principles, has been described as the single best guide to the meaning of a claim term, and is thus highly relevant to the interpretation of claim terms. And I understand for terms that do not have a customary meaning within the art, the specification usually supplies the best context of understanding the meaning of those terms.

27. I further understand that other claims of the patent in question, both asserted and unasserted, can be valuable sources of information as to the meaning of a claim term. Because the claim terms are normally used consistently throughout the patent, the usage of a term in one claim can often illuminate the meaning of the same term in other claims. Differences among claims can also be a useful guide in understanding the meaning of particular claim terms.

28. I understand that the prosecution history can further inform the meaning of the claim language by demonstrating how the inventors understood the invention and whether the inventors limited the invention in the course of prosecution, making the claim scope narrower than it otherwise would be. Extrinsic evidence, such as dictionaries, may also be consulted in construing the claim terms.

29. I understand that, in *Inter Partes* Review (IPR) proceedings, a claim of

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a patent shall be construed using the same claim construction standard that would be used to construe the claim in a civil action filed in a U.S. district court (which I understand is called the “*Phillips*” claim construction standard), including construing the claim in accordance with the ordinary and customary meaning of such claim as understood by one of ordinary skill in the art and the prosecution history pertaining to the patent.

30. I have been instructed by counsel to apply the “*Phillips*” claim construction standard for purposes of interpreting the claims in this proceeding, to the extent they require an explicit construction. The description of the legal principles set forth above thus provides my understanding of the “*Phillips*” standard as provided to me by counsel.

31. Additionally, I have reviewed proposed constructions advanced by Petitioners and Patent Owner in the pending district court litigation. (Ex. 1012.) As relevant to the ’109 patent, those construction are listed below:

’109 Patent Claim Term	Patent Owner’s Construction	Petitioners’ Construction
“mirror mode”	A mode to display the current appearance of a user as if reflected in a mirror	A mode of operating as a mirror, where a “mirror” is a reflective surface, or as a display that mimics a reflection of a mirror.

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'109 Patent Claim Term	Patent Owner's Construction	Petitioners' Construction
"display mode"	A mode to display a previously captured user appearance	A mode of operating as a display.

(Ex. 1012 at 003-004.) In addition, I understand that the parties have agreed that the term "appears to mimic a reflection in a mirror" means "appears to mimic the image that would have reflected from a mirror, i.e., from a reflective surface," and that the term "mirror-mimicking image" means "an image that mimics the image that would have reflected from a mirror, i.e., from a reflective surface." As I will demonstrate below, it is unnecessary for me to opine on which side's construction is correct, as the prior art discloses and renders obvious the challenged claims under any of these proposed constructions. I further understand that the parties have agreed that the preamble of claim 1 is limiting.¹ (Ex. 1012 at 002.)

¹ I also note that in the pending district court litigation, and as I will explain for limitation 1[f] below, Petitioners have argued that the term "the non-ordered steps" in claim 1 creates an indefiniteness issue. (Ex. 1012 at 008-010.) As I explained fully for limitation 1[f], this issue does not prevent me from providing an opinion on the invalidity of the challenged claims over the prior art. Although there may be various interpretations of the claim language that render the full scope of the claim

B. Obviousness

32. I understand that a patent claim is obvious if, as of the critical date (i.e., either the earliest claimed priority date (pre-AIA) or the effective filing date (AIA), it would have been obvious to a person having ordinary skill in the field of the technology (the “art”) to which the claimed subject matter belongs.

33. I understand that the following factors should be considered in analyzing obviousness: (1) the scope and content of the prior art; (2) the differences between the prior art and the claims; and (3) the level of ordinary skill in the pertinent art. I also understand that certain other facts known as “secondary considerations” such as commercial success, unexplained results, long felt but unsolved need, industry acclaim, simultaneous invention, copying by others, skepticism by experts in the field, and failure of others may be utilized as indicia of nonobviousness. I understand, however, that secondary considerations should be connected, or have a “nexus,” with the invention claimed in the patent at issue.

34. I understand that a reference qualifies as prior art for obviousness purposes when it is analogous to the claimed invention. The test for determining

not reasonably certain, as shown by my analysis below, the prior art discloses and renders obvious the claim under any reasonable interpretation of that language.

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what art is analogous is: (1) whether the art is from the same field of endeavor, regardless of the problem addressed, and (2) if the reference is not within the field of the inventor's endeavor, whether the reference still is reasonably pertinent to the particular problem with which the inventor is involved.

35. I understand that a person of ordinary skill in the art is assumed to have knowledge of all prior art. I understand that one skilled in the art can combine various prior art references based on the teachings of those prior art references, the general knowledge present in the art, or common sense. I understand that a motivation to combine references may be implicit in the prior art, and there is no requirement that there be an actual or explicit teaching to combine two references. Thus, one may take into account the inferences and creative steps that a person of ordinary skill in the art would employ to combine the known elements in the prior art in the manner claimed by the patent at issue. I understand that one should avoid "hindsight bias" and ex post reasoning in performing an obviousness analysis. But this does not mean that a person of ordinary skill in the art for purposes of the obviousness inquiry does not have recourse to common sense.

36. I understand that when determining whether a patent claim is obvious in light of the prior art, neither the particular motivation for the patent nor the stated purpose of the patentee is controlling. The primary inquiry has to do with the

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objective reach of the claims, and that if those claims extend to something that is obvious, then the entire patent claim is invalid.

37. I understand one way that a patent can be found obvious is if there existed at the time of the invention a known problem for which there was an obvious solution encompassed by the patent's claims. I understand that a motivation to combine various prior art references to solve a particular problem may come from a variety of sources, including market demand or scientific literature. I understand that a need or problem known in the field at the time of the invention can also provide a reason to combine prior art references and render a patent claim invalid for obviousness. I understand that familiar items may have obvious uses beyond their primary purpose, and that a person of ordinary skill in the art will be able to fit the teachings of multiple prior art references together like the pieces of a puzzle. I understand that a person of ordinary skill is also a person of at least ordinary creativity. I understand when there is a design need or market pressure to solve a problem and there are a finite number of identified, predictable solutions, a person of ordinary skill has good reason to pursue the known options within his or her technical grasp. If this finite number of predictable solutions leads to the anticipated success, I understand that the invention is likely the product of ordinary skill and common sense, and not of any sort of innovation. I understand that the fact that a

combination was obvious to try might also show that it was obvious, and hence invalid, under the patent laws. I understand that if a patent claims a combination of familiar elements according to known methods, the combination is likely to be obvious when it does not more than yield predictable results. Thus, if a person of ordinary skill in the art can implement a predictable variation, an invention is likely obvious. I understand that combining embodiments disclosed near each other in a prior art reference would not ordinarily require a leap of inventiveness.

38. I understand that obviousness may be shown by demonstrating that it would have been obvious to modify what is taught in a single piece of prior art to create the patented invention. Obviousness may also be shown by demonstrating that it would have been obvious to combine the teachings of more than one item of prior art. I understand that a claimed invention may be obvious if some teaching, suggestion, or motivation exists that would have led a person of ordinary skill in the art to combine the invalidating references. I also understand that this suggestion or motivation may come from the knowledge of a person having ordinary skill in the art, or from sources such as explicit statements in the prior art. I understand that when there is a design need or market pressure, and there are a finite number of predictable solutions, a person of ordinary skill may be motivated to apply common sense and his skill to combine the known options in order to solve the problem.

39. I understand the following are examples of approaches and rationales that may be considered in determining whether a piece of prior art could have been combined with other prior art or with other information within the knowledge of a person having ordinary skill in the art:

- (1) Some teaching, motivation, or suggestion in the prior art that would have led a person of ordinary skill to modify the prior art reference or to combine prior art reference teachings to arrive at the claimed invention;
- (2) Known work in one field of endeavor may prompt variations of it for use in the same field or a different field based on design incentives or other market forces if the variations would have been predictable to a person of ordinary skill in the art;
- (3) Combining prior art elements according to known methods to yield predictable results;
- (4) Applying a known technique to a known device, method, or product ready for improvement to yield predictable results;
- (5) Applying a technique or approach that would have been “obvious to try” (choosing from a finite number of identified, predictable solutions, with a reasonable expectation of success);

(6) Simple substitution of one known element for another to obtain predictable results; or

(7) Use of a known technique to improve similar products, devices, or methods in the same way.

40. I understand that, when determining whether a claimed combination is obvious, the correct analysis is not whether one of ordinary skill in the art, writing on a blank slate, would have chosen the particular combination of elements described in the claim. Instead, I understand the correct analysis considers whether one of ordinary skill, facing the wide range of needs created by developments in the field of endeavor, would have seen a benefit to selecting the combination claimed.

41. I understand that the test for obviousness is not whether the features of a secondary reference may be bodily incorporated into the structure of the primary reference. The test for obviousness, in other words, is not whether the references could be physically combined but whether the claimed inventions are rendered obvious by the teachings of the prior art as a whole.

IV. THE '109 PATENT

A. Overview of the Specification

42. The '109 patent states that it “relates generally to imaging and display systems and, more particularly, to monitors, and interactive displays, e.g., in retail

and/or service environments, medical or home situations, video conferencing, gaming, etc.” (’109, 1:26-29.) According to the patent, “[s]pecific implementations relate to making a flat panel display appear as a mirror.” (’109, 1:29-31.)

43. In the “Background of the Invention” section, the patent asserts that a customer shopping for consumer articles, such as clothes, may experience a “frustrating and inefficient shopping experience” as a result of not being able to recall and compare previous trials of consumer articles, such as their appearance when trying on clothes. (’109, 1:35-60.) This issue is partly owing to the use of conventional mirrors (“i.e., reflective surface”), “the common and most reliable tool for an individual to explore actual self-appearance, in real time.” (’109, 1:61-63.)

44. The patent therefore seeks to replace a conventional mirror with a combination of camera and screen—i.e., as noted, “to mak[e] a flat panel display appear as a mirror.” Figure 6 of the ’109 patent illustrates an example. As shown below, a standard mirror is replaced with a digital screen **640** that displays images captured by camera **630** after processing by computerized image processor **645**:

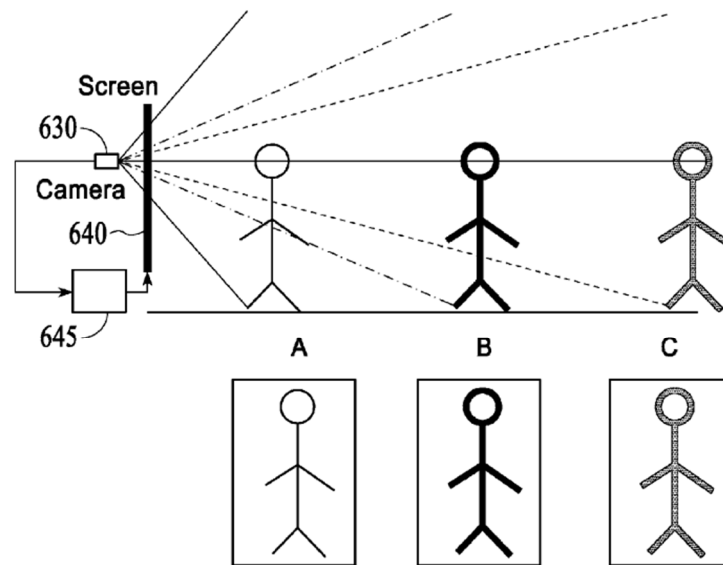


FIG. 6

('109, Fig. 6, 14:13-29.)

45. The patent acknowledges that the idea of replacing a conventional mirror with a camera and screen is not new, but contends that prior art techniques are not convincing or reliable. ('109, 1:61-2:3.) The patent observes that an image generated by a camera is different than an image generated by a mirror because **(1)** a person's reflection in a mirror is as if the person were standing at a distance that is double the person's distance to the mirror, **(2)** when a person's distance to a mirror changes, the angle of the person's field of view (FOV) changes, **(3)** as a person's distance to a mirror changes, the reflection of the person's eyes in the mirror will always stay on the same virtual line into the mirror, and **(4)** an image generated by

a mirror appears to be reversed because the forward/backward axis is flipped.² ('109, 2:4-48.)

46. With these issues in mind, the patent discusses how an image captured by a camera can be manipulated such that when it is displayed on screen it “resembles a mirror image, i.e., an image the user would have seen if the screen was actually a standard mirror.” ('109, 14:6-17:54.) According to the patent, exemplary manipulations include: **(1)** adaptive FOV “to compensate for the changes in distances between the user and the screen, so that the user will see his image at the same size, just like in a mirror” ('109, 14:29-39), **(2)** flipping the image vertically to “support the right-to-left behavior of the mirror” ('109, 14:40-53), and **(3)** adaptive point of view (POV) “to fit the view point that would occur with a conventional mirror” ('109, 15:48-52). The patent asserts that performing these manipulations “results in an image that mimics a reflection of a mirror positioned at the location of the screen”:

² As the '109 patent observes, these differences can largely be explained with the basic principle for plane mirrors that “angle of incidence equals angle of reflection” ('109, 2:43-46)—an everyday concept of specular light reflection that should be familiar to anyone who has taken an introductory physics class in high school.

[A]ttempting to solve the virtual mirror problem by only flipping the image vertically as was proposed in the prior art is insufficient to create a mirror experience. When using a camera, once the user gets closer to the camera/screen the user's image becomes larger, and vice versa, as opposed to a conventional mirror where the user will always see himself roughly at the same size with a bit of a different FOV, regardless of his distance from the mirror. In addition, getting closer to the camera introduces image distortion that needs to be corrected in a much more advanced computerized method. Performing an adaptive POV and adaptive FOV prior to displaying the image on the screen results in an image that mimics a reflection of a mirror positioned at the location of the screen.

('109, 15:59-16:5.) According to the patent, manipulations can be carried out using a "transformation mapping" that can include "angle, tilt, azimuth, scale, spatial translation (i.e., elevation linear offset or horizontal offset) etc." ('109, 29:30-40.) "The final transformation is a matrix multiplication of the individual transformation to generate the individual distortions." ('109, 29:40-42.)

47. I discuss additional aspects of the '109 patent as needed in my analysis below.

B. The Challenged Claims

48. This Declaration addresses claims 1, 2, 6, 8, 9 and 17. Independent claim 1, the sole independent claim, is representative and recites:

Declaration of Chandrajit Bajaj, Ph.D., in Support of
Petition for *Inter Partes* Review of
U.S. Patent No. 8,982,109 B2

1. A method for operating a system having a monitor, a camera, and a processor, so as to display a mirror-mimicking image on the monitor, by performing non-ordered steps comprising:
 - [a] obtaining a digital image from a camera;
 - [b] flipping the image about a vertical axis so as to reverse right and left sides of the image;
 - [c] applying a transformation mapping to the image to modify the image such that it appears to mimic a reflection of a mirror;
 - [d] resizing the image to reduce variations caused by changes in object's distance to the camera;
 - [e] displaying the image on the monitor after performing the flipping, transformation mapping, and resizing;
 - [f] wherein the non-ordered steps are performed on a series of images of a live video feed from the camera;
 - [g] determining distance to a user appearing in the live video feed; and,
 - [h] varying rate at which the non-ordered steps are performed on the series of images according to the distance.

('109, 30:52-67 (Claim 1; bracketed notations (e.g., [a]) added).)

49. I address the claims further in my detailed analysis in **Part V** below.

V. APPLICATION OF THE PRIOR ART TO CHALLENGED CLAIMS

50. I have reviewed and analyzed the prior art references and materials listed in **Part I.B** above. In my opinion the claims of the '109 patent would have been obvious to a person of ordinary skill in the art based on the following combinations of the prior art.

Ground	Claims	Basis for Challenge
1	1-2, 6, 8-9, 17	Obvious over Rosenberg [Ex. 1003] in view of Francois [Ex. 1004], and Vidunas [Ex. 1005], in further view of Dunton [Ex. 1006] and Yong [Ex. 1007]
2	1-2, 6, 8-9, 17	Obvious over Rosenberg in view of Francois, and Vidunas [Ex. 1005], in further view of Suzuki [Ex. 1008]

51. I am informed by counsel that each of the references cited in the grounds above qualifies as prior art to the challenged claims because each reference was filed and/or published before the earliest priority date for the '109 patent (December 2012).

A. Brief Summary of Prior Art

1. Rosenberg [Ex. 1003]

52. **Rosenberg**, U.S. Patent App. Pub. No. US 2007/0040033 A1, is entitled “Digital Mirror System with Advanced Imaging Features and Hands-Free Control.” I am informed that Rosenberg qualifies as prior art because it states on its

face that it was filed on September 26, 2006 and published on February 22, 2007, both dates being before the '109 patent priority date.

53. Rosenberg discloses a “digital mirror system ... adapted to provide real-time captured images that approximate what a user would see when viewing an ordinary mirror” that is strikingly similar to the '109 patent. (Rosenberg, ¶0006; *see also id.*, ¶0025, claim 1.) The system includes a monitor and camera, as shown in Figure 3 below, which depicts camera 302 mounted above display 301:

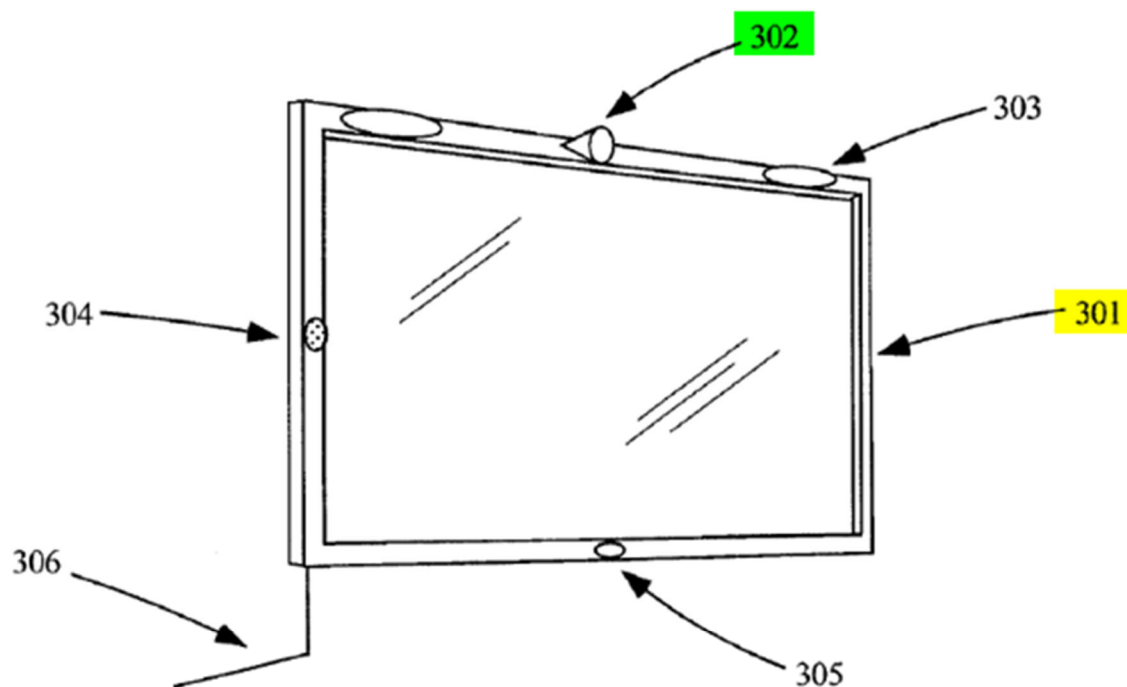


Fig. 3

(Rosenberg, Fig. 3; *see also* Rosenberg, ¶0062.) Real-time video images captured

by the camera are processed so that when displayed a user sees what they would have seen if standing before a traditional optical mirror, as illustrated in Figure 5:

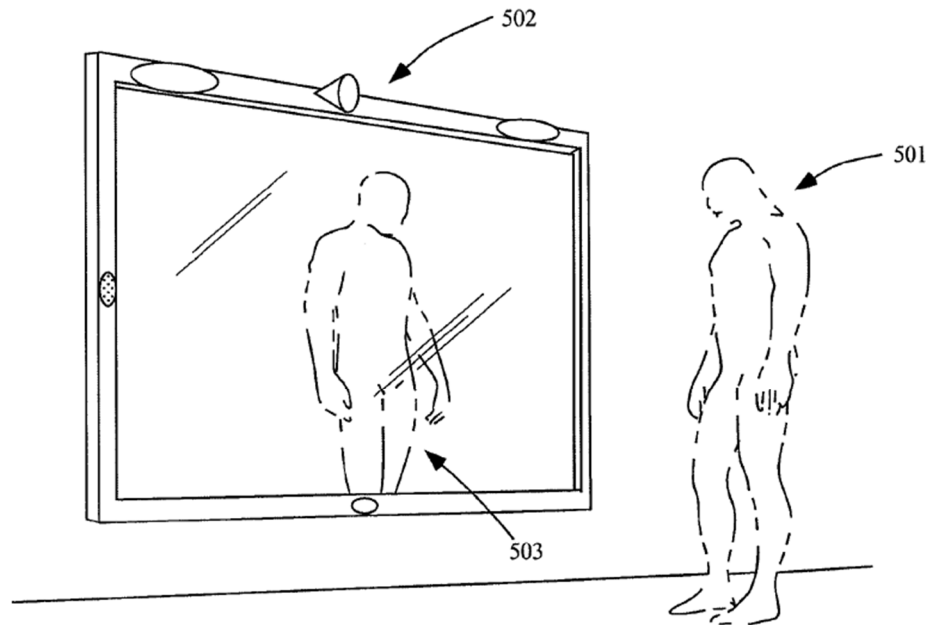


Fig. 5

(Rosenberg, Fig. 5; *see also id.*, ¶¶0006 (“A processor controls the camera to capture the at least one image”), 0026 (describing “traditional mirror mode” where a stream of captured images are left-right inverted “to present the user with a traditional mirror image of himself or herself”), 0035 (describing “left-right image inversion processor” and explaining that same processor unit can perform the various described processing functions), 0074 (“mirroring routines running upon the processor”), claim 1.) Rosenberg explains that the image processing includes scaling them to “appear[] like a traditional life-size mirror image[s],” and inverting

them left-right before displaying them on the screen:

FIG. 5 illustrates a computer rendering of a human user **501** standing in front of a wall-mounted embodiment of the advanced digital mirror system **502** according to at least one embodiment of the present invention. The user's image is captured as a real-time video image by a camera upon or within the digital mirror **502** as described previously. A representation of that real-time video image is then displayed upon the wall mounted screen of the digital mirror **502** with a displayed size and scaling such that it appears like a traditional life-size mirror image **503**. In a traditional mirror emulation mode, the real-time video image is left-right inverted prior to display upon the screen. Thus the user **501** standing before the digital display is given the visual impression that he or she is standing before a traditional wall mirror, viewing a traditional mirror image of himself or herself.

(Rosenberg, ¶0077.) I will provide more information about Rosenberg in my discussion below.

2. Francois [Ex. 1004]

54. **Francois** is an academic paper titled "A Handheld Mirror Simulation" by Alexandre R.J. Francois and Eun-Young Elaine Kang, which states on its face that it was published in the Proceedings of the 2003 International Conference on Multimedia and Expo. I am informed that Francois qualifies as prior art because it was published in 2003, which is before the '109 patent priority date.

55. My Declaration relies on Francois primarily for limitation 1[c] reciting **“applying a transformation mapping to the image to modify the image such that it appears to mimic a reflection of a mirror”** and limitation 1[d] reciting **“resizing the image to reduce variations caused by changes in the object’s distance to the camera.”** As explained above and in more detail in my analysis below, Rosenberg describes techniques to give a person standing before a digital display “the visual impression that he or she is standing before a traditional wall mirror, viewing a traditional mirror image of himself or herself.” (Rosenberg, ¶0077; *see also, e.g., id.*, ¶0006 (“to provide real-time captured images that approximate what a user would see when viewing an ordinary mirror”).) The techniques in Rosenberg include both flipping captured images left-right and scaling them such that they “appear[] like a traditional life-size mirror image.” (Rosenberg, ¶0077.) But Rosenberg does not provide technical details about how its system transforms images to mimic a mirror reflection, or how its system resizes images.

56. Francois discloses a computer-based display system similar to Rosenberg to simulate the appearance one would see when looking into a conventional mirror, but Francois provides more details about how the images are digitally transformed to create this simulated appearance. More specifically, Francois describes the “design and construction of a handheld mirror simulation

device.” (Francois at 021, Abstract.) Figure 1 of Francois, reproduced below, illustrates its mirror simulation system:

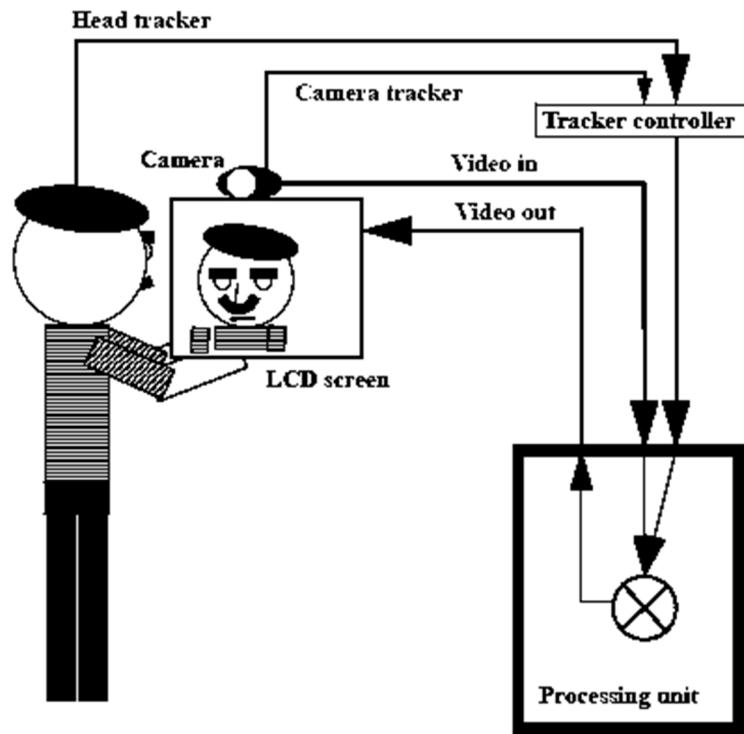


Figure 1. Handheld mirror simulation system.

(Francois, Fig. 1, at 021.) As shown above, the system includes an LCD screen and camera. Real-time video from the camera is fed into a processing unit, which outputs processed video to the LCD screen. (Francois at 023, Section “3. System Integration”.) The system as shown above also includes a “Head tracker” and “Camera tracker,” which provide real-time positional data needed to transform the video images from the perspective of the camera to the user’s perspective. (Francois at 023, Section “3. System Integration”; *see also id.* at 021, Section “1. Introduction”)

(“The continuous input video stream and tracker data is used to synthesize, in real-time, a continuous video stream displayed on the LCD screen.”.) The output video, according to Francois, “is a close approximation of what the user would see on the screen surface if it were a real mirror.” (Francois at 021, Section “1. Introduction”; *see also id.* at 023, Section “3. System Integration” (“The result is a convincing handheld mirror simulation”).)

57. Francois describes a “geometric analysis of mirror and camera imaging, leading to the image transform for mirror simulation” (Francois, 021, Introduction) and derives a set of “transformation equations that relate the user’s view to the camera image.” (Francois at 023, Section “2.3 User view synthesis”; *see also id.*, 021-023, Section “2. Geometric Analysis”). Francois explains that, with the equations, “the transform relating the user’s view to the camera view is reduced to a scaling and a translation” and “[t]he major field-of-view variations occurring [sic] when varying the angle of view and distance to the mirror, are convincingly simulated.” (Francois at 023, Section “2.3 User view synthesis”). As I explain in great detail in my analysis below, applying Francois’s mirror transformation equations scales an image based on the user’s distance to the mirror/display, *e.g.*, by scaling up the object’s image when the object’s distance from the camera equipped mirror display increases. Thus, as I will explain, Francois discloses and renders

obvious **“applying a transformation mapping to the image to modify the image such that it appears to mimic a reflection of a mirror”** and **“resizing the image to reduce variations caused by changes in the object’s distance to the camera.”**

3. Vidunas [Ex. 1005]

58. **Vidunas**, U.S. Patent No. 8,587,653 B1, is entitled “Modifying the Resolution of Video Before Transferring to a Display System.” I am informed that Vidunas qualifies as prior art because it states on its face that it was filed on April 30, 2010, which is before the ’109 patent priority date.

59. My Declaration relies on Vidunas in combination with Rosenberg and Francois primarily for limitation 1[d] reciting **“resizing the image to reduce variations caused by changes in the object’s distance to the camera.”** As mentioned above and demonstrated further below, the resizing of limitation 1[d] is performed as a result of the mirror transformation equations in Francois, which will scale an image based on the user’s distance to the mirror/display, *e.g.*, by scaling up the image when the distance increases. The result of these transformations, as explained below, is to mimic the reflection of a mirror.

60. As I will explain for limitation 1[d], it would have been obvious that in order to display a scaled image on the monitor as taught in Francois, if the image has been scaled-up, it would have been necessary to “crop” the image to fit the

dimensions of the physical display. The term “cropping” refers to a well-known image processing step involving removal of unnecessary or unused areas from an image. Cropping generally involves trimming the edges or sides of an image to magnify or emphasize an object of interest in the image. It is likely that anyone who had used a photo editing tool by December 2012 (such as the photo apps commonly found on mobile phones) would have been familiar with “cropping” a digital image.

61. Francois does not expressly state that scaled-up images are cropped, and as such, I have cited to Vidunas which discloses such a technique. Vidunas explains that “[m]any modern video cameras can capture video at resolutions greater than that which can be displayed by many modern display systems, such as computer monitors.” (Vidunas, 1:26-28.) Because higher resolution images consume more data, they require more processing power to display and more bandwidth to transport over a computer network. (Vidunas, 1:32-37, 3:14-17 (“The higher the resolution of a video, the more bandwidth will be needed on link 111 to transfer the video because more data is needed to represent more pixels in higher resolution video.”), 11:6-11 (“The amount of CPU resources required to decompress images is directly proportional to the image resolution, so as image resolution has increased, so have the processing requirements to decompress images. Similarly, the network bandwidth required to transmit images increases as the resolution increases.”).) This

additional processing power and bandwidth are thus wasted when using a lower resolution display or computer monitor, to the extent portions of the higher resolution images will not be presented to the user on the display.

62. Vidunas addresses this problem by disclosing a number of techniques for “reduc[ing] the resolution of video before transference to a display system.” (Vidunas, 1:39-41.) The purpose of these techniques is “modifying the video... to produce modified video having a reduced quantity of pixels in each of the plurality of images and transferring the modified video for display of at least a portion of the scene in the viewing area by the display system.” (Vidunas, 1:45-49.) One exemplary technique of reducing the number of pixels in video images involves cropping an image, as shown in Figure 6:

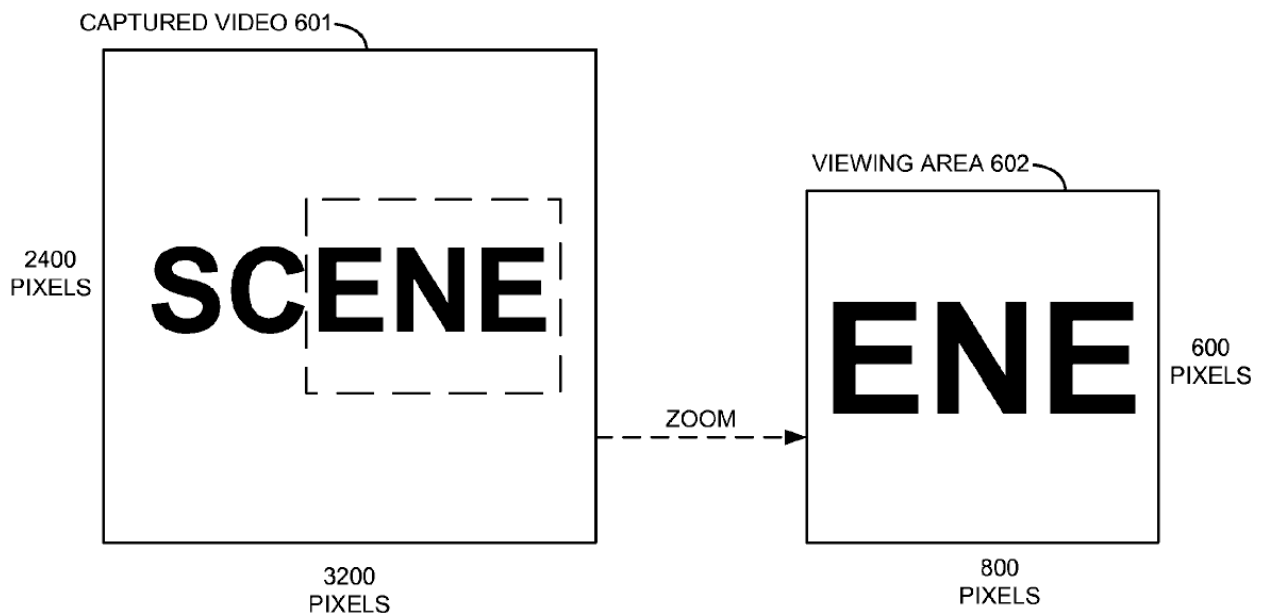


FIGURE 6

(Vidunas, Fig. 6.) Figure 6 shows cropping of an image from a video **601** having a resolution of 3200x2400 pixels to fit smaller viewing area **602**, in this example a smaller display with resolution of 800x600 pixels. (Vidunas, 7:41-49.)

63. Figure 6 above shows a process that Vidunas refers to as “digital zooming,” which “crops a section of pixels out of the images of captured video **601**.” (Vidunas, 7:66-8:1.) “For example, digital Zooming crops the pixels within the dashed rectangle out of captured video **601**. Thus, the amount of pixels within the dashed rectangle stays the same while all the pixels outside the dashed rectangle are removed for the modified video.” (Vidunas, 8:1-6.)

64. Vidunas discloses that cropping can be performed based on user selection, or automatically based on objects in the image. “For example, the processing system may be instructed to monitor for faces. Upon detecting the event of item, the processing system may automatically crop and scale the area of the video scene where the event or item was detected.” (Vidunas, 8:23-27.) I will provide more information about Vidunas in my discussion below.

4. Dunton [Ex. 1006] and Yong [Ex. 1007]

65. **Dunton**, U.S. Patent No. 6,512,521 B2, is entitled “Increasing Image Field of View and Frame Rate in an Imaging Apparatus.” **Yong**, U.S. Patent No. 8,264,587 B2 is entitled “Increasing Frame Rate for Imaging.” I am informed that

Dunton and Yong qualify as prior art to the '109 patent because both references state on their face that they were filed, and issued, before the '109 patent priority date.

66. My Declaration relies on Dunton and Yong for limitation 1[h], which recites the step of “**varying the rate at which the non-ordered steps are performed on the series of images according to the distance,**” with the non-ordered steps referring to at least the previously-recited steps of obtaining a digital image from a camera (limitation 1[a]), flipping the image (limitation 1[b]), applying a transformation mapping and resizing the image (limitations 1[c]-1[d]), and displaying the image (limitation 1[e]). As I will explain below, limitation 1[h] would have been obvious based on Rosenberg and Francois, in combination with teachings in Dunton and Yong as discussed below.

67. Dunton and Yong disclose a technique for varying the “frame rate” associated with processing video captured by a video camera. The term “frame rate” generally refers to the frequency (or rate) at which sequential images (or “frames”) of a video are captured, processed, and/or displayed. Frame rate is commonly expressed as a number of frames-per-second (FPS). Motion pictures, for example, commonly use a standard frame rate of 24 frames-per-second. In the context of a computer-based process that captures images (“frames”) from a video camera, the term “frame rate” is often used to refer to the rate at which the system performs the

overall process of capturing digital images and performing the necessary processing to enable those images to be displayed.

68. Persons of ordinary skill in the art have long understood that the frame rate used to produce a video can have a direct impact on the user's experience when viewing a video. Low frame rate videos are often associated with videos having choppy or jumpy motion, whereas higher frame rate videos are generally associated with smoother and more natural motion. But increasing the frame rate significantly increases the amount of data that the video requires – for example, increasing a video's frame rate from 30fps to 60fps means that the video will contain twice as many images. This increase generally results in the higher frame-rate video requiring more processing power, storage, and network bandwidth. The appropriate frame rate for a video application thus often involves a trade-off between video quality and efficient utilization of computer resources.

69. **Dunton** and **Yong** both disclose what would have been well-known to persons of ordinary skill in the art – the ability to increase the frame rate for a video when the frames of the video consume less data (for example, as a result of reducing the amount of data in the video frames). The “Background” section of Dunton, for example, explains:

To meet a given image frame rate over a limited transmission

bandwidth, one solution is to simply electronically scale the detailed still image frames into lower resolution image frames prior to transmitting them. Alternatively, the detailed image can be “cropped” to a smaller size, and therefore lower resolution image. In this way, the amount of spatial data per image frame is reduced, so that a greater frame rate can be achieved between the digital camera and the host computer.

(Dunton, 1:35-43.) Dunton discloses one example in which this technique can be used to provide different frame rates based on the distance to the camera, *e.g.*, in Dunton’s implementation, a higher frame rate when capturing near image data (which consumes less data than distant image data):

In order to obtain the smaller near image data 170 and greater frame rate when the apparatus 100 is configured with the optical system 108 in the near position, the signal processing block 110 and the sensor 114 are configured (by control signals and data received from the system controller 160, see FIG. 1) to process only the pixel signals originating from those rows and columns of the sensor 114 that define the region on which the smaller image is formed...

The fewer sensor signals result in both lower processing times in the signal processing block 110, and greater image frame rate through a limited bandwidth interface between the sensor 114 and signal processing block 110. This in turn results in greater image frame rate through the host communication interface 154 (see FIG. 1).

(Dunton, 4:61-5:15.) The example above discloses what is akin to a “cropping”

technique in which only a portion of the image provided by the camera is processed, *e.g.*, those pixels associated with near image data **170**. The surrounding pixels which show more distant objects are thus disregarded and not processed by the system. (*Id.*, Fig. 4.) In any case, in this implementation in Dunton, because there is less data associated with video frames that include just near image data **170**, the frame rate for the video can be increased.

70. **Yong** discloses a similar technique for increasing the frame rate of a video in response to reducing the size and/or resolution of frames of the video:

A new method, apparatus and software product are presented for implementing algorithms for improving (*i.e.*, increasing) a frame rate by reducing a size and resolution (*i.e.*, size/resolution) of selected (or chosen) versus unselected image frames captured by a sensor in an image processing pipeline before displaying (or before encoding stage) in electronic devices (*e.g.*, cameras, wireless camera phones, etc.), according to various embodiments of the present invention.

(Yong, 4:25-32.) As with Dunton, the size and/or resolution reduction in Yong can result in an increase in frame rate because it decreases the amount of data used for the video frames, thus reducing the amount of processing time. (Yong, *e.g.*, 6:6-15.)

71. The techniques in Dunton and Yong represent an application of a universal truism in computer science that would have been apparent to a person of ordinary skill in the art, *i.e.*, that a computer system can process data more quickly

when there is less data to process. I will provide more detail about Dunton and Yong in my discussion of limitation 1[h], below. As I will demonstrate below, limitation 1[h] would have been obvious based on Rosenberg, Francois, and Vidunas, in further view of Dunton and Yong. As noted, Francois specifically discloses mirror transformation equations that can scale an image (*e.g.* scale up or enlarge) based on the distance of the viewer to the mirror/display. Based on the combination of Francois and Vidunas, as described for limitation 1[d] below, when images (frames) of a video are scaled up to account for an increase in distance, those images would have been cropped to fit the screen, thus reducing the amount of data they consume. It thus would have been obvious that based on the teachings of Francois and Vidunas to increase the frame rate for those images, and in further view of the disclosures of Dunton and Yang.

5. Suzuki [Ex. 1008]

72. Suzuki, U.S. Patent No. 8,264,573 B2, is entitled “Imaging Apparatus and Reproducing Apparatus Which Changes Frame Rate Based on Zoom Operation.” I am informed that Suzuki qualifies as prior art because it states on its face that it was filed, and issued, before the ’109 patent priority date.

73. My Declaration relies on Suzuki as an alternative to Dunton and Yong for claim limitation 1[h], reciting the step of “**varying the rate at which the non-**

ordered steps are performed on the series of images according to the distance.”

Suzuki provides an alternative approach and rationale for varying the frame rate. Dunton and Yong, as discussed above, disclose increasing a video frame rate in response to reducing the amount of data in the images. Suzuki discloses increasing the frame rate for a different purpose – to increase the amount of video information recorded for important scenes in a video, to increase video quality.

74. To this end, Suzuki discloses an imaging apparatus (such as a video camera) that includes a “zoom” function, and which can increase the frame rate for recorded video in response to use of the zoom function. For example, Suzuki discloses that the frame rate of the imaging apparatus can be increased during, before, and/or after a “zoom operation,” depending on the needs of the user. (Suzuki, Abstract (“During a zoom operation period or a period including the zoom operation period and periods before and after the zoom operation, a video signal from the imaging unit is recorded in a recording medium at a high recording frame rate.”).) A “zoom operation” in Suzuki includes either a zoom-in or zoom-out operation. (Suzuki, *e.g.*, 13:55-58.)

75. Figures 15A-15D show one example of how the frame rate of a video recording is operated at a higher frame rate during a zoom operation:

FIG.15A

ZOOM
OPERATION

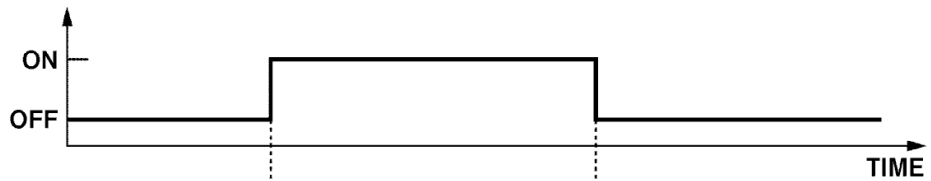


FIG.15B

FRAME RATE
CONTROL
SIGNAL

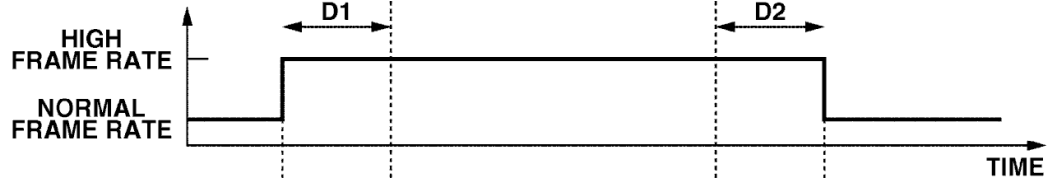


FIG.15C

CAPTURED
FRAMES

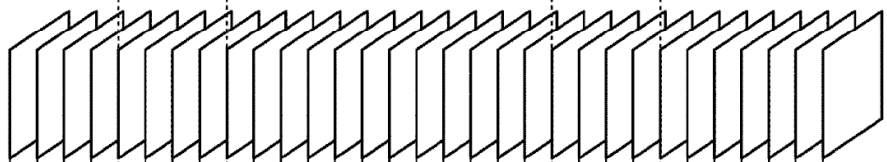
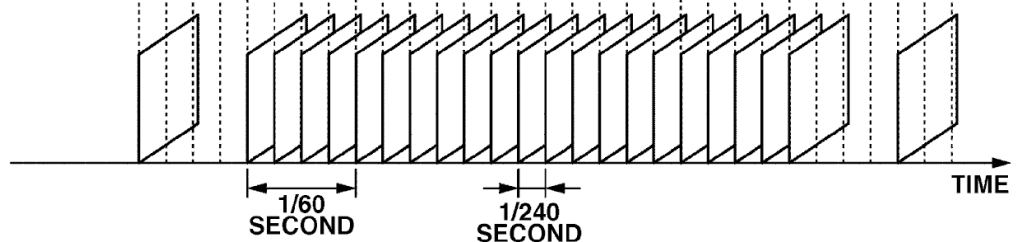


FIG.15D

RECORDED
FRAMES



(Suzuki, Figs. 15A-D.) Figures 15A-D show overlapping timing diagrams in which “the horizontal axis represents time.” (Suzuki, 13:2.) Figure 15A shows a period of time during which a zoom operation takes place during recording. (Suzuki, 13:3-4.) Figure 15B shows that, during zoom operation, the imaging apparatus operates at a high frame rate. (Suzuki, 13:4-8, 13:13-19.) Figure 15B also shows the ability to operate at a high frame rate for a period before (D1) and after (D2) the zoom operation, in this case, “at a high rate of 1/240-second intervals.” (Suzuki, 13:13-18.) “The lengths of periods D1 and D2 may be different from each other.” (Suzuki, 13:18-19.) As shown in Figure 15D, the end result recording at a frame rate of

240fps for the period during and after (D2) the zoom period. Although not pertinent to our discussion here, the particular example in Figure 15D shows frames *captured* during period (D1) at a high frame rate, but when stored as *recorded* frames, they were “thinned” to a lower 1/60-second interval frame rate. (Suzuki, 13:29-32.)

76. My Declaration does not rely on Suzuki for its particular implementation but for a more broadly applicable teaching – the desirability of increasing frame rate when a video is showing objects that are closer. As almost anyone who had used a video camera (including a camera on a mobile phone) would have appreciated, a zoom operation is often performed to focus the image on a target object in the image – in a sense, to bring that object “closer” to the camera. Of course, a zoom operation does not physically bring an object in the image closer to the camera, but it does change the angle of view of the camera, magnifying the target object and making it appear closer to the viewer. Suzuki confirms the desirability of increasing the frame rate in this situation, such as when capturing close-up image information such as a person’s facial expressions:

Thus, according to the present exemplary embodiment, in addition to a Zoom operation period, video is recorded in the recording medium **48** at a high frame rate during certain periods before and after the zoom operation period. Generally, when a user carries out a zoom operation, video captured before and after a zoom-in operation or a zoom-out

operation includes a target object. Thus, the video includes important scenes that reflect the photographers intention, and examples of such scenes include goal scenes in sports games and close up facial expressions. By recording the video captured before and after a zoom operation at a high frame rate as described above, the video captured before and after the zoom operation can be displayed effectively.

(Suzuki, 13:52-64.) For example, therefore, Suzuki discloses that a frame rate for video can be increased after a “zoom-in” operation, such as after zooming-in on a user’s face, in order to capture important information such as “close up facial expressions.” (*Id.*) Suzuki thus suggests increasing frame rate when the images are capturing images that are closer to the camera. I will provide more detail about Suzuki in my discussion of **Ground 2** below.

B. Priority Date of the ’109 Patent

77. As noted in **Part II** above, the face of the ’109 patent states that it issued from an application filed on March 15, 2013, as a continuation-in-part to U.S. Patent Application No. 13/088,369 (issuing as U.S. Patent No. 8,624,883) (“’369 Application”) filed on April 17, 2011, which in turn claims priority as a continuation to an application filed on March 1, 2006, U.S. Patent Application No. 11/817,411 (issuing as U.S. Patent No. 7,948,481) (“’411 Application”). I understand that in the pending litigation, the Patent Owner has not asserted that the claims of the ’109 patent are entitled to the priority date of the ’369 or the ’411 Applications, and thus

Declaration of Chandrajit Bajaj, Ph.D., in Support of
Petition for *Inter Partes* Review of
U.S. Patent No. 8,982,109 B2

has not claimed a priority date earlier than December 18, 2012 (the filing date of provisional application No. 61/738,957). I have nevertheless been asked to independently analyze the '369 Application (which I understand is substantially identical to the '411 Application) to determine whether Patent Owner would have any basis to argue that these applications support an earlier priority date for the '109 patent. As I will explain below, these applications provide no such support.

78. I understand and am informed by counsel that under the patent laws, for the '109 patent to be entitled to the benefit of an earlier-filed patent application, the challenged claims must be supported by disclosure in the earlier application, *i.e.*, the earlier application must disclose the subject matter of the claims and enable a person of ordinary skill in the art to make and use the claims. The '369 Application (Ex. 1009) clearly does not satisfy this test as numerous limitations of the challenged claims are not disclosed, or even suggested, in the earlier applications. Looking at claim 1 (the sole independent claim in the '109 patent), the '369 Application does not disclose, for example, **“flipping the image about a vertical axis so as to reverse right and left sides of the image”** (limitation 1[a]), **“applying a transformation mapping to the image to modify the image such that it appears to mimic a reflection of a mirror”** (limitation 1[b]), or **“resizing the image to reduce variations caused by changes in object’s distance to the camera”** (limitation

1[c]). Nor does the '369 Application disclose the subsequent steps of claim 1 (limitations 1[d]-[h]), which by their terms build upon and thus depend from limitations 1[b]-1[d]. And because every other claim in the '109 patent depends from claim 1, those claims likewise are not supported by the '369 Application.

79. I have attached as Exhibit **1011** a redline comparison showing the differences between the application that resulted in the '109 patent and the earlier '369 Application. As shown, a massive amount of new material was added when the applicants filed the CIP application for the '109 patent on March 15, 2013, that was not present in the '369 Application. This new material provides the only potential support for the above-mentioned claim limitations, which are not mentioned at all (let alone adequately described) in the '369 Application. (Ex. 1011 at 002-003, 0027-0061.) In my opinion and as shown in Exhibit 1011, the inventors were not in possession of the subject matter of the challenged claims listed as of the filing of the '369 Application on April 17, 2011, and thus, were also not in possession of the claimed subject matter when they filed the '411 Application on March 1, 2006.

C. Ground 1: Claims 1, 2, 6, 8, 9 and 17 Are Obvious Over Rosenberg in View of Francois, Vidunas, Dunton and Yong

1. Claim 1

80. For reference, claim 1 recites:

Declaration of Chandrajit Bajaj, Ph.D., in Support of
Petition for *Inter Partes* Review of
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1. A method for operating a system having a monitor, a camera, and a processor, so as to display a mirror-mimicking image on the monitor, by performing non-ordered steps comprising:
 - [a] obtaining a digital image from a camera;
 - [b] flipping the image about a vertical axis so as to reverse right and left sides of the image;
 - [c] applying a transformation mapping to the image to modify the image such that it appears to mimic a reflection of a mirror;
 - [d] resizing the image to reduce variations caused by changes in object's distance to the camera;
 - [e] displaying the image on the monitor after performing the flipping, transformation mapping, and resizing;
 - [f] wherein the non-ordered steps are performed on a series of images of a live video feed from the camera;
 - [g] determining distance to a user appearing in the live video feed; and,
 - [h] varying rate at which the non-ordered steps are performed on the series of images according to the distance.

(’109, 30:52-67 (Claim 1; bracketed notations (e.g., [a]) added).)

81. The preamble of claim 1 recites “[a] **method for operating a system having a monitor, a camera, and a processor, so as to display a mirror-**

mimicking image on the monitor, by performing non-ordered steps comprising.” Although I understand that the preamble of a claim generally does not limit the claim, I am informed that the parties have agreed that the preamble of claim 1 is limiting. (Ex. 1012 at 002.) If the preamble provides a claim limitation here, it is disclosed by the prior art.

82. Rosenberg discloses a “digital mirror system... adapted to provide real-time captured images that approximate what a user would see when viewing an ordinary mirror.” (Rosenberg, ¶0006; *see also id.*, ¶0025, claim 1.) The system includes **a monitor**, **a camera**, and **a processor**, as Rosenberg diagrams in Figure 13:

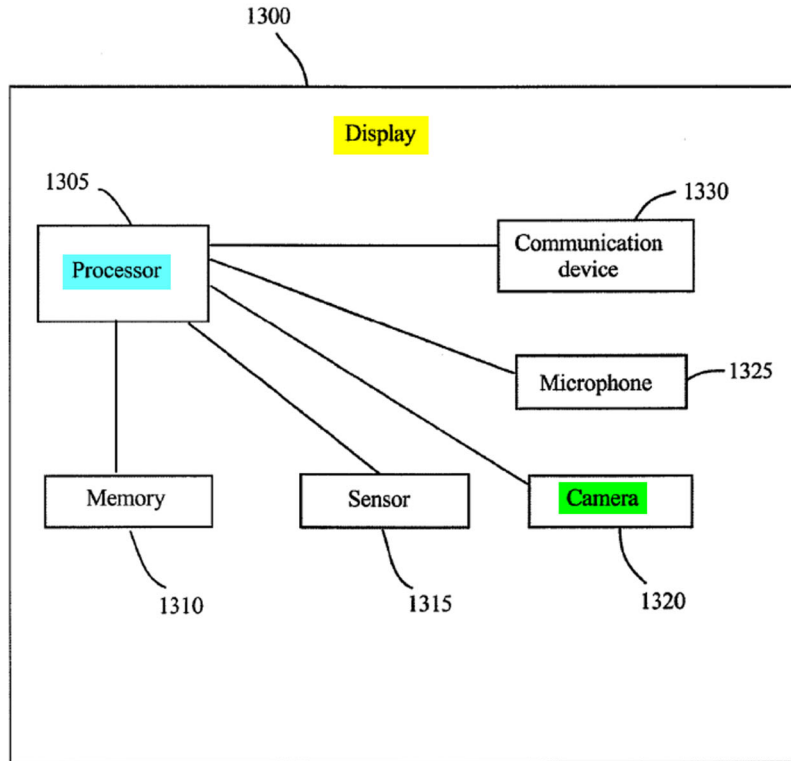


Fig. 13

(Rosenberg, Fig. 13; *see also id.*, ¶0109.) Figure 3 reproduced below depicts an embodiment of such a system showing camera 302 mounted above the screen area of display 301. (Rosenberg, ¶0062.)

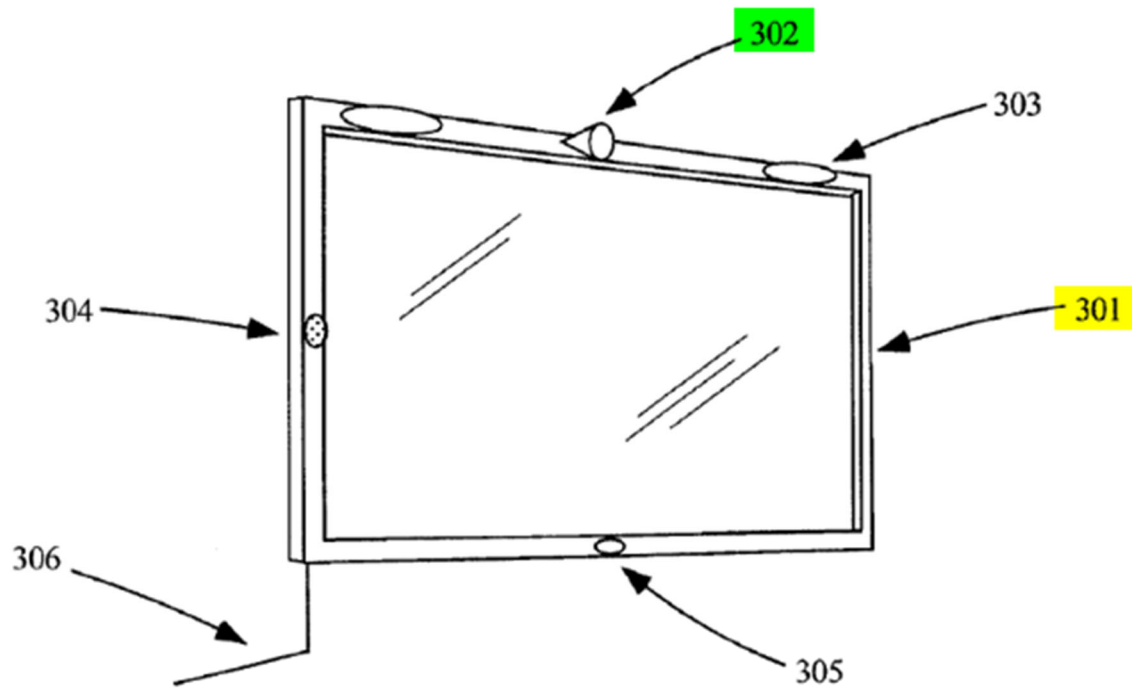


Fig. 3

(Rosenberg, Fig. 3.) A processor controls the camera to capture images and processes them so that when displayed a user sees what they would have seen if standing before a traditional optical mirror, as illustrated in Figure 5:

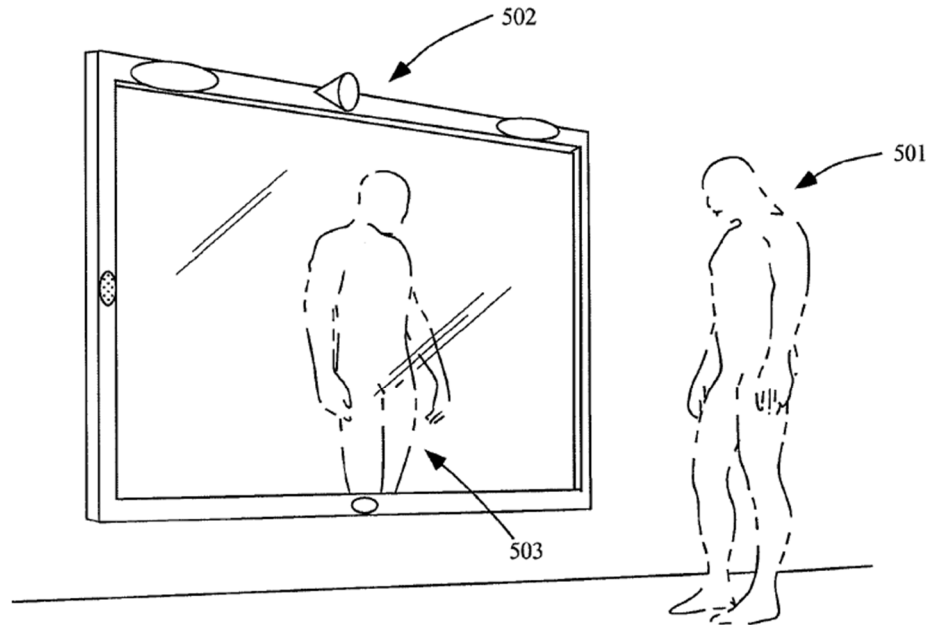


Fig. 5

(Rosenberg, Fig. 5; *see also id.*, ¶¶0006 (“A processor controls the camera to capture the at least one image”), 0026 (describing “traditional mirror mode” where a stream of captured images are left-right inverted “to present the user with a traditional mirror image of himself or herself”), 0035 (describing “left-right image inversion processor” and explaining that same processor unit can perform the various described processing functions), 0074 (“mirroring routines running upon the processor”)., claim 1.) Rosenberg therefore discloses **“a system having a monitor, a camera, and a processor,”** as claimed.

83. Rosenberg also discloses a method of operating its system, **“so as to display a mirror-mimicking image on the monitor,”** as recited in the preamble.

Referring to Figure 5 shown above, Rosenberg explains that the system captures real-time video images, scales them to “appear[] like a traditional life-size mirror image[s],” and inverts them left-right before displaying them on the screen:

FIG. 5 illustrates a computer rendering of a human user **501** standing in front of a wall-mounted embodiment of the advanced digital mirror system **502** according to at least one embodiment of the present invention. The user’s image is captured as a real-time video image by a camera upon or within the digital mirror **502** as described previously. A representation of that real-time video image is then displayed upon the wall mounted screen of the digital mirror **502** with a displayed size and scaling such that it appears like a traditional life-size mirror image **503**. In a traditional mirror emulation mode, the real-time video image is left-right inverted prior to display upon the screen. Thus the user **501** standing before the digital display is given the visual impression that he or she is standing before a traditional wall mirror, viewing a traditional mirror image of himself or herself.

(Rosenberg, ¶0077.) I understand that the parties in the pending litigation agreed that the term “**mirror-mimicking image**” refers to an image that “*mimics the image that would have been reflected from a mirror, i.e., from a reflective surface.*” Rosenberg clearly discloses a “mirror-mimicking image” because the displayed image, as noted, provides “the visual impression that [the user] is standing before a traditional wall mirror, viewing a traditional mirror image of [the user]” (Rosenberg,

¶0077). A person of ordinary skill in the art would have understood Rosenberg's reference to a "traditional wall mirror" to refer to a conventional mirror with a reflective surface. (Rosenberg, *e.g.*, ¶0003 ("At its core, a typical household mirror is operative to reflect an image of a user, enabling that user to view himself or herself when standing before it.").) Rosenberg therefore discloses a displayed image that mimics the image that would have been reflected from a reflective surface mirror. Rosenberg therefore discloses a method for operating a system having a monitor, a camera, and a processor, "**so as to display a mirror-mimicking image on the monitor,**" as recited.

84. Although Rosenberg alone sufficiently discloses the preamble, I have also cited to Francois in my discussion of the limitations below to provide technical details about how to display a mirror-mimicking image. As shown below in the discussion of limitation 1[c], which further recites applying a transformation mapping to the image to modify the image such that it "**appears to mimic a reflection of a mirror,**" the display of a "**mirror-mimicking image**" would also have been obvious over Rosenberg in view of Francois. In any case, as explained below, the claimed method is disclosed by and rendered obvious by Rosenberg in view of Francois, Vidunas, Dunton and Yong.

(a) “obtaining a digital image from a camera;” (Claim 1[a])

85. Rosenberg discloses this limitation. Rosenberg explains that its digital mirror system obtains a digital image from a camera:

[T]he digital mirroring modes and functions and features [are] operative to display images upon the screen that are based upon image data collected in real-time from a camera aimed at the person or persons standing before the screen at that real time and thereby replicating the function of a real mirror.

(Rosenberg, ¶0055; *see also id.*, ¶¶0006 (“[A] digital mirror system is provided that has a digital mirror display to display at least one image. A camera captures the at least one image.”).) Rosenberg further discloses obtaining a digital image by capturing real-time digital video. (Rosenberg, ¶¶ 0038 (“When in one of these real-time mirroring modes, the hardware and software rapidly update the image upon the display screen with a representation of the real-time digital video imagery collected from the camera.”), 0007-0008, 0057, 0061, 0077, claim 1 (“the digital camera captures real-time video imagery of a user... the processor is operative to cause a representation of the real-time video imagery captured by the digital camera to be displayed upon the digital mirror display screen”).)

(b) “flipping the image about a vertical axis so as to reverse right and left sides of the image;” (Claim 1[b])

86. Rosenberg discloses this limitation. Rosenberg explains that as part of

mimicking a conventional mirror, the system processes the captured digital image and inverts it left-to-right along its vertical axis, thereby reversing the right and left sides of the image:

[E]mbodiments of the present invention provide a wall-mounted flat panel display and one or more digital camera(s) configured to provide real-time images of a user who stands before the display. In a traditional mirror mode of an embodiment of the present invention, the real-time images are streamed video images captured by a camera mounted upon the display, the real-time streamed video images being a left-right inverted representation of the video signal captured by the camera. This left-right inverted representation is generally produced by flipping the pixels of the image around the vertical centerline such that right side of the user, from the user's perspective, appears upon the right side of the display, and the left side of the user, from the user's perspective, appears upon the left side of the display. The left-right inversion process is generally performed by a processing electronics at a high rate of speed so that the left-right inverted video image of the user is presented substantially in real-time to the user (i.e., there is not a noticeable time lag for the user). This left-right inversion process is performed to present the user with a traditional mirror image view of himself or herself, inverted in a similar way as would be seen in a traditional optical mirror.

(Rosenberg, ¶0026; *see also id.*, ¶¶0035 (“The processor is also operative to function in coordination with the left-right image inversion processor described previously

that inverts the real-time video image from the camera into a real-time mirror image representation.”), 0077 (“In a traditional mirror emulation mode, the real-time video image is left-right inverted prior to display upon the screen.”), 0083 (“In a common embodiment, the basic mode of operation is the traditional mirror emulation mode in which a left-right inverted representation of the camera imagery is streamed substantially in real-time to the mirror display screen.”).) A person of ordinary skill in the art would have understood Rosenberg’s disclosure of “flipping the pixels of the image around the vertical centerline” (Rosenberg, ¶0026), to disclose “**flipping the image about a vertical axis**,” because the vertical centerline in Rosenberg refers to a vertical axis. The passages above from Rosenberg also disclose flipping in Rosenberg “**reverse[s] right and left sides of the image**,” as claimed. This is because the flipping, as Rosenberg explains, causes the “right side of the user, from the user's perspective, [to] appear[] upon the right side of the display, and the left side of the user, from the user's perspective, [to] appear[] upon the left side of the display.” (Rosenberg, ¶0026.) This is the **reverse** of what someone would see in a non-flipped digital image of themselves (*i.e.*, the right side of the image shows the left side of the user, and vice versa). Rosenberg therefore discloses flipping the image about a vertical axis “**so as to reverse right and left sides of the image.**”

(c) “applying a transformation mapping to the image to modify the image such that it appears to mimic a reflection of a mirror;” (Claim 1[c])

87. As explained below, this limitation would have been obvious over Rosenberg in view of Francois.

88. As noted, Rosenberg describes techniques to give a person standing before a digital display “the visual impression that he or she is standing before a traditional wall mirror, viewing a traditional mirror image of himself or herself.” (Rosenberg, ¶0077; *see also, e.g., id.*, ¶0006 (“to provide real-time captured images that approximate what a user would see when viewing an ordinary mirror”).) The techniques include both flipping captured images left-right and scaling them such that they “appear[] like a traditional life-size mirror image.” (Rosenberg, ¶0077.) But Rosenberg does not provide details about how its system transforms images to mimic a mirror reflection. I have therefore relied on Rosenberg in further view of **Francois**, to show that limitation 1[c] would have been obvious.

89. Francois discloses a computer-based display system similar to Rosenberg to simulate the appearance one would see when looking into a conventional mirror, but Francois provides more details about how the images are digitally transformed to create this simulated appearance. More specifically, Francois describes the “design and construction of a handheld mirror simulation

device.” (Francois at 021, Abstract.) Figure 1 of Francois, reproduced below, illustrates its mirror simulation system:

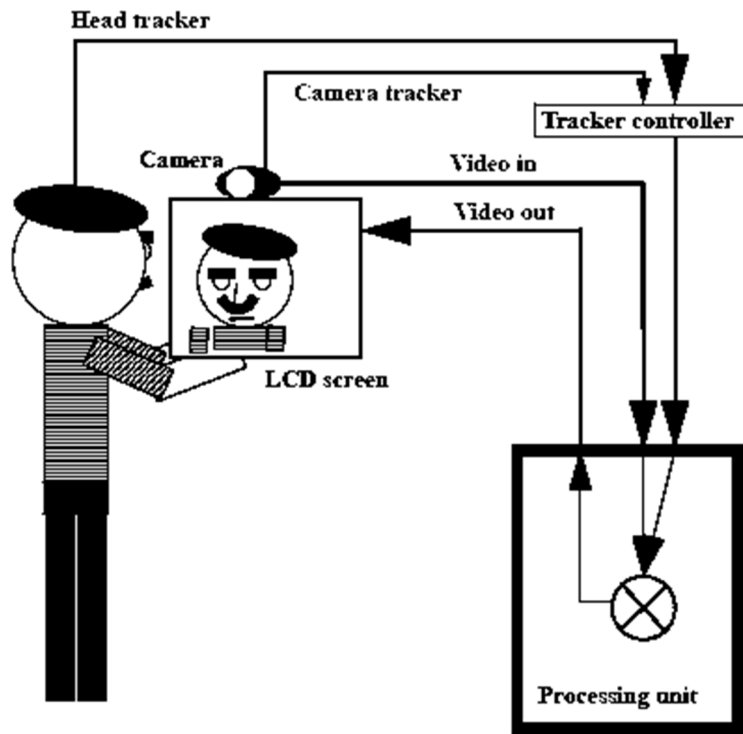


Figure 1. Handheld mirror simulation system.

(Francois, Fig. 1, at 021.) As shown above, the system includes an LCD screen and camera. Real-time video from the camera is fed into a processing unit, which outputs processed video to the LCD screen. (Francois at 023, Section “3. System Integration”.) The system as shown above also includes a “Head tracker” and “Camera tracker,” which provide real-time positional data needed to transform the video images from the perspective of the camera to the user’s perspective. (Francois at 023, Section “3. System Integration”; *see also id.* at 021, Section “1. Introduction”)

(“The continuous input video stream and tracker data is used to synthesize, in real-time, a continuous video stream displayed on the LCD screen.”.) The output video, according to Francois, “is a close approximation of what the user would see on the screen surface if it were a real mirror.” (Francois at 021, Section “1. Introduction”; *see also id.* at 023, Section “3. System Integration” (“The result is a convincing handheld mirror simulation”).) Figure 6 of Francois summarizes the series of steps carried out to perform the real-time mirror mimicking functionality (Francois, Fig. 6, at 023.):

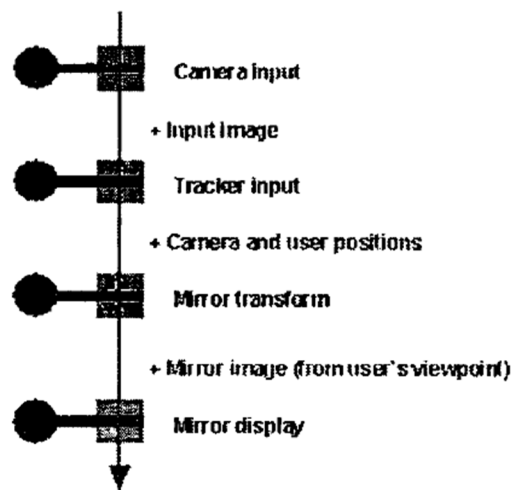


Figure 6. Mirror simulation application graph.

90. Notably, in describing what its system does to mimic a mirror, Francois makes many of the same observations as the '109 patent. For example, like the '109 patent, which contends that simply flipping an image left-right is insufficient to create a mirror experience, Francois similarly seeks to “provide a better experience

to the user than the traditional fixed camera / fixed display / horizontal image flip mirror setting.” (’109, 15:59-61; Francois at 021, Section “1. Introduction”.) And like the ’109 patent’s observations regarding field of view and perspective, Francois also similarly recognizes that “[o]ne important clue is the evolution of the user’s field of view in the mirror as her position with respect to the mirror changes.” (*E.g.*, ’109, 2:10-27; Francois at 021, Section “1. Introduction”.) As explained below, like the ’109 patent, Francois addresses these field of view and perspective issues by **applying a transformation mapping to the image(s)** obtained from the system’s camera.

91. Francois discloses transformations that would plainly satisfy the claimed “**transformation mapping**.” Francois describes a “geometric analysis of mirror and camera imaging, leading to the image transform for mirror simulation” (Francois, 021, Introduction.) More specifically, Francois describes how to derive a set of “transformation equations that relate the user’s view to the camera image.” (Francois at 023, Section “2.3 User view synthesis”; *see also id.*, 021-023, Section “2. Geometric Analysis”). As explained below, Francois does this by first describing the user’s view, then a camera’s view, and then describing a transformation of the image relating the two. This transformation, as described in more detail below, transforms the image captured by the camera to more closely

approximate the image that would be seen from the user's perspective as though the user were looking at the reflective surface of a conventional mirror.

92. A first step of the transformation mapping in Francois is to determine what the user would see from its perspective. Francois explains that “[w]hen a person looks into a planar mirror, they see what they would see from the symmetrical (virtual) point of view,” as depicted in Figure 2:

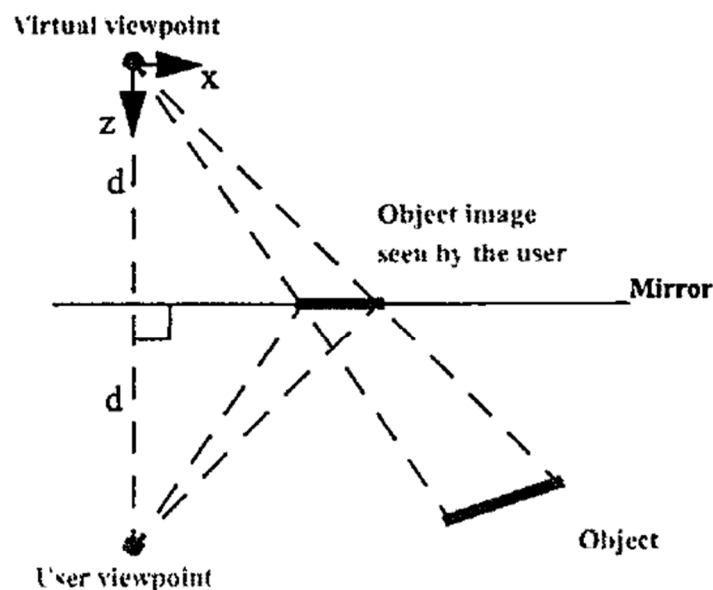


Figure 2. Mirror geometry.

(Francois at 021-022, Section “2.1 Mirror geometry”.) Francois explains that “the image perceived by the viewer on the mirror surface is a perspective projection on the mirror plane with respect to the virtual viewpoint.” (Francois at 021-022, Section “2.1 Mirror geometry”.) The image formed by the mirror can be described by the following equations, where d is the user's (and virtual viewpoint's) distance from

the mirror:

$$\begin{bmatrix} U_p \\ V_p \\ W_p \end{bmatrix} = \begin{bmatrix} 1 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 \\ 0 & 0 & 1/d & 0 \end{bmatrix} \begin{bmatrix} x \\ y \\ z \\ 1 \end{bmatrix} \quad \begin{aligned} x_p &= U_p / W_p = dx/z \\ y_p &= V_p / W_p = dy/z \end{aligned}$$

(Francois at 022, Section “2.1 Mirror geometry”.) These equations, which map an object’s real-world coordinates (x, y, z) to the mirror plane coordinates (x_p, y_p) using a projection matrix would have been familiar to any undergraduate student taking an introductory course in 3-D computer graphics or computer vision. The equations describe where a point in the 3-D real-world space will be located on the 2-D space of the mirror plane (in essence transforming a 3-D scene into a 2-D image seen from the viewpoint’s perspective).

93. It is useful to note that Francois’ derivation above is with the user’s real and virtual viewpoint coordinates expressed in the same world coordinate system (X,Y,Z) as the object’s coordinates (x,y,z). Hence objects which are attached to a user’s view point (as a person viewing his reflection in a mirror) are mapped to the mirror plane in the same fashion and with the same transformation. (*See also* Francois, Fig. 6 (showing that the user (object) positions are transformed to the mirror image (from user’s viewpoint).)

94. Whereas the first step was to determine the viewpoint of the user, the

second step is to determine the viewpoint of the camera capturing the image. Francois explains that “[a] camera whose position and orientation are fixed with respect to the mirror produces a video stream that corresponds to this particular viewpoint.” (Francois at 022, Section “2.2 Pinhole camera geometry”.) Francois diagrams the camera’s view in Figure 3:

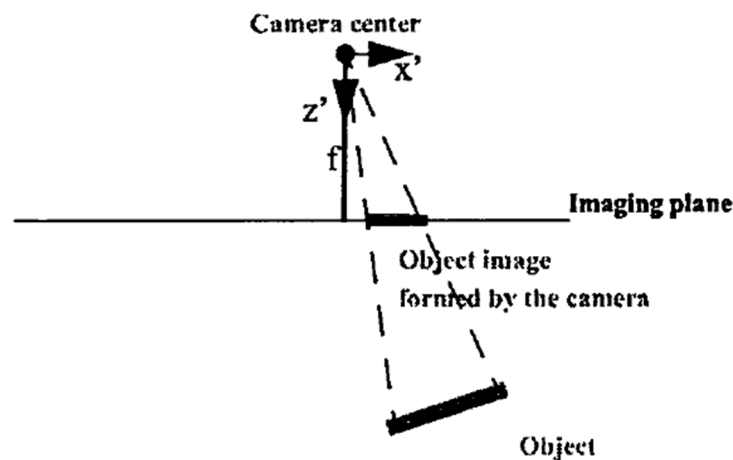


Figure 3. Pinhole camera geometry.

(Francois at 022, Section “2.2 Pinhole camera geometry”.) As shown in the figure above, the camera center (i.e., the lens) is distance f —the lens’s focal length—from the imaging plane where the image of the object is formed.³ The equations to map

³ As one may know from personal experience, in reality an imaging plane is distance f behind the camera lens. As a convention in 3-D graphics, the imaging plane is placed distance f in front of the camera lens. This convention slightly simplifies the math involved, but does not otherwise change the analysis.

the camera's view to the real world are similar to the equations relating a user's view to the real world, except that they use the camera's focal length f instead of the user's distance d —in essence simply replacing the mirror plane with the camera's imaging plane:

$$\begin{bmatrix} U_p \\ V_p \\ W_p \end{bmatrix} = \begin{bmatrix} 1 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 \\ 0 & 0 & 1/f & 0 \end{bmatrix} \begin{bmatrix} x' \\ y' \\ z' \\ 1 \end{bmatrix} \quad \begin{aligned} x'_p &= U_p / W_p = fx' / z' \\ y'_p &= V_p / W_p = fy' / z' \end{aligned}$$

(Francois at 022, Section “2.2 Pinhole camera geometry”).)

95. Francois then describes a 4x4 matrix translation transformation that allows placing the camera so that the image plane and mirror planes coincide. Here t_x , t_y , and t_z are translations in the x, y, and z dimensions, respectively, that relate (x, y, z) to (x', y', z')

$$\begin{bmatrix} x \\ y \\ z \\ 1 \end{bmatrix} = \begin{bmatrix} 1 & 0 & 0 & t_x \\ 0 & 1 & 0 & t_y \\ 0 & 0 & 1 & t_z \\ 0 & 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} x' \\ y' \\ z' \\ 1 \end{bmatrix}$$

(Francois at 022, Section “2.3 User view synthesis”).)

96. Francois then turns to describing the key step in providing a convincing

mirror simulation—how to “synthesize the images corresponding to the user’s viewpoint from the image captured by the camera.” (Francois at 022, Section “2.3 User view synthesis”.) Francois explains that, to do so, “we must relate them geometrically,” which yields the following matrix projection equations using basic matrix algebra:

$$\begin{bmatrix} U_p \\ V_p \\ W_p \end{bmatrix} = \begin{bmatrix} 1 & 0 & 0 & t_x \\ 0 & 1 & 0 & t_y \\ 0 & 0 & 1/d & t_z/d \end{bmatrix} \begin{bmatrix} x' \\ y' \\ z' \\ 1 \end{bmatrix} \quad \begin{aligned} x_p &= d(x' + t_x)/(z' + t_z) \\ y_p &= d(y' + t_y)/(z' + t_z) \end{aligned}$$

(*Id.*) Francois then states that because “we are designing our mirror as a first person interaction tool, we assume that the center of interest is the user itself and that the background is of lesser importance. We thus model the world as a plane parallel to the mirror/imaging plane, at the same distance as the user’s viewpoint (see Figure 5)”. The z' component can then simply be fixed to $z' = f + d$. (Francois at 023, Section “2.3 User view synthesis”.) Putting everything together, Francois explains that “[t]he transformation equations that relate the user’s view to the camera image are thus”:

$$\begin{aligned} x_p &= d((f + d)x'_p/f + t_x)/((f + d) + t_z) \\ y_p &= d((f + d)y'_p/f + t_y)/((f + d) + t_z) \end{aligned}$$

(Francois at 023, Section “2.3 User view synthesis”.) Francois explains that the only

parameters in the equations above are: (1) the focal length (f), (2) the distance to the user (d), and (3) the translation parameters (t_x , t_y , t_z) used to align the camera image plane and mirror plane. (*Id.*) In general, as would be familiar to any undergraduate student taking an introductory course in 3-D computer graphics or computer vision, the image plane and mirror plane alignment would require relative translation and orientation transformation in the same 4x4 matrix as above. Francois also discloses that the focal length f can be obtained by known camera calibrations, while the position and orientations of the user's viewpoint and the camera center can be obtained simply by tracking devices (refer also to Francois's steps diagrammed in Fig 6). With Francois's technique, "[t]he major field-of-view variations occurring [sic] when varying the angle of view and distance to the mirror, are convincingly simulated." (*Id.*)

97. Francois therefore discloses **"applying a transformation mapping"**—Francois's "transformation equations," which map the camera's view to the user's view, in combination with left-right flipping—**"to the image to modify the image such that it appears to mimic a reflection of a mirror."** This is shown in the **"Mirror transform"** step in Figure 6 of Francois:

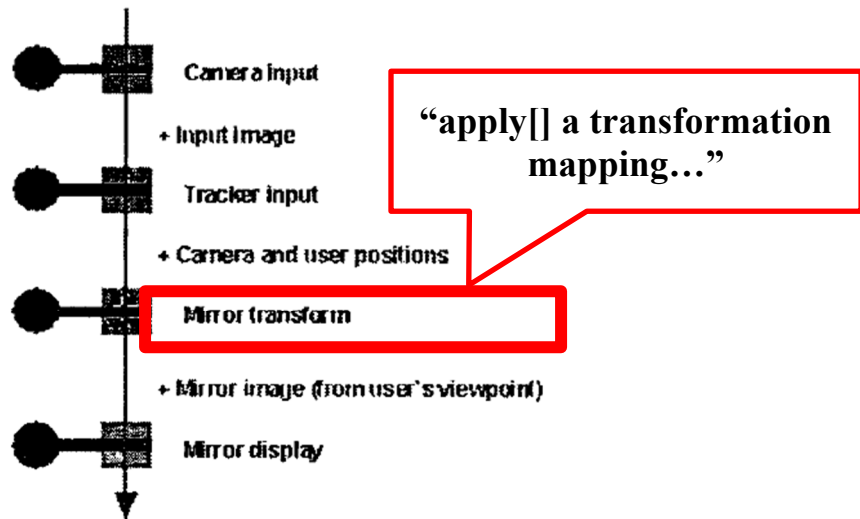


Figure 6. Mirror simulation application graph.

(Francois, Fig. 6, at 023.) Francois clearly discloses that its transformation mapping modifies the captured video images such that the images “**appear to mimic a reflection of a mirror.**” I understand that in the pending litigation, the parties have agreed that this phrase requires that the images appear to “*mimic the image that would have reflected from a mirror, i.e., from a reflective surface.*” Francois confirms that the purpose of its transformation mappings is “to simulate a real mirror on a computer screen.” (Francois, 021, Introduction).

98. That Francois discloses the claimed transformation mapping is further confirmed by the specification of the '109 patent. In describing the claimed transformation mapping, the '109 patent explains that “[p]erforming an adaptive POV [point of view] and adaptive FOV [field of view] prior to displaying the image on the screen results in an image that mimics a reflection of a mirror positioned at

the location of the screen.” (’109, 15:59-16:5; *see also id.*, 2:4-48).) This is substantially similar to the technique in Francois of transforming the image by synthesizing the user’s point of view with the field of view associated with the mirror. (Francois, 023 (right column) (“The major field-of-view variations occurring when varying the angle of view and distance to the mirror, are convincingly simulated.”).)

99. **Rationale and Motivation to Combine (Rosenberg and Francois)**. It would have been obvious to a person of ordinary skill in the art to combine Rosenberg with Francois’s teachings regarding camera-to-user viewpoint image transformations. The combination would have predictably resulted in the digital mirror system of Rosenberg in which video images captured by the camera and left-right inverted were further processed using Francois’s transformation equations, thereby producing images that “convincingly simulated” “the major field-of-view variations occurring [sic] when varying the angle of view and the distance to the mirror.” (Francois at 023, Section “2.3 User view synthesis”.) The combination therefore would have resulted in **“applying a transformation mapping to the image to modify the image such that it appears to mimic a reflection of a mirror,”** as claimed. In fact, as noted, Francois explains that “the transform relating the user’s view to the camera view is reduced to a scaling and a translation” (*id.*)—

two types of image manipulation that the '109 patent expressly identifies as examples of the claimed transformation mapping. ('109, 29:30-40.) As I will show below, a person of ordinary skill in the art would have been amply motivated to combine Rosenberg and Francois in this manner to provide this functionality.

100. Rosenberg and Francois are analogous references to the '109 patent. As noted, the '109 patent states that it relates “to making a flat panel display appear as a mirror.” ('109, 1:29-31.) Both Rosenberg and Francois similarly describe techniques for adapting a flat panel display to display images that mimic the behavior of a conventional mirror. (E.g., Rosenberg, ¶¶0006, 0077, Figs. 3 & 5; Francois at 021, Abstract.) Both references thus fall within the same field as the '109 patent. Both Rosenberg and Francois are also reasonably pertinent to the problem faced by the inventor of how to implement a display that displays images that mimic a reflection in a mirror. These references are also reasonably pertinent to a number of implementation problems, such how to digitally transform camera-captured images to provide such a mirror-mimicking appearance.

101. A person of ordinary skill in the art would have had ample motivation to combine. With respect to Rosenberg, as noted, it states that a captured video image is scaled “such that it appears like a traditional life-size mirror image.” (Rosenberg, ¶0077.) But Rosenberg does not appear to include detailed teachings

on how to perform the transformations needed to make a digital image “appear[] like a traditional life-size mirror image.” (*Id.*) A person of ordinary skill in the art, therefore, would have naturally turned to an analogous reference such as Francois, which picks up where Rosenberg leaves off by disclosing specific equations and techniques for translating and scaling images captured by a camera so that they appear like a conventional mirror image when displayed.

102. Francois also provides multiple express motivations to combine. Francois explains that simply flipping an image left-right over its vertical axis, without performing further transformations, provides a less convincing mirror display experience. (Francois at 021, Section “1. Introduction”.) After discussing his translation and scaling equations, Francois explains:

Note that under our assumptions, the transform relating the user’s view to the camera view is reduced to a scaling and a translation. This model provides a straightforward and efficient way of synthesizing the viewer’s image stream from the camera stream, while remaining a reasonable approximation for a large class of applications. The major field-of-view variations occurring [sic] when varying the angle of view and the distance to the mirror, are convincingly simulated.

(Francois, at 023, Section “2.3 User view synthesis.”.) The above passage provides multiple express motivations to combine, explaining that the disclosed transformation techniques provide “a straightforward and efficient technique,”

applicable to “a large class of applications,” and capable of “convincingly simulat[ing]” the field of view (FOV) variations that one would see when viewing a conventional mirror. A person of ordinary skill in the art would thus have been motivated to adapt Rosenberg to implement the transformation techniques in Francois to achieve these benefits. A person of ordinary skill in the art, in other words, would have readily appreciated the benefits and advantages of incorporating Francois’s teachings and techniques into Rosenberg’s system, and would have been motivated to do so to provide a more convincing mirror-like display of digital images. Images produced under the proposed combination would thus have enjoyed the benefits of images flipped along vertical axis as disclosed in Rosenberg (which is one aspect of providing a convincing mirror experience), as well as the more sophisticated mirror transformations in Francois as described above, resulting in a mirror simulation superior to one provided under Rosenberg alone.⁴

⁴ Nor would a person of ordinary skill in the art have perceived any technological incompatibility in applying, to images obtained from a digital camera, both the Francois transformations described in the text, and vertical axis flipping as disclosed in Rosenberg. The image transformation equations from Francois do not flip the image along a vertical axis, but like Rosenberg, Francois contemplates flipping (or

103. I further note that nothing in Rosenberg or Francois would have discouraged the combination. To start, both references describe techniques for providing a simulated mirror using a “real-time” video stream. While some embodiments described in Rosenberg depict a wall-mounted display whereas Francois describes a smaller, handheld display, nothing in Rosenberg (or the ’109 patent claims) imposes restrictions on the size of the display. Rosenberg, in fact,

mirroring) a transformed image prior to display in order to create a convincing mirror simulation. (See Francois, Fig. 6, 023 (disclosing step of “**Mirror image (from user’s viewpoint)**” after “**Mirror transform**” and before “**Mirror display**”).)

Francois thus discloses image transformations that would have seamlessly operated alongside conventional image flipping mirror techniques. This is further confirmed in Rosenberg which, as I noted earlier, discloses “scaling” an image in addition to flipping in order to provide an image that “appears like a traditional life-size mirror image.” (Rosenberg, ¶0077.) Rosenberg thus reinforces that image transformations such as scaling (which is performed by the Francois equations) could readily have been combined with, and operated alongside, the vertical flipping in Rosenberg. In a real-world application of the proposed combination, the image mirroring step in Francois would not be necessary as Rosenberg already provides that functionality.

notes how its system may use a smaller display. (Rosenberg, ¶0050 (“Zooming out is particularly useful if a user wants to see a full length image of himself or herself on a mirror screen that is not naturally full-length.”).) Moreover, Rosenberg incorporates by reference U.S. Patent No. 6,811,492 B1 to Minoru Arakawa (“Arakawa”) [Ex. 1027]. (Rosenberg, ¶0005.) Arakawa describes improvements to the well-known Nintendo Game Boy handheld gaming device to enable “videophone” and “self-portrait” functionality using a digital camera coupled to the device. (*E.g.*, Arakawa, 1:28-29, 1:36-53, 4:56-5:5, 5:50-6:5, 11:4-37, Figs. 1A, 10-12.) Rosenberg, in turn, identifies Arakawa’s “self-portrait” mode as in need of improvement. (Rosenberg, ¶0005 (“Although such technology does allow for self-viewing, there is a substantial need for a significantly more versatile digital mirror system with a variety of unique and useful digital mirroring features and functions.”).) Rosenberg’s recognition that its techniques would improve “self-portrait” functionality in small-screen devices further shows that Rosenberg’s techniques are not limited to larger, wall-mounted systems. And Francois, for its part, notes that it was applying its techniques to “a large (simulated) mirror on a wall,” thus further confirming that a person of ordinary skill in the art would have found Francois and Rosenberg fully combinable, and would have been motivated to apply Francois’s teachings to a larger display as shown in Rosenberg’s exemplary

embodiments. (Francois at 023, Section “4 Related Work and Applications”.) More fundamentally, because the transformations described in Francois do not depend on the form factor or size of the display, a person of ordinary skill in the art would have appreciated that the transformations would have been applicable to larger or wall-mounted display devices.

104. A person of ordinary skill in the art would have had a reasonable expectation that the above-described combination would have been successful. The combination would have entailed the use of existing hardware and software technologies and techniques, as confirmed by the fact that Francois describes an actual, working simulated mirror prototype. And as I explained extensively above, the transformations described in Francois would have been straightforward to any undergraduate student taking an introductory course in 3-D computer graphics or computer vision. The disclosures in Rosenberg and Francois thus provide more than sufficient detail to implement their teachings in the manner described above.

(d) “resizing the image to reduce variations caused by changes in object’s distance to the camera;” (Claim 1[d])

105. Limitation 1[d] recites “**resizing the image**” separately from the step of “**applying a transformation mapping to the image**” in limitation 1[c], but the ’109 patent contemplates that the claimed resizing can occur as part of the claimed transformation mapping. (*See, e.g.*, ’109, 29:38-40 (“The transformation mapping

can be one that includes angle, tilt, azimuth, scale, spatial translation (i.e., elevation linear offset or horizontal offset) etc.”), 17:18-27.) This is confirmed by dependent claim 6, which depends from claim 1 and is addressed below, which recites that “**the step of resizing the image is performed integral to the step of applying the transformation mapping.**” This is precisely what Francois discloses.

106. As explained above for limitation 1[c], Francois describes a transformation to the image, based on an object’s distance (d), **to modify the image such that it appears to mimic a reflection of a mirror.** As I further explain below, the transformation mapping described in Francois also results in “**resizing the image to reduce variations caused by changes in object’s distance to the camera,**” with “object” corresponding (for example) to the person/viewer who is looking at the mirror/display. As explained below, the transformations in Francois result in an image being scaled up (resized) when the distance of the user to the display (d) increases. A person of ordinary skill would have understood that this step would take place in order to “convincingly simulate[]” “the major field-of-view variations occurring [sic] when varying the angle of view and the distance to the mirror,” as Francois teaches. (Francois at 023, Section “2.3 User view synthesis”.)

107. By way of background, anyone who has looked at themselves in a mirror while walking closer to the mirror may have noticed a well-known phenomenon –

the person as shown in the mirror remains approximately the same size regardless of the distance to the mirror. The reason is straightforward and well-understood – when viewing an object in the real world (*i.e.* not in a mirror), differences in distance cause the object to appear correspondingly smaller (with increased distance) or larger (with decreased distance). But when looking at a reflective mirror, these viewable differences in size are significantly reduced by the fact that the angle of the person’s field of view (FOV) changes as their distance to the mirror changes. Accordingly, the purpose of the claimed step of “**resizing the image to reduce variations caused by changes in object’s distance to the camera,**” is to modify the image to simulate the consistent-size viewing phenomenon provided by traditional mirrors.

108. This is directly acknowledged in the “Background” section of the ’109 patent, which explains that “the angle of the user’s Field of View (FOV) changes when the user changes the distance, e.g., gets closer, to the mirror.” (’109, 2:10:12.) Figure of the ’109 patent illustrates this:

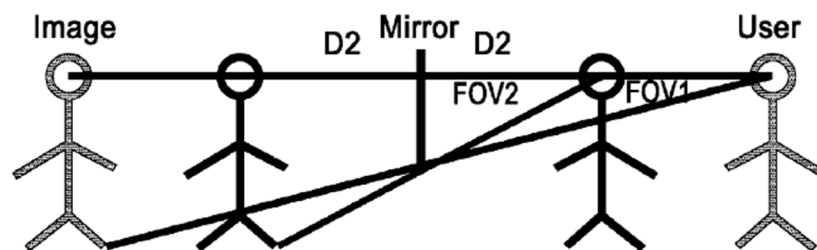


FIG. 5B

(’109, Fig. 5B, 2:19-23.) As the Background patent explains in reference to Figure

5B, “when the user approaches the mirror, the FOV angle increases, which is why he continues to see the same size reflection (FOV1<FOV2), so that the user actually sees himself roughly at the same size, but closer.” (’109, 2:19-23.) This phenomenon of showing an approximately consistent size, regardless of the distance of the object, is a well-known characteristic of conventional mirrors.

109. As the ’109 patent acknowledges, the mirror view “is a noticeable difference from a camera, wherein as the user gets closer to the camera, he appears larger in the image.” (’109, 2:23-27.) The ’109 patent explains that this difference is “mainly because the FOV of a camera is fixed,” whereas in a mirror, the person’s FOV changes as their distance the mirror changes. (’109, 2:23-27.)

110. The ’109 patent observes that, to address this difference, “[a]n adaptive FOV is required in order to compensate for the changes in the distances between the user and the screen, so that the user will see his image at the same size, just like in a mirror.” (’109, 14:29-33.) The ’109 patent explains that one way to accomplish adaptive FOV is to use the camera’s “zoom” feature, which can be either a “mechanical” or “digital” zoom. (’109, 14:33-39.) A “mechanical” zoom typically involves manipulating a camera’s optical components (*e.g.* lenses) to increase the size of an image before it is captured. A “digital” zoom, in contrast, refers to a software process that manipulates an image after it is captured – typically by

cropping or enlarging the image and then scaling the image to its original dimensions, thus resulting in a “zoomed in” image.⁵ Thus, claim 1[d] at least encompasses at least digitally zooming (*e.g.* enlarging) captured images based on distance so that they mimic the changing FOV associated with images from a conventional mirror. In other words, “zooming” of the image when the distance increases can offset or compensate for the fact that an object in the image becomes smaller as its distance from the camera increases.

111. As explained for limitation 1[c], the proposed combination of Rosenberg and Francois discloses that a captured image is scaled so, when displayed, it mimics how it would appear in a mirror. Francois, in particular, discloses equations for scaling images of a real-time video stream based on the measured distance to a user in front of the display, expressed as the distance d . (*E.g.*, Francois at 022 (Fig. 2) & 023, Section “2.3 User View Synthesis” (“The positions and orientations of the user’s viewpoint and the camera center provided by the tracking devices, allow to compute both the distance d and the change of referential translation parameters.”).) Francois explains that, with equations and for the model of the environment, “the transform relating the user’s view to the camera view is

⁵ (*See, e.g.*, Ex. 1014 at 004 (describing optical and digital zoom).)

reduced to a scaling and a translation.” (Francois at 023, Section “2.3 User view synthesis”.) The scaling in Francois discloses the claimed “**resizing**.” Reviewing Francois’s transformation equations that map the user’s view to the camera image (Francois, 023),

$$x_p = d((f + d)x'_p / f + t_x) / ((f + d) + t_z)$$
$$y_p = d((f + d)y'_p / f + t_y) / ((f + d) + t_z)$$

one can see that the equations use the user’s distance (d) as a multiplicative factor for both the x and y values, thus causing increasing the output values as the user’s distance from the mirror (d) increases. In other words, as the user moves away from the camera/display, the value of “ d ” increases and thus the image is scaled up.

112. I have provided a simplified example to illustrate how the transformation equations in Francois result in “**resizing the image to reduce variations caused by changes in object’s distance to the camera**,” as claimed. As explained, Francois’s equations relate a point (x'_p, y'_p) in an image captured by a camera to a point (x_p, y_p) in a transformed image that corresponds to the user’s viewpoint looking into a mirror. For purposes of this example and showing limitation 1[d], I have assumed translation parameters (*i.e.*, t_x , t_y , t_z) of zero, thus effectively removing alignment of the camera image and mirror plane from the equation, in order to isolate and thus clearly illustrate how the equations result in

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image scaling based on distance. And for simplicity, I have assumed a focal length (*i.e.* f) of one. This simplifies and reduces the two equations in Francois to the following:

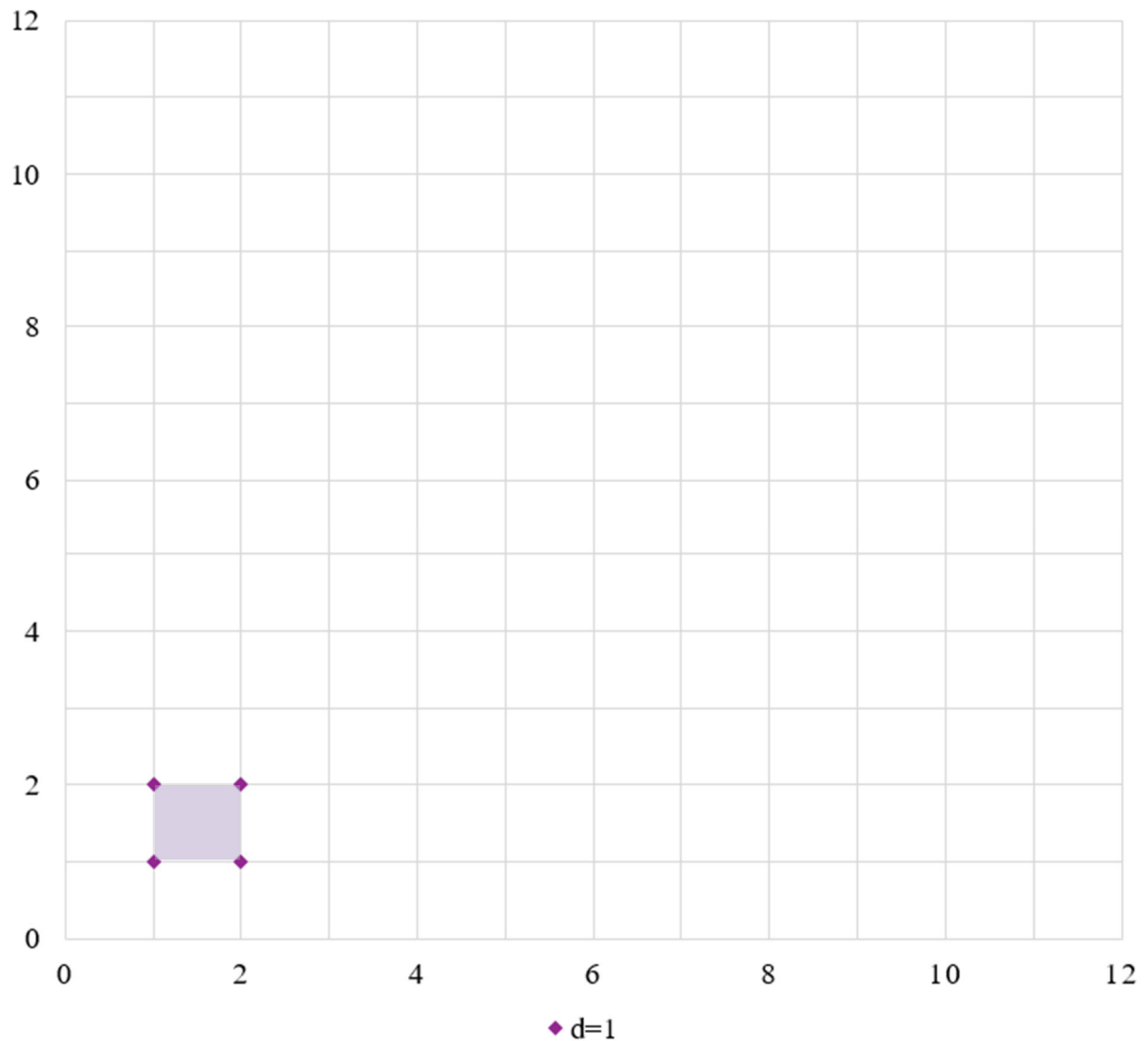
$$\begin{aligned}x_p &= d(1+d)x'_p / (1+d) \\y_p &= d(1+d)y'_p / (1+d)\end{aligned}$$

And removing the common factor $(1+d)$ that appears in both the numerator and denominator of these equations further reduces them to:

$$\begin{aligned}x_p &= d(x'_p) \\y_p &= d(y'_p)\end{aligned}$$

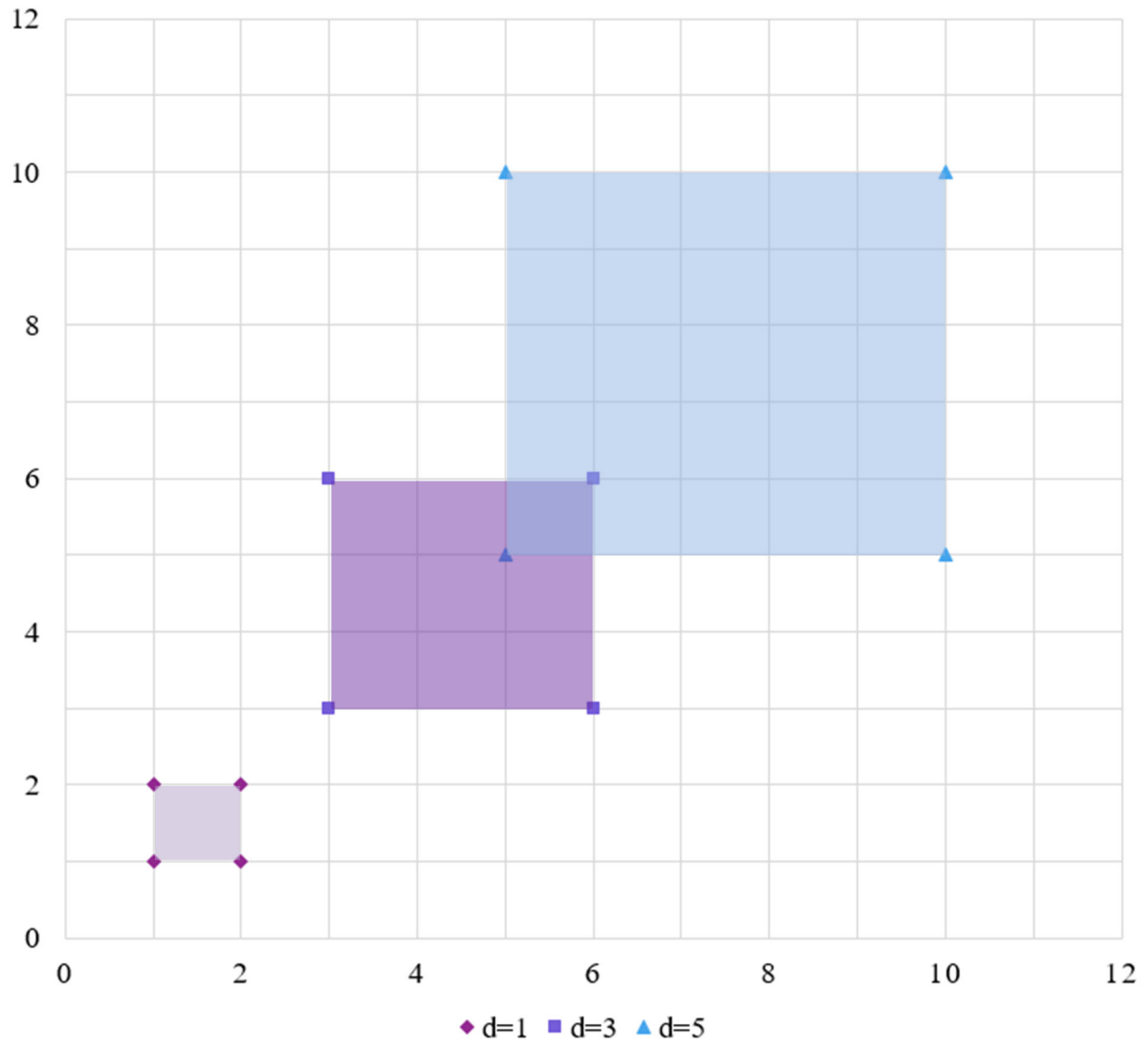
Now let's assume, for simplicity of illustration, an original image captured by a camera with four points forming a square, with (x, y) coordinates of (1,1), (1,2), (2,1), and (2,2) and the object at a distance of 1 (*i.e.* $d=1$) as shown below:

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Now let's see what happens when we “plug in” these (x, y) coordinates into Francois's equations and vary the distance (d), for example, by increasing it to three ($d=3$) and to five ($d=5$). The outcome is that the equations in Francois will result in “scaling up” of the image, with the points being remapped in a way that increases the size of the square. Under this simplified example, at distance $d=3$ the square is

scaled up three times, and at distance $d=5$ the square is scaled up five times:



This highly-simplified example illustrates how Francois's equations will resize an image, in this case enlarging an object in the image as its distance (d) increases. Of course, in a real-world example, the value associated with distance (d) may not be a simple integer and may have a more complex relationship with the coordinates used to describe the image, and the translation parameters for aligning the camera image

and mirror plane (*i.e.*, t_x , t_y , t_z) would likely not be zero. But regardless of how distance (d) relates numerically to the coordinates of the image, or the particular values of the translation parameters, increasing distance (d) will enlarge the image because distance (d) is a multiplier in the Francois equations as discussed above.

113. As noted, Francois discloses that, using his equations – including the distance-based scaling as described above – “[t]he major field-of-view variations occurring when varying the angle of view and **the distance** to the mirror, are convincingly simulated.” (Francois, 023, right column.) This convincing simulation is accomplished, in part, by the resizing/scaling of the image based on variations in distance (d), accomplished by the equations in Francois. Accordingly, when viewing the resized image on the (fixed size) display screen, the image will more closely simulate the effect of a mirror. This understanding is reflected in Francois’s observations that (1) “[t]he major field-of-view variations occurring [sic] when varying the angle of view and distance to the mirror, are convincingly simulated”; (2) “the field of view covered by the mirror depends only on the position of the user with respect to the mirror edges” and (3) “[t]he user sees on the screen what they would see on a real mirror.” (Francois at 021, Section “1. Introduction”; 022, Section “2.1 Mirror Geometry”; 023, Section “2.3 User view synthesis”).

114. I have provided a further illustration below to conceptually show how

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the transformations described in Francois would have resulted in an image being resized based on an object's distance, to simulate the visual perception of a mirror.

We start with three photographic images of a boy, each shown at a different distance:



The boy's distance to the camera in the three images above increases from left-to-right. The boy, in other words, is closest to the camera in the left-most image and farthest away in the right-most image. Because these are images provided by a camera – not a mirror reflection – the boy's size in the image significantly decreases as distance to the camera increases.

115. To convincingly simulate a mirror view, as explained, the boy should remain approximately the same size regardless of his distance to the camera. This can be accomplished by scaling the image using a zooming technique as disclosed in Francois. For example, let's zoom or enlarge the two images on the right to accommodate the increasing the distance of the boy to the camera:



The blue box represents a fixed size associated with a computer display on which the images will be shown. As illustrated, as the boy's distance to the camera increases, the image captured by the camera is enlarged, which is what would occur when applying Francois's equations. As a result, when the enlarged images are displayed – cropped to the display size shown in the blue box – the boy appears approximately the same size in all the three images:



This illustrates how, using a scaling-up technique based on distance as disclosed in Francois, a more convincing mirror-like appearance for the middle and right-side images is provided. A person of ordinary skill in the art would have therefore understood that Francois teaches “**resizing**” an image satisfying limitation 1[d], as the enlarging of the image results in an approximately consistent size of the object in the image regardless of the distance of the object (in this case a person) to the

camera. It therefore would have been obvious, based on the proposed combination of Rosenberg and Francois, to “**resiz[e] the image to reduce variations caused by changes in object’s distance to the camera,**” as claimed. The rationale and motivation to combine Rosenberg and Francois that I explained in connection with claim 1[c] applies here as well. Francois itself provides a clear motivation to implement its techniques, as explained, by stating that his transformations (including scaling) result in “convincingly simulat[ing]” a mirror reflection. (Francois, 023, right column.)

116. In my examples above, when an enlarged or scaled-up image is displayed, it is cropped so as to fit the size of the computer display device or monitor. As explained in **Part V.A.3** above, cropping refers to a well-known image processing step of removing unnecessary or unused areas from an image, as in the examples above, by trimming the edges or sides of an image to eliminate those portions that will not be presented on the display. Cropping was (and remains to this day) a widely known technique such that anyone had ever used a photo editing tool by December 2012 (such as a mobile phone’s photo app) would likely have been familiar with the process of “cropping” a digital image.

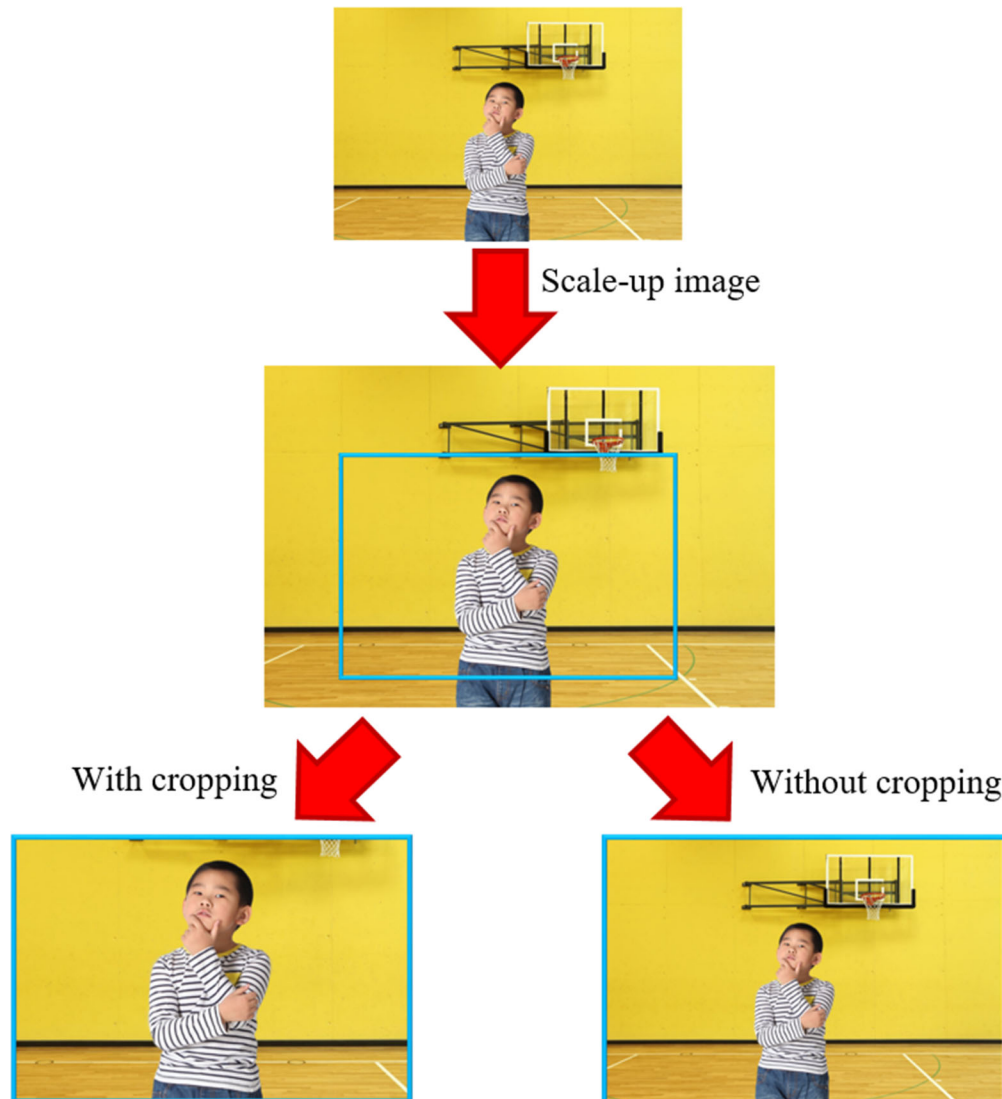
117. Francois does not expressly state that it performs cropping on images that are scaled-up, but it would have been obvious to implement the transformations

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of Francois using cropping when, as shown in the examples above, the image is scaled up. As explained extensively above, Francois discloses that its equations, including the distance-based scaling as described above, are intended to simulate the field-of-view one would see when looking at a regular mirror. It thus would have been obvious that, in order to simulate a mirror-like presentation (in which an object is approximately the same size regardless of the distance), an image that was enlarged or scaled-up based on increased distance would have been cropped, as shown again in the middle and right examples from above:



118. With respect to the middle and right-side image, if they were not cropped to fit the display as shown in blue rectangles in this example, the boy would not look larger in the scaled-up image, as more of the display area would be devoted to the surrounding image, thus resulting in the boy being correspondingly smaller:



119. Without cropping, as shown in this example, the boy in the scaled-up image does not look significantly larger than the original image – thus defeating the purpose of scaling up in the first instance. It thus would have been obvious to any person of ordinary skill in the art that the resizing of the images in Francois, when the images are scaled-up based on increased distance, would have been cropped to achieve Francois’ objective in which “[t]he major field-of-view variations occurring

when varying... **the distance** to the mirror, are convincingly simulated.” (Francois, 023, right column.)

120. Although a person of ordinary skill in the art would have found cropping obvious based on Francois alone, cropping of a scaled-up image would also have been obvious in further view of Vidunas. As explained in Part V.A.3, Vidunas explains that “[m]any modern video cameras can capture video at resolutions greater than that which can be displayed by many modern display systems, such as computer monitors.” (Vidunas, 1:26-28.) Because higher resolution images consume more data, they require more processing power to display and more bandwidth to transport over a computer network. (Vidunas, 1:32-37.) This additional processing power and bandwidth are wasted when using a lower resolution display or computer monitor to the extent portions of the higher resolution images will not be presented to the user on the display.

121. Vidunas addresses this problem by disclosing a number of techniques for “reduc[ing] the resolution of video before transference to a display system.” (Vidunas, 1:39-41.) The end result of these techniques is “modifying the video... to produce modified video having a reduced quantity of pixels in each of the plurality of images and transferring the modified video for display of at least a portion of the scene in the viewing area by the display system.” (Vidunas, 1:45-49.) One

exemplary technique in Vidunas involves cropping an image, as shown in Figure 6:

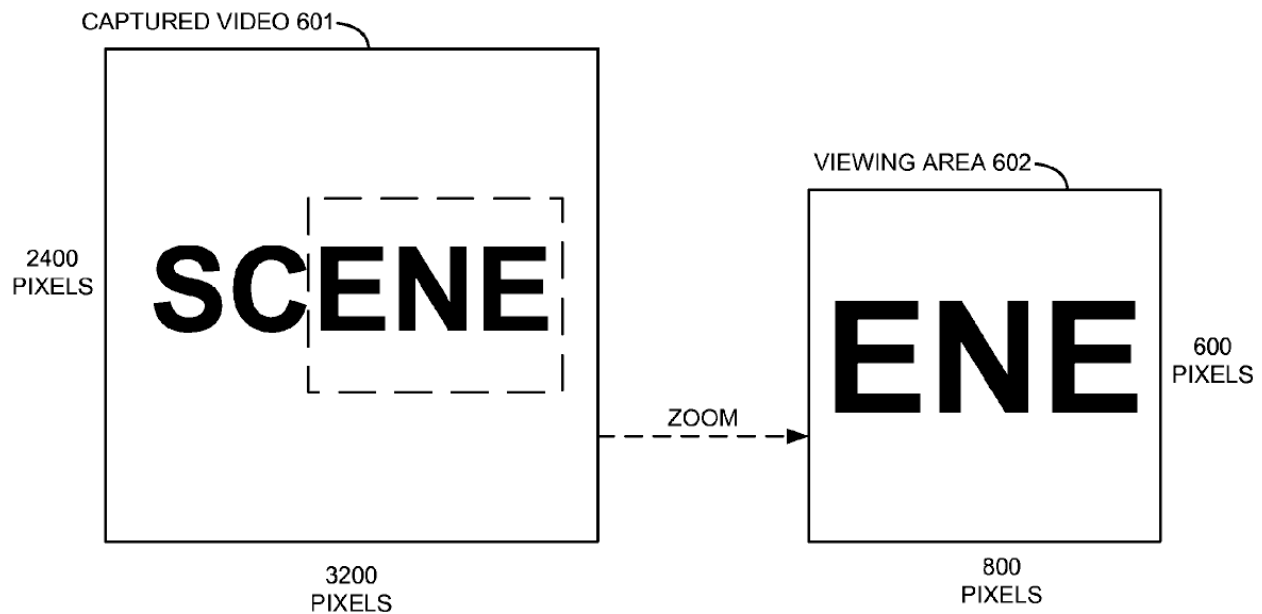


FIGURE 6

(Vidunas, Fig. 6.) Figure 6 shows cropping of an image from a video **601** having a resolution of 3200x2400 pixels to fit smaller viewing area **602**, in this example a display with a resolution of 800x600 pixels. (Vidunas, 7:41-49.)

122. Figure 6 above shows a process that Vidunas refers to as “digital zooming,” which “crops a section of pixels out of out of the images of captured video **601**.” (Vidunas, 7:66-8:1.) “For example, digital Zooming crops the pixels within the dashed rectangle out of captured video **601**. Thus, the amount of pixels within the dashed rectangle stays the same while all the pixels outside the dashed rectangle are removed for the modified video.” (Vidunas, 8:1-6.)

123. Vidunas discloses that cropping can be performed based on user

selection, or automatically based on objects in the image. “For example, the processing system may be instructed to monitor for faces. Upon detecting the event of item, the processing system may automatically crop and scale the area of the video scene where the event or item was detected.” (Vidunas, 8:23-27.)

124. **Rationale and Motivation to Combine (Rosenberg and Francois with Vidunas)**: It would have been obvious to combine Rosenberg and Francois with the cropping and image reduction techniques in Vidunas. The combination would have predictably resulted in the digital mirror system based on Rosenberg and Francois, in which images that are scaled-up or enlarged using the Francois transformation equations would have been “cropped” to fit the size of the display device. As I will show below, a person of ordinary skill in the art would have been amply motivated to combine Rosenberg and Francois with Vidunas to provide this functionality.

125. Vidunas is an analogous reference to the ’109 patent as both fall within the fields of processing and display of video. In fact, an embodiment in ’109 patent discloses “filters to improve image quality,” which may “perform cropping or image resizing as needed for optimization of the image.” (’109, 18:33-36; *see also id.*, 21:1-3 (“The scaling of the image can be matched and cropped to represent the true size of a supposed reflection at a mirror, or slightly smaller.”).) Vidunas’ disclosure of image zooming and cropping techniques would have been reasonably pertinent to

a problem faced by the inventor of how to modify and display a digital image to better mimic the appearance provided through a mirror reflection.

126. A person of ordinary skill in the art would have had ample motivation to combine. With respect to Francois, as noted, as noted, it expressly discloses that (1) “[t]he major field-of-view variations occurring [sic] when varying the angle of view and distance to the mirror, are convincingly simulated”; (2) “the field of view covered by the mirror depends only on the position of the user with respect to the mirror edges” and (3) “[t]he user sees on the screen what they would see on a real mirror.” (Francois at 021, Section “1. Introduction”; 022, Section “2.1 Mirror Geometry”; 023, Section “2.3 User view synthesis”).) It would have been obvious to a person of ordinary skill in the art that, to achieve these benefits when images are scaled up based on increased distance, as noted, it would have been necessary to crop the image to the display size. This is further enhanced by the disclosure in Vidunas, which confirms that the cropping can be used to emphasize an area of the images where human faces are detected. (Vidunas, 8:21-27.) It thus would have been obvious to crop the images of the mirror display system described in the Rosenberg-Francois combination to emphasize the user looking at the display.

127. A person of ordinary skill in the art would also have appreciated clear efficiency benefits of cropping an image as disclosed in Vidunas. Vidunas

repeatedly emphasizes that because higher resolution images consume more data, they require more processing power to display and more bandwidth to transport over a computer network. (Vidunas, 1:32-37, 3:14-17 (“The higher the resolution of a video, the more bandwidth will be needed on link 111 to transfer the video because more data is needed to represent more pixels in higher resolution video.”), 11:6-11 (“The amount of CPU resources required to decompress images is directly proportional to the image resolution, so as image resolution has increased, so have the processing requirements to decompress images. Similarly, the network bandwidth required to transmit images increases as the resolution increases.”).) Vidunas explains that “[s]caling the images before compression will dramatically reduce the bandwidth required to transmit the compressed images, and it will reduce the CPU power required to decompress the images on the workstation.” (Vidunas, 11:42-46.) Reducing the size of video images by “cropping” unneeded portions reduces the burden on computing resources by decreasing the amount of data the images consume.

128. These and other benefits of cropping would have been immediately apparent to a person of ordinary skill in the art, even without the express motivations in Vidunas. Because cropping reduces the number of pixels – and thus the amount of data – that the images of the video require, the system would have consumed less

processing power (to process the images), less storage (to store the images), and less network bandwidth (to transmit the images). This would have been particularly beneficial to a mirror-display system, such as the one disclosed in Rosenberg, in which video images could have been stored and/or transmitted over a network. (Rosenberg, *e.g.*, ¶¶0108 (“Another feature enabled by the mirror system of embodiments of the present invention is known as image-archiving in which images and/or video clips may be saved and stored for later retrieval.”), 0109 (“The communication device **1330** is utilized to receive and transmit images across a network.”).)

129. A person of ordinary skill in the art would have had at least a reasonable expectation of success in implementing the proposed combination. As noted, image cropping was a well-known technique that involves nothing more than removal of portions of an image, which would have been trivially implemented by anyone with even a rudimentary understanding of known image processing techniques.

(e) **“displaying the image on the monitor after performing the flipping, transformation mapping, and resizing;” (Claim 1[e])**

130. This step merely recites the display of the image after steps 1[b]-1[d] have been performed. Both Rosenberg and Francois disclose displaying captured video images after performing processing on them, and Vidunas discloses display

after the images are cropped to fit the viewing area of the display. (*E.g.*, Rosenberg, ¶0077 (“the real-time video image is left-right inverted prior to display upon the screen”), claim 19 (“inverting the real-time video image prior to displaying the inverted real-time video image upon the display screen”); Francois at 023, Fig. 6 (“Mirror transform” and “+ Mirror image (from user’s viewpoint)” steps before “Mirror display” step), Vidunas, 8:8:9-17) Under the proposed combination, “**the image**” displayed would have been subjected to the flipping, transformation mapping, resizing (including cropping), as discussed above. It also would have been obvious that the image would have been displayed “**on the monitor,**” *i.e.*, a display screen. (Rosenberg, ¶0077 & Fig. 5 (wall-mounted screen); Francois, at 023 (“Real-time camera and tracker inputs are used to synthesize the mirror image stream and display it in real-time on the LCD screen.”), Vidunas, 10:29-33 (“Display system **1002** comprises components that are capable of displaying video in viewing area **1008**. Display system **1002** may be... a cathode ray tube monitor, or any other type of display monitor.”).)

131. The proposed combination thus would have predictably resulted in the displaying an image on the display screen after performing the flipping, transformation mapping and resizing steps described for limitations 1[b]-1[d], and the cropping (of scaled-up images) as described in Vidunas. The rationale and

motivations to combine Rosenberg, Francois and Vidunas explained in connection with limitations 1[c] and 1[d] apply here as well.

(f) **“wherein the non-ordered steps are performed on a series of images of a live video feed from the camera;” (Claim 1[f])**

132. This limitation would have been obvious over Rosenberg in view of Francois and Vidunas. As noted, both Rosenberg and Francois disclose techniques to mimic a mirror by processing images in real-time from a camera’s live video stream. (*E.g.*, Rosenberg, ¶¶0006 (“real-time captured images”), 0026 (“real-time streamed video images”), 0077, claim 1 (“real-time video imagery captured by the digital camera”); Francois at 021, “Abstract” (“The continuous input video stream and tracker data is used to synthesize, in real-time, a continuous video stream displayed on the LCD screen.”), 022, Section “1. Introduction,” 023, Section “3. System Integration” (“Real-time camera and tracker inputs are used to synthesize the mirror image stream and display it in real-time on the LCD screen”); *see also* Vidunas, 4:36-49 (“Video source **101** may be a video camera, a computer web cam, a digital camera, or some other device capable of capturing video images – including combinations thereof.”).) It would have been apparent and obvious that the real-time video in Rosenberg and Francois provides **“a series of images of a live video feed,”** as claimed, because real-time video provides a series of live images captured by the video camera. The combination of Rosenberg and Francois therefore would

have predictably resulted in the recited steps being **performed on a series of images of a live video feed from the camera**, as claimed. The rationale and motivation to combine Rosenberg and Francois that I explained in connection with claim 1[c] applies here as well.

133. Moreover, I note that steps 1[a], [b], [c] and 1[e] are performed by the combination of Rosenberg, Francois and Vidunas for each of the series of images of a live video feed, depending on the nature of the video data, the resizing step recited in step 1[d] might not necessarily occur for every single video image received by the system. For example, the distance of the person to the camera might be such that the claimed “resizing” is unnecessary (for example, when the person’s distance to the camera is equal to the camera’s focal length and translation is zero—an unlikely real-world scenario, in part because camera focal length is typically on the order of millimeters or centimeters). This is reflected in step 1[d] itself, which recites “resizing the image to reduce variations caused by changes in object’s distance to the camera.” But in any case, it would have been obvious that, when implementing the proposed combination of Rosenberg and Francois, to provide a series of images in which the distance to the camera would have necessitated some degree of resizing, thus performing some amount of resizing and thus satisfying step 1[d]. Hence it would have been obvious, under the proposed combination of Rosenberg and

Francois, to perform steps 1[a]–1[e] on a series of images of live video feed from the camera.

134. As noted, the preamble of claim 1 recites “**performing non-ordered steps comprising,**” and limitation 1[f] recites that “**the non-ordered steps are performed.**” I understand that, in the pending litigation, Petitioner has argued that the term “**non-ordered steps**” creates an indefiniteness issue because the actual steps as recited in claim 1 do impose requirements on the order in which at least some of them are performed. The claim makes clear, for example, that limitation 1[a], “obtaining a digital image from a camera,” must occur before limitations 1[b]–[d], which recite that the obtained image is flipped, transformation mapped, and resized – an image obviously cannot be flipped, transformation mapped, and resized as recited in these steps 1[b]–1[d], until after that image has been acquired from a camera in step 1[a]. And steps 1[b]–1[d] must clearly occur before limitation 1[e], which expressly recites “displaying the image on the monitor **after** performing the flipping, transformation mapping, resizing.” Accordingly, I understand that the Petitioner in the pending litigation has argued that the claim’s recitation of “**non-ordered steps**” is inconsistent with the fact that at least some of the claim steps themselves must, based on their logic, grammar, and express terms, occur in a particular sequence.

135. But for purposes of my analysis, this inconsistency provides no obstacle in applying the prior art to claim 1, as the prior art discloses step 1[a] occurring before steps 1[b]-1[d], which in turn occur before step 1[e]. The inclusion of the phrase “**non-ordered steps**” does not impact my analysis because it suggests, at most, an intent by the patentee to *broaden* the claim to permit – but not require – that the steps be performed out of order. This does not affect my analysis because I have shown how the steps are applied in the order specified in by the claim steps – thus satisfying both a broader approach suggested by the “**non-ordered steps**” language, and a narrower **ordered** approach indicated by the claim steps themselves. In other words, because the prior art discloses the more restrictive/narrower interpretation of claim 1, it likewise discloses a broader interpretation.

(g) “**determining distance to a user appearing in the live video feed; and,**” (Claim 1[g])

136. This limitation would have been obvious over Rosenberg in view of Francois. The equations in Francois, as explained previously, take into account the distance of the user to the camera, expressed as distance d . To obtain this value, Francois discloses a head tracker used to determine the user’s distance to the display/camera. (Francois at 021, Fig. 1, Section “1. Introduction” (“trackers giving in real time the positions and orientations of the camera and the user’s head”), 023, Section “2.3 User view synthesis” (“The positions and orientations of the user’s

viewpoint and the camera center provided by the tracking devices, allow to compute both the distance d and the change of referential translation parameters.”).)

137. I note that limitation 1[g] merely requires determining distance to a user, without specifying any particular technique, algorithm, device, or technology for making the claimed distance determination. In any case, it would have been obvious that, under the proposed combination of Rosenberg and Francois, the system would determine the distance to a user who appears in the live video feed provided by the camera. The rationale and motivation to combine Rosenberg and Francois that I explained in connection with claim 1[c] applies here as well, and a person of ordinary skill in the art would have been motivated to provide a means of determining distance of a user (such as the head tracker in Francois) in order to perform the scaling transformations of Francois – which expressly rely on the distance parameter (d). As explained for limitation 1[d], the equations in Francois rely on the distance of the user to provide a more convincing mirror display, as explained. I note that Rosenberg similarly discloses that its system includes “one or more proximity and/or motion sensors” for “detecting whether a person (or a similar object) is located before and/or moves before the display screen” (Rosenberg, ¶0069; *see also, e.g., id.*, ¶¶0032, 0056), further confirming that Francois’s teachings regarding use of a head tracker are readily combinable and compatible with

Rosenberg.

(h) “varying rate at which the non-ordered steps are performed on the series of images according to the distance.” (Claim 1[h])

138. Rosenberg, Francois and Vidunas do not expressly describe varying the rate at which the “non-ordered steps” (described above) are performed. But this would have been obvious in further view of Dunton [Ex. 1006] and Yong [Ex. 1007]. As noted in **Part V.A.4** above, Dunton and Yong disclose techniques for varying the “frame rate” associated with processing video captured by a video camera. The term “frame rate” generally refers to the frequency (or rate) at which sequential images (or “frames”) of a video are captured, processed, and/or displayed. Frame rate is commonly expressed as a number of frames-per-second (FPS).

139. Dunton and Yong both disclose what would have been well-known to persons of ordinary skill in the art – the ability to increase the frame rate by cropping or otherwise reducing the frames so they consume less data. The “Background” section of Dunton, for example, explains:

To meet a given image frame rate over a limited transmission bandwidth, one solution is to simply electronically scale the detailed still image frames into lower resolution image frames prior to transmitting them. Alternatively, the detailed image can be “cropped” to a smaller size, and therefore lower resolution image. In this way, the amount of spatial data per image frame is reduced, so that a greater

frame rate can be achieved between the digital camera and the host computer.

(Dunton, 1:35-43.) Dunton specifically discloses that this technique can be used to provide different frame rates based on the distance to the camera, *e.g.*, by increasing the frame rate when capturing near (instead of distant) objects:

In order to obtain the smaller near image data 170 and greater frame rate when the apparatus 100 is configured with the optical system 108 in the near position, the signal processing block 110 and the sensor 114 are configured (by control signals and data received from the system controller 160, see FIG. 1) to process only the pixel signals originating from those rows and columns of the sensor 114 that define the region on which the smaller image is formed...

The fewer sensor signals result in both lower processing times in the signal processing block 110, and greater image frame rate through a limited bandwidth interface between the sensor 114 and signal processing block 110. This in turn results in greater image frame rate through the host communication interface 154 (see FIG. 1).

(Dunton, 4:61-5:15.) The example above discloses what is akin to a “cropping” operation because only a portion of the image provided by the camera is processed (*e.g.*, those pixels associated with near image data 170) the surrounding pixels are disregarded and not processed by the system. (*Id.*, Fig. 4.) In the particular implementation described in Dunton, this results in less data, which in turn enables

the frame rate to be increased. This technique further underscores Dunton's more fundamental teaching – when the amount of data consumed by images in a video is reduced, by whatever means, the frame rate can be increased.

140. **Yong** discloses a similar technique for increasing the frame rate of a video by reducing the size and/or resolution of frames of the video:

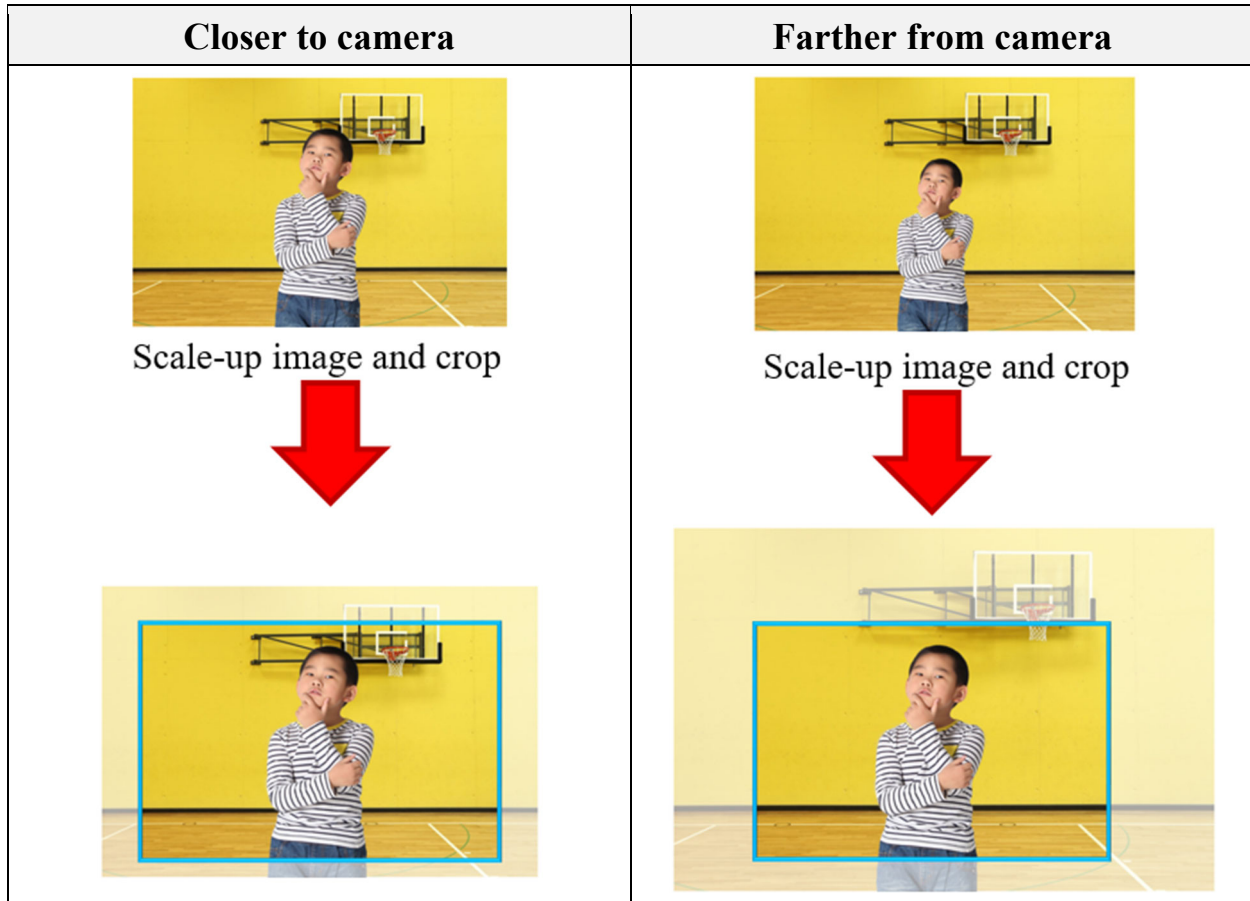
A new method, apparatus and software product are presented for implementing algorithms for improving (i.e., increasing) a frame rate by reducing a size and resolution (i.e., size/resolution) of selected (or chosen) versus unselected image frames captured by a sensor in an image processing pipeline before displaying (or before encoding stage) in electronic devices (e.g., cameras, wireless camera phones, etc.), according to various embodiments of the present invention.

(Yong, 4:25-32.) This results in an increase in frame rate because, as Yong explains, reducing the image in size or resolution reduces the amount of processing time required for the reduced frames of the video. (Yong, *e.g.*, 6:6-15.)

141. Dunton and Yong disclose a video-specific example of a universal truism plainly obvious to a person of ordinary skill in the art – a computer system can process data more quickly when there is less of it to process. As applied to video, Dunton and Yong disclose varying the frame rate for video image processing based on the amount of data the images consume – *e.g.*, increasing the frame rate for a video when the images of the video are modified such that they consume less data.

142. **Manner, Rationale and Motivation to Combine (Rosenberg, Francois and Vidunas with Dunton and Yong)**: It would have been obvious to combine the mirror-display system disclosed by the combination of Rosenberg, Francois, and Vidunas with the frame rate variation techniques disclosed in Dunton and Yong. The combination would have predictably resulted in the system described by the proposed combination of Rosenberg, Francois, and Vidunas in which the frame rate for the video is varied (*e.g.* increased) as a result of the transformations in Francois and Vidunas that reduce the amount of data that the images consume.

143. As explained in great detail for limitation 1[d], Francois discloses mirror transformation equations that, among other things, scale images based on the distance of the viewer to the mirror/display. These equations, for example, would result in an image being scaled up or enlarged when the viewer is further away from the display. For example, as shown in the images below, as the boy moves farther from the camera, more of the image is cropped for the display:



As further explained for limitation 1[d], images that were scaled-up or enlarged using the Francois equations would be *cropped* to fit the size of the display monitor, which would in turn have reduced the amount of data for the images. As shown by the example images shown above, the amount of data that is cropped and thus removed from the image (the area outside the **blue** rectangles) increases when the user is further away from the camera because, as noted, the amount of scaling increases with distance under the Francois equations. Accordingly, as the person moves further away from the camera, the amount of scaling and cropping increases,

thus reducing the amount of data the resulting image will consume.

144. It thus would have been obvious, based on the further combination with Dunton and Yong, to *increase* the frame rate for the mirror display system of the proposed combination of Rosenberg, Francois, and Vidunas, when processing images that were scaled-up to account for increased distance. Under the proposed combination, therefore, this increase in frame rate would have increased the number of frames-per-second that the system could process – thus increasing the rate at which the proposed combination is capable of capturing digital images from a camera, flipping images about a vertical axis, applying transformation mappings and resizing the images, and then displaying the images, based on the teachings of Rosenberg, Francois and Vidunas – thus “**varying rate at which the non-ordered steps are performed on the series of images,**” as claimed. This varying also occurs “**according to the distance,**” as claimed, because the measured distance (d) is used in the Francois equations in order to scale up an image based on increasing distance. That scaling up, as noted, results in reducing the amount of data for the image and thus increasing the frame rate as taught in Dunton and Yong. Under the proposed combination, in other words, the rate at which the mirror system under the combination of Rosenberg, Francois and Vidunas performs steps 1[a] through 1[e] will increase when the distance of the user to the mirror/display increases.

145. To be clear, although Dunton and Yong disclose specific techniques for reducing the size of an image in a video, my proposed combination need not (and thus does not) rely on those techniques. As explained at length in the discussion of limitations 1[b]-1[d], the proposed combination relies on Rosenberg, Francois, and Vidunas to produce a frame that, when scaled up and cropped when the distance increases, will consume less data. My combination relies on Dunton and Yong for their more general teachings of increasing video frame rate in response to a reduction in the amount of frame data – teachings that apply regardless of the particular techniques used to reduce the image data.

146. Dunton and Yong are analogous references in the field of image processing and display of video. As noted in the discussion of Vidunas, an embodiment in '109 patent discloses “filters to improve image quality,” which may “perform cropping or image resizing as needed for optimization of the image.” ('109, 18:33-36; *see also id.*, 21:1-3 (“The scaling of the image can be matched and cropped to represent the true size of a supposed reflection at a mirror, or slightly smaller.”).) The '109 patent also discloses techniques for increasing the frame rate for video “so as to smooth the video.” ('109, 30:33-36.) The disclosures in Dunton and Yong of increasing frame rate would have been reasonably pertinent to a problem faced by the inventor of how to improve and/or optimize the appearance

and performance of video, for example, by increasing frame rates.

147. A person of ordinary skill in the art would have had a clear motivation to combine to improve the appearance and performance of video. As noted in **Part V.A.4**, it was well-known to persons of ordinary skill in the art that the frame rate can have a direct impact on the user's experience when viewing a video. Low frame rates are often associated with videos in which motion appears choppy or jumpy, whereas higher frame rates are generally associated with smoother and more natural motion. It would have been apparent and obvious that the scaling-and-cropping that occurs (based on Francois and Vidunas) when the distance increases would have resulted in a reduction in the amount of image data. Dunton provides an express motivation to increase the frame rate in this situation by explaining that when an image is cropped to a smaller size, "the amount of spatial data per image frame is reduced," and as such, "a greater frame rate can be achieved between the digital camera and the host computer." (Dunton, 1:38-43.)

148. The technique in Dunton and Yong would have been particularly beneficial because, by increasing the frame rate, video quality would have been improved. Although the improvement would have occurred only when the user moves *further* away from the mirror/display – and not closer – this would not have discouraged a person of ordinary skill in the art from the proposed combination.

This is because a person of ordinary skill in the art would have welcomed any improvement in frame rate (and thus video quality), even if that improvement did not manifest in all possible use cases or scenarios. A person of ordinary skill in the art would have recognized that, in developing best performing video applications, it is often beneficial to operate at the highest possible frame rate based on available computing resources (e.g. processing power, storage, network bandwidth). As such, a person of ordinary skill in the art would have been motivated to take advantage of the computing resources made available by the reduction in the amount of image data, by increasing the frame rate as taught in Dunton and Yong and thereby improving the quality of video.

149. A person of ordinary skill in the art would have also been motivated by the fact that, under the technique described in Dunton and Yong, an increase in frame rate could have been accomplished without imposing an undue burden on the system. As noted in **Part V.A.4**, increasing frame rate ordinarily requires greater processing power, storage, and network bandwidth because of the increase in data required by the additional frames. Ordinarily the persons of ordinary skill in the art thus understood that choosing a video frame rate often involved difficult trade-offs between maintaining video quality and efficient utilization of computing resources. But the techniques in Dunton and Yong would have simplified these trade-off

decisions because the increased frame rate here would have been at least partially (if not entirely) offset by the reduction in the amount of data that each frame consumes as a result of the scaling and cropping described above. The technique in Dunton and Yong thus could have achieved the benefit of an increased frame rate while imposing fewer (if any) additional burdens on computing resources.

150. Finally, Dunton provides a further motivation to combine by expressly disclosing a relationship between the video frame rate and distance of the object to the camera. Dunton, as noted, expressly describes increasing the frame rate for a video when capturing near image data. (Dunton, 4:61-5:15.) I note that this is the *reverse* of the relationship under the proposed combination, in which the frame rate goes up when object distance increases. But this would have presented no obstacle to a person of ordinary skill in the art, as this difference is based entirely on the idiosyncrasies of the particular implementation in Dunton in which near image data consumes less data because the system only processes a portion of the data captured by the image sensor. (Dunton, *e.g.*, 4:61-5:9.) A person of ordinary skill in the art would have immediately understood that, under the proposed combination of Rosenberg, Francois, and Vidunas, the *reverse* is true, *i.e.* images showing distant objects consume less data, because enlarging and cropping distant objects to convincingly simulate a mirror reflection results in less data being used for those

images. Dunton nevertheless presents a further motivation to combine by directly disclosing a relationship between distance and video frame rate.

151. A person of ordinary skill in the art would have had at least a reasonable expectation of success at implementing the proposed combination. As noted, the teachings of Dunton and Yong that I have applied state little more than the obvious truism that data can be processed more quickly when there is less of it to process. It would have been trivial for a person of ordinary skill in the art to adapt the mirror system based on Rosenberg, Francois, and Vidunas to increase the rate at which the system captures, flips, transforms, resizes and displays images based on increasing distance (d), as the system would have had direct access to the distance (d) and its relationship to the amount of data consumed by the transformed images. A person of ordinary skill in the art could have implemented the claimed varying using routine and conventional programming techniques.

2. Claim 2

152. Claim 2 depends from claim 1, and further recites “**wherein the transformation mapping renders an image appearing to have been taken from a camera positioned at eye-level height and pointing horizontally.**” As explained below, the additional limitations of claim 2 are disclosed by and would have been obvious over Rosenberg in view of Francois.

153. Starting with “a camera positioned at eye-level height and pointing horizontally,” Rosenberg discloses that the camera of its digital mirror system can be positioned in various places relative to the display, such as within the display at approximately eye-level height and pointing straight ahead, as Rosenberg illustrates in Figure 4 with camera 402 within display 401:

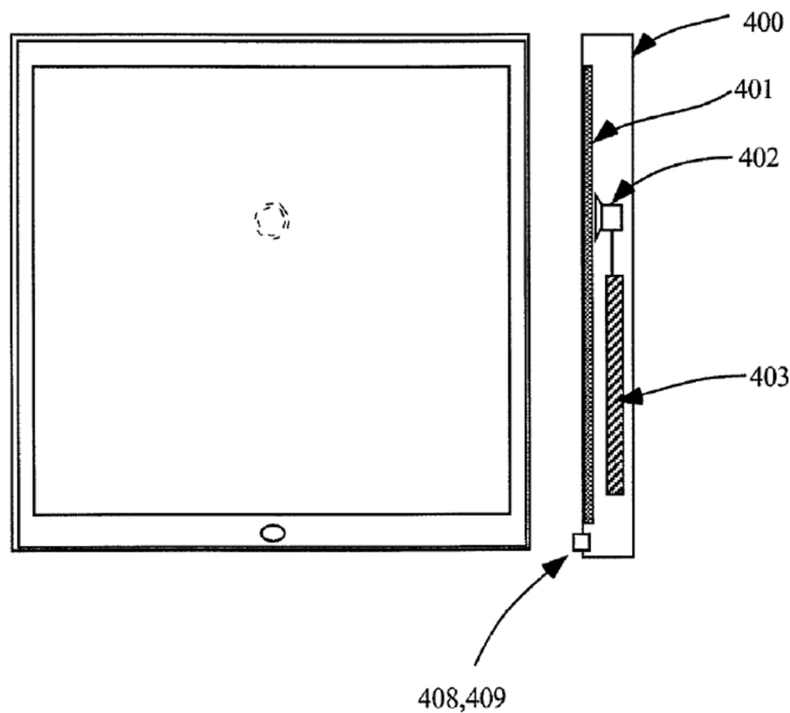


Fig. 4

(Rosenberg, Fig. 4; *see also id.*, ¶0075.) Rosenberg explains that the camera is positioned at approximately eye-level height of a typical user and points horizontally with respect to the display’s surface (and also the floor, as a “wall mirror”):

Unlike the embodiment shown in FIG. 3 where the camera is mounted above the display screen, the embodiment shown in FIG. 4 has a camera 402 mounted within the screen area. Such embodiments may be preferred because they yield more realistic replications of traditional mirrors because the displayed image that is from a vantage that is straight ahead. Such embodiments of the present invention often strive to achieve placement of the camera 402 such that the image captured by the camera 402 is taken from a vantage point that is centered horizontally with respect to the display screen and **at an elevation vertically that generally corresponds with a user's typical eye level**. In this way the user is looking straight at the camera 402 when standing centered before the digital mirror display screen.

(Rosenberg, ¶0075; *see also id.*, ¶¶0027 (“[T]he camera is mounted within the screen area of the display itself, approximately at eye-level of typical users....”), 0028 (“...placement of the camera such that the image captured by the camera is taken from a vantage point that is centered horizontally with respect to the display screen and at an elevation vertically that generally corresponds with a user's typical eye level.”), 0060 (“Embodiments of the present invention may utilize thin monitors, using flat panel display technologies along with digital camera technology and a set of unique user interface methods and apparatus to provide an innovative digital hanging wall mirror for use in people's homes.”), 0061.)

154. A person of ordinary skill in the art would have understood and found

it obvious that applying Francois's **transformation mapping** to an image captured by such the eye-level camera in Rosenberg would have predictably resulted in **“render[ing] an image appearing to have been taken from a camera positioned at eye-level height and pointing horizontally,”** as claimed, in at least two ways. First, in the case of a typical user, Rosenberg teaches that the image would have been be taken from a camera positioned at eye-level height and pointing horizontally. (Rosenberg, *e.g.*, ¶0075.) Francois's transformations in that case would simply render a scaled and/or translated image as appropriate, but the image would still have the appearance of having been taken from the perspective of a camera positioned at eye-level height and pointing horizontally. A person of ordinary skill in the art would have been motivated to capture user images using an eye-level camera, as disclosed in Rosenberg, to provide images that more closely approximates the user's viewpoint. Such images would have provided better “starting points” for Francois' transformation equations as it would be “closer” to the user's viewpoint (as compared to a camera above the display). And because these starting point images more closely approximate the user's viewpoint than a camera mounted above the display, Francois's transformation equations would have imposed more modest transformations to relate the user's viewpoint to the camera-captured images. A person of ordinary skill in the art would have appreciated that more severe

transformations create a risk of distortions, blurring, insufficient image coverage for the field of view, or other undesirable artifacts in the images. Reducing the need to perform more severe transformations would have resulted in an improvement to the appearance of displayed transformed images.

155. Second, even in an embodiment of the proposed combination involving a camera that is **not** physically at eye-level, the transformation mapping under the proposed combination would still “**render[] an image appearing to have been taken from a camera positioned at eye-level height and pointing horizontally,**” as claimed. For example, Rosenberg discloses an embodiment in which the camera is positioned *above* the display, and thus, not at eye level. (Rosenberg, *e.g.*, ¶0061 (“In basic embodiments, the camera is mounted directly above the screen area of the display **200**, generally near the horizontal center.”).) Even in such an embodiment, using the techniques in Francois, the captured image would have been advantageously translated in the vertical direction to the user’s eye-level height. (*E.g.*, Francois at 023, Section “2.3 User view synthesis” (“The positions and orientations of the user’s viewpoint and the camera center provided by the tracking devices, allow to compute both the distance d and the change of referential translation parameters.”).) A person of ordinary skill in the art would have understood and found it obvious that the head tracking device in Francois would

have provided eye-level information, and would have been motivated to use such a tracker in view of both Rosenberg's and Francois's express teachings and motivations. Rosenberg, for example, explains that "an eye-level viewing angle" "provides a highly realistic mirror replication image" and that "users are familiar" with such a vantage point. (Rosenberg, ¶¶0061, 0027.) Francois similarly seeks to provide a "convincing" mirror simulation and recognizes the desirability of simulating eye contact, a more advanced form of eye-level viewing. (Francois at 024, Section "Conclusion".) A person of ordinary skill in the art, therefore, would have been motivated to use the head tracker information such that images rendered by Francois's transformations appeared to have been taken at eye-level height, even if the camera was not physically mounted at eye level. In a digital mirror system having a camera pointing horizontally as Rosenberg expressly teaches, this would have resulted in Francois's **"transformation mapping render[ing] an image appearing to have been taken from a camera positioned at eye-level height and pointing horizontally,"** as claimed.

3. Claim 6

156. Claim 6 depends from claim 1, and further recites **"wherein the step of resizing the image is performed integral to the step of applying the transformation mapping."**

157. I fully addressed the additional limitations of claim 6 in my analysis of claims 1[c] and 1[d] above. As I explained, a person of ordinary skill would have understood the image scaling step that takes place as part of Francois's transformation equations to correspond to **“resizing the image,”** as claimed. Because the scaling is performed as part of the transformation equations (**the transformation mapping**), the scaling is therefore **“performed integral to the step of applying the transformation mapping,”** as recited in claim 6.

4. Claim 8

158. Claim 8 depends from claim 1, and further recites **“further comprising applying a translation transformation to move the image within display area of the monitor.”** The additional limitations of claim 8 are disclosed by and obvious over Rosenberg, Francois and Vidunas.

159. With respect to Rosenberg, it describes a “composite image” feature to display multiple images collected by the camera at different points in time. (Rosenberg, ¶0048.) The feature involves moving an image from the center of the display area to the left or right, thereby creating a “multi-view mirroring” experience:

[F]or example, a user can freeze his left profile by turning to the right and uttering “freeze.” The user then can move the frozen image to the left side of the display by uttering “move left”. The image then appears

on the left side of the display and the central display resume the standard mirroring function. The user can then freeze his right profile by turning to the left and uttering “freeze”. The user can then move the frozen image to the right side of the display by uttering “move right.” The image then appears on the right side of the display and the central display again resumes the standard mirroring function. Now the user is looking in a mirror, as presented on the central portion of the digital mirror screen display, while having his left and right profiles presented on either side of the mirror.

(Rosenberg, ¶0048.) A person of ordinary skill in the art would have understood that, by moving an image to the left or right within the display area as Rosenberg teaches, the system **appl[ied] a translation transformation**—i.e., transformed the image by moving its location (translating it) to the left or right. (*See, e.g.*, Ex. 1013 at 006 (defining “transform” as “[i]n mathematics and computer graphics, to alter the position, size, or nature of an object by moving it to another location (translation), making it larger or smaller (scaling), turning it (rotation), changing its description from one type of coordinate system to another, and so on.”).) A person of ordinary skill in the art would have been motivated to implement this feature in the proposed combination to achieve the benefits of Rosenberg’s frozen images feature, as identified in Rosenberg above.

160. And even putting aside the frozen images feature in Rosenberg, the

mirror transformation in Francois, as explained, itself comprises a **“translation transformation to move the image within display area of the monitor,”** as claimed. This is because the transformation equations in Francois map an image captured by a camera to a user’s viewpoint, by using image translation and scaling as discussed in detail for limitations 1[c] and 1[d] above. (*E.g.*, Francois at 023, Section “2.3 User view synthesis” (“The only parameters are f , d , and [txtytz]....[T]he transform relating the user’s view to the camera view is reduced to a scaling and a translation.”); *see also id.* at 022, Section “2.3 User view synthesis” (“Thus the 4x4 matrix relating the two coordinate systems is reduced to a simple translation of the origin.”).) In other words, Francois teaches **applying a translation transformation** to a captured image **to move the image within display area of the monitor** so that the displayed image corresponds to the user’s view instead of the camera view. The translation process in Francois, in other words, results in **“mov[ing] the image within display area of the monitor,”** as claimed, because the image will be adjusted such that objects in the image will be in different locations when viewed on the screen, as a result of transforming the image to reflect the viewpoint of the user. The same is true for the resizing and cropping process in Francois and Vidunas – they will also result in **“mov[ing] the image within display area of the monitor,”** as claimed, because the image will be resized such that objects

will be in different locations as viewed on the screen, as a result of resizing the image based on the distance of the user, and cropping the image to fit the viewable area of the display.

161. Therefore, the proposed combination renders claim 8 obvious.

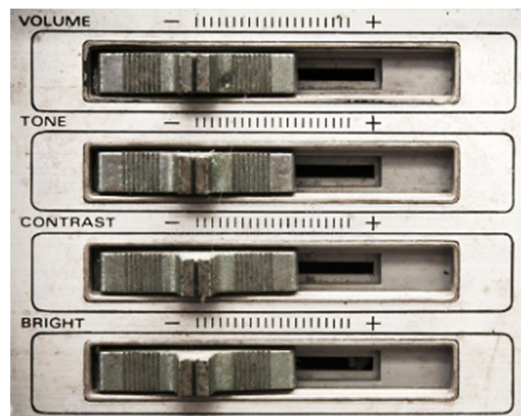
5. Claim 9

162. Claim 9 depends from claim 1, and further recites “**further comprising changing illumination intensity of individual or groups of pixels of the monitor, so as to enhance shading or illumination in the image.**” Claim 9 does not recite any non-obvious distinction over the prior art.

163. Rosenberg, for example, discloses a “lighting emulation feature” in which “well known image processing techniques are used upon the real-time video imagery to alter the natural lighting conditions of the imagery to that of a simulated lighting condition.” (Rosenberg, ¶0116.) “For example, image processing routines may be employed to alter the real-time video image such that the displayed lighting conditions simulate one of natural light, florescent light, or incandescent light.” (*Id.*) A person of ordinary skill in the art would have understood and found it obvious that the application of “well known image processing techniques” in this would have predictably resulted in changing illumination intensity of pixels on the display, enhancing shading or illumination in the image.

164. This teaching in Rosenberg discloses and renders obvious “changing illumination intensity of individual or groups of pixels of the monitor, so as to increase shading or illumination in the image,” as claimed. Rosenberg explains, as noted that the “user may selectively view himself or herself in lighting conditions other than that which are present in the area of the digital mirror system,” such as natural, fluorescent, or incandescent light as noted. This will result in changing the illumination of the pixels of the digital image that make up the user as shown on the display (“groups of pixels of the monitor”), thus enhancing the illumination of the image as claimed.

165. Aside from the *software-based* techniques in Rosenberg for changing illumination intensity, it would also have been obvious to simply use the built-in *hardware* controls of any conventional computer display. It was well-known that conventional TVs and computer displays had built-in controls for altering the contrast and brightness of displayed images. (See, e.g., Ex. 1015 at 007-008 (entry for “contrast” stating that “Displays often provide hardware adjustments for controlling contrast”) see also Ex. 1016 at 005 (entry for “contrast” stating that “all television sets and computer VDUs [visual display units] provide a separate



control to adjust the contrast”).) It was well-known that brightness and contrast adjustments could enhance an image’s illumination and shading by changing the illumination intensity of individual or groups of pixels of a display. (*E.g.*, Ex. 1015 at 008; *see also* Ex. 1016 at 005 (explaining “contrast” as “[t]he ratio between the luminous intensity of the darkest and lightest areas in a visual image, which governs how well the human eye can discriminate different objects.”).)

6. Claim 17

166. Claim 17 depends from claim 1, and further recites **“storing the live video feed in a digital storage device and selectively operating the system in one of a mirror mode or display mode, wherein during mirror mode displaying on the monitor transformed images of what the camera sees at that particular moment while during display mode displaying on the monitor a transformed images of what the camera saw in the past and obtained from the digital storage device.”** Rosenberg discloses and renders obvious the additional limitations of claim 17.

167. Turning first to **“storing the live video feed in a digital storage device,”** Rosenberg explains that its digital mirror system includes memory (such as RAM—a “digital storage device”) for storing “real-time video imagery from the camera.” (Rosenberg, ¶¶0044 (“the image frame buffer maintains in memory the

last 10 seconds of live imagery captured”), 0045, 0089 (“When employing the mirror image-buffer feature, the user is given the ability to selectively store certain time duration real-time video imagery from the camera.....The memory may be of any form common to art—for example, RAM with DMA access.”).)

168. Next, Rosenberg discloses “**selectively operating the system in one of a mirror mode or display mode.**” Rosenberg explains that its digital mirror system can be selectively operated in various modes, including a “traditional mirror mode” for displaying a live mirror image of the user (“**mirror mode**”) and an “image buffering” mode for replaying previously-captured video (“**display mode**”). In what Rosenberg calls its “traditional mirror mode,” “real-time images are streamed video images captured by a camera mounted upon the display, the real-time streamed video images being a left-right inverted representation of the video signal captured by the camera.” (Rosenberg, ¶0026.) Under the proposed combination with Francois, these real-time images would have been enhanced using the transformation mapping techniques that include translation and scaling, as discussed extensively in detail for claim 1. As a result, under the proposed combination, the traditional mirror mode of Rosenberg would “**display[] on the monitor transformed images of what the camera sees at that particular moment,**” as claimed.

169. Turning to the claimed “**display mode,**” a user can switch to “image

buffering” mode in Rosenberg to view previously-captured video by, for example, using a voice command such as “view buffer” or “replay.” (Rosenberg, ¶¶0045-0046.) In “image buffering” mode, “[i]nstead of the real-time imagery, the previously buffered camera frames are displayed, showing for example the previous 10 seconds of imagery captured by the camera and displayed upon the mirror.” (Rosenberg, ¶0045; *see also id.*, ¶0046 (“the imagery displayed upon the screen is routed from the buffer”).) Under the proposed combination with Francois, the images replayed from storage – just like the real time images as discussed – would have been enhanced using the transformation mapping techniques that include translation and scaling, as discussed extensively in detail for claim 1. As a result, under the proposed combination, the image buffering mode would **“display[] on the monitor transformed images of what the camera saw in the past and obtained from the digital storage device,”** as claimed. A user can switch back to real-time mirror mode by using a voice command such as “end replay” or “end.” (Rosenberg, ¶0046.)

170. Rosenberg (alone or in combination with Francois’s additional teachings regarding simulating a mirror) discloses a **“mirror mode”** and a **“display mode”** under both parties’ proposed constructions of those terms. In Rosenberg’s traditional mirror mode (**“mirror mode”**), a real-time mirror image of a user

standing in front of the camera is displayed back to the user. It is therefore “[a] mode to display the current appearance of a user as if reflected in a mirror,” as Patent Owner has proposed. (Ex. 1012 at 003.) And it is also “[a] mode of operating as a mirror, where a ‘mirror’ is a reflective surface, or as a display that mimics a reflection of a mirror,” as Petitioners have proposed. (Ex. 1012 at 003.) In Rosenberg’s “image buffering” mode (“**display mode**”), previously-captured images of a user standing in front of the camera are displayed back to the user. It is therefore “[a] mode to display a previously captured user appearance,” as Patent Owner has proposed. (Ex. 1012 at 004.) And it is also “[a] mode of operating as a display,” as Petitioners have proposed. (Ex. 1012 at 004.)

171. Turning to the last parts of claim 17, they simply restate functional descriptions of “mirror mode” and “display mode” and are therefore disclosed and obvious for the reasons already explained above. As explained, **during** Rosenberg’s traditional mirror mode (“**mirror mode**”), under the proposed combination with Francois, “**transformed images of what the camera sees at that particular moment**” are “**displayed on the monitor.**” (*E.g.*, Rosenberg, ¶¶0026 (“In a traditional mirror mode...real-time images are streamed video images captured by a camera mounted upon the display, the real-time streamed video images being a left-right inverted representation of the video signal captured by the camera.”), 0077.)

And **during** Rosenberg's image buffering mode ("**display mode**"), under the proposed combination, "**transformed images of what the camera saw in the past and obtained from the digital storage device**" are "**displayed on the monitor.**" (E.g., Rosenberg, ¶¶0045 ("Instead of the real-time imagery, the previously buffered camera frames are displayed, showing for example the previous 10 seconds of imagery captured by the camera and displayed upon the mirror....In general, when a user is engaged in a traditional mirror mode immediately prior to the buffering feature being engaged, the buffered real-time imagery is displayed as left-right inverted representation."), 0046 ("the imagery displayed upon the screen is routed from the buffer").)

D. Ground 2: Claims 1, 2, 6, 8, 9 and 17 Are Obvious Over Rosenberg in View of Francois and Vidunas, in Further View of Suzuki

172. **Ground 1** relied on Rosenberg, Francois, and Vidunas for all limitations of the challenged claims except limitation 1[h], "**varying rate at which the non-ordered steps are performed on the series of images according to the distance,**" for which Ground 1 also cited to Dunton and Yong. **Ground 2** presents an alternative mapping for limitation 1[h] by citing Suzuki (Ex. 1008) instead of Dunton and Yong, thus providing a different way of varying the rate at which the steps of claim 1 could be performed according to the distance of the user.

173. **Ground 2** thus establishes that the challenged claims are obvious over

Rosenberg in view of Francois, Vidunas, and in further view of Suzuki. For all limitations of all challenged claims, except limitation 1[h], the mapping from Ground 1 for Rosenberg, Francois, and Vidunas applies equally to Ground 2. For limitation 1[h], whereas Ground 1 relies on Dunton and Yong for increasing a video frame rate in response to reducing the amount of data in the images, Ground 2 relies on Suzuki for increasing the frame rate for a different purpose – to increase video quality by increasing the frame rate when objects being recorded are closer.

174. Suzuki discloses an imaging apparatus (such as a video camera) that includes a “zoom” function, and which can increase the frame rate for recorded video in response to use of the zoom function. For example, Suzuki discloses that the frame rate of the imaging apparatus can be increased during, before, and/or after a “zoom operation,” depending on the needs of the user. (Suzuki, Abstract (“During a zoom operation period or a period including the zoom operation period and periods before and after the zoom operation, a video signal from the imaging unit is recorded in a recording medium at a high recording frame rate.”).) A “zoom operation” in Suzuki includes either a zoom-in or zoom-out operation. (Suzuki, *e.g.*, 13:55-58.)

175. Figures 15A-15D show one example of how the frame rate of a video recording is operated at a higher frame rate during a zoom operation:

FIG.15A

ZOOM
OPERATION

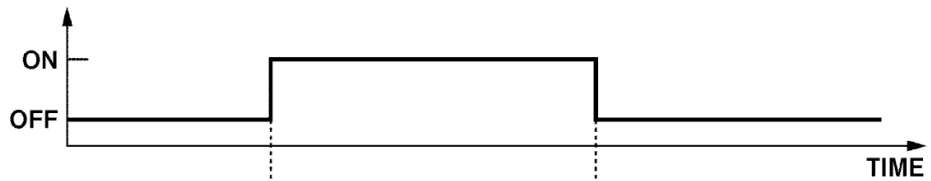


FIG.15B

FRAME RATE
CONTROL
SIGNAL

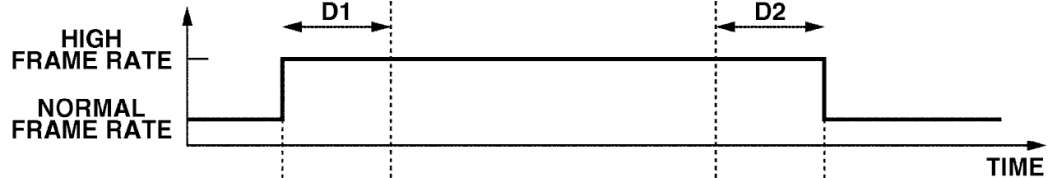


FIG.15C

CAPTURED
FRAMES

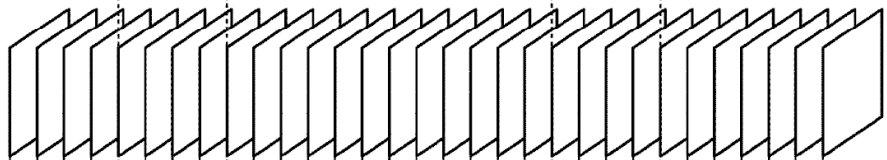
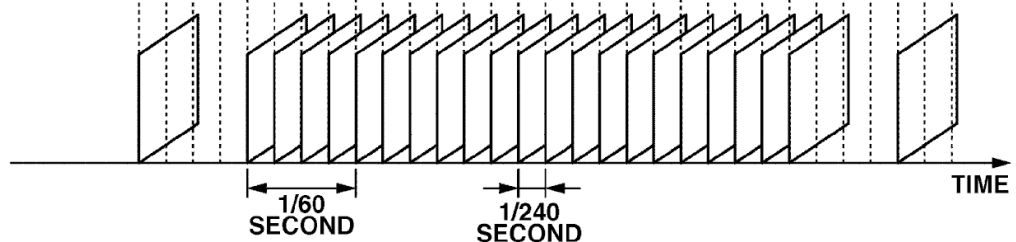


FIG.15D

RECORDED
FRAMES



(Suzuki, Figs. 15A-D.) Figures 15A-D show overlapping timing diagrams in which “the horizontal axis represents time.” (Suzuki, 13:2.) Figure 15A shows a period of time during which a zoom operation takes place during recording. (Suzuki, 13:3-4.) Figure 15B shows that, during a zoom operation, the imaging apparatus operates at a high frame rate. (Suzuki, 13:4-8, 13:13-19.) Figure 15B also shows the ability to operate at a high frame rate for a period before (D1) and after (D2) the zoom operation, in this case, “at a high rate of 1/240-second intervals.” (Suzuki, 13:13-18.) “The lengths of periods D1 and D2 may be different from each other.” (Suzuki, 13:18-19.) As shown in Figure 15D, the end result recording at a frame rate of

240fps for the period during and after (D2) the zoom period. Although not pertinent to our discussion here, the particular example in Figure 15D shows frames *captured* during period (D1) at a high frame rate, but when stored as *recorded* frames, they were “thinned” to a lower 1/60-second interval frame rate. (Suzuki, 13:29-32.)

176. As noted in **Part V.A.5**, my Declaration does not rely on Suzuki for its particular frame rate implementation, but for its broadly-applicable teaching of increasing frame rate for video when recording objects that appear closer in the video. As almost anyone who had used a video camera (including a camera on a mobile phone) would have appreciated, zoom operations are typically performed to focus on a target object in the image – in a sense, to bring that object “closer” to the camera. Suzuki confirms the desirability of increasing the frame rate in this situation, such as when capturing close-up image information such as a person’s facial expressions:

Thus, according to the present exemplary embodiment, in addition to a Zoom operation period, video is recorded in the recording medium **48** at a high frame rate during certain periods before and after the zoom operation period. Generally, when a user carries out a zoom operation, video captured before and after a zoom-in operation or a zoom-out operation includes a target object. Thus, the video includes important scenes that reflect the photographers intention, and examples of such scenes include goal scenes in sports games and close up facial

expressions. By recording the video captured before and after a zoom operation at a high frame rate as described above, the video captured before and after the zoom operation can be displayed effectively.

(Suzuki, 13:52-64.) For example, therefore, Suzuki discloses that a frame rate for video can be increased after a “zoom-in” operation, such as after zooming-in on a user’s face, in order to capture important information such as “close up facial expressions.” (*Id.*)

177. ***Manner, Rationale and Motivation to Combine (Rosenberg, Francois and Vidunas with Suzuki)***: It would have been obvious to combine the mirror-display system disclosed by the combination of Rosenberg, Francois, and Vidunas with the frame rate variation techniques disclosed in Suzuki. The combination would have predictably resulted in the system described by the proposed combination of Rosenberg, Francois, and Vidunas in which the frame rate for the video is varied (*e.g.* increased) when the user is closer to the camera.

178. It thus would have been obvious, based on the further combination with Suzuki, to *increase* the frame rate for the mirror display system of the proposed combination of Rosenberg, Francois, and Vidunas, when the user is closer to the mirror/display. As explained for limitation 1[g] in **Ground 1**, Rosenberg and Francois both disclose techniques for determining a distance of the user, for example as expressed in the distance (*d*) in Francois. Under the proposed combination,

therefore, it would have been obvious to increase the frame rate when the user is closer to the mirror/display, in order to provide greater detail for the video. The increase in frame rate would thus have increased the rate at which the “non-ordered steps” of claim 1 (*i.e.*, capturing digital images from a camera, flipping images about a vertical axis, applying transformation mappings and resizing the images, and then displaying the images) are performed – thus **“varying rate at which the non-ordered steps are performed on the series of images according to distance.”**

179. To be clear, my Declaration does not rely on Suzuki for its particular implementation of a zoom feature, but for its more broadly applicable teaching of the desirability of increasing frame rate when the video is capturing objects that appear to be closer to the camera. A zoom operation as disclosed in Suzuki does not physically bring an object in the image closer to the camera, but it does change the angle of view of the camera, thus magnifying the target object and making it appear closer. And almost anyone who had used a video camera (including a camera on a mobile phone) would have appreciated, a zoom operation is often performed to focus the image on a target object in the image by bring it “closer” to the camera. And this is where Suzuki provides a clear motivation to combine by increasing the frame rate of video to improve its quality.

180. As noted in the discussion of Ground 1, it was well-known that frame

rate can have a direct impact on the user's experience when viewing a video, with higher frame rates being generally associated with smoother and more natural motion. Suzuki acknowledges a phenomenon that persons of ordinary skill in the art and even laypersons would have immediately recognized – when objects move closer to the viewer (regardless of whether they move physically closer or appear closer because of zooming or magnification), the viewer can perceive see far more detailed information about the object's movements. This observation true regardless of whether the target object is another person, an insect, the shape of a falling drop of water, or any other object capable of fast and subtle movements. Using the example of a person, when he or she moves closer to a viewer, the viewer can see far more detail about the person's movements including body language, facial micro-expressions, and many other subtle movements.

181. Suzuki expressly notes this by explaining that an increase in frame rate would be warranted to capture “close up facial expressions.” (Suzuki, 13:52-64.) A person of ordinary skill in the art would have thus been motivated to increase the frame rate for the mirror system built based on Rosenberg, Francois, and Vidunas when the viewer is closer to the camera, in order to better capture this additional information when the user is closer to the mirror/display.

182. I acknowledge that under the proposed combination of **Ground 1**, the

frame rate increases when the viewer moves *farther away* from the mirror/display, whereas in **Ground 2**, the reverse is true – the frame rate increases when the viewer moves *closer* to the mirror/display. But in my opinion, this difference in behavior does not undermine either Ground 1 or Ground 2 because they are based on different but equally compelling motivations. Ground 1 increases frame rate to take advantage of the reduction in image data when the user is further away, whereas Ground 2 increases the frame rate to increase video detail for closer objects. A person of ordinary skill in the art would have found these to be valid justifications for varying the frame rate and may have found either to be the more compelling justification based on the specific needs of the target system. For example, the rationale in **Ground 1** might be more attractive to a person of ordinary skill in the art operating in a computing environment in which computing resources (such as limits on processing, storage and network bandwidth) are more scarce, whereas **Ground 2** might be more attractive to an application that prioritizes video image quality and has fewer constraints on computing resources. For both grounds, a person of ordinary skill in the art would have been motivated to combine for the reasons expressed.

183. A person of ordinary skill in the art would have had at least a reasonable expectation of success at implementing the proposed combination. As noted, my

proposed combination does not rely on Suzuki for its technical implementation, but for its more general suggestion of increasing frame rate when the apparent distance of the target object to the viewer decreases. The ability to alter the frame rate for a recording system was well-known and readily implemented using conventional programming techniques.

VI. NO SECONDARY CONSIDERATIONS OF NONOBVIOUSNESS

184. As explained in **Part III.B**, I understand that “secondary considerations” may be used as indicia of nonobviousness, provided that any such consideration has a nexus to the invention claimed. I understand from Petitioners’ counsel that Patent Owner in the related district court litigation has not yet identified any evidence related to secondary considerations with a nexus to the claimed invention. Nor am I aware of any information, such as commercial success, unexplained results, long felt but unsolved need, industry acclaim, simultaneous invention, copying by others, skepticism by experts in the field, and failure of others, suggesting that the claims addressed in this Declaration are not obvious. To the extent Patent Owner later provides information it claims relates to secondary considerations, I reserve the right to supplement my analysis and opinions to comment on it.

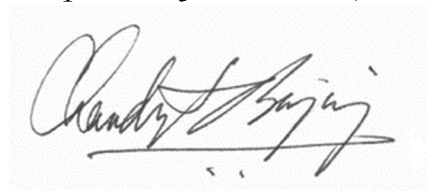
VII. CONCLUSION

185. In signing this Declaration, I recognize that the Declaration will be filed as evidence in a contested case before the Patent Trial and Appeal Board of the United States Patent and Trademark Office. I also recognize that I may be subject to cross-examination in this proceeding. If required, I will appear for cross-examination at the appropriate time. I reserve the right to offer opinions relevant to the invalidity of the '109 patent claims at issue and/or offer testimony in support of this Declaration.

186. I hereby declare that all statements made herein of my own knowledge are true and that all statements are made on information and belief are believed to be true, and further 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 18 U.S.C. § 1001.

Dated: January 28, 2022

Respectfully submitted,

A handwritten signature in black ink, appearing to read "Chandrajit Bajaj", written over a horizontal line.

Chandrajit Bajaj, Ph.D.
Austin, Texas

EXHIBIT A

CHANDRAJIT L. BAJAJ

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PERSONAL

Born April 19, 1958

Married, 2 sons, 1 daughter

United States Citizen

EDUCATION

1980 B.TECH. (Electrical Engineering), Indian Institute of Technology, Delhi

1983 M.S. (Computer Science), Cornell University

1984 Ph.D. (Computer Science), Cornell University

PROFESSIONAL EXPERIENCE

- Assistant Professor of Computer Sciences, Purdue University, 1984-89
- Associate Professor of Computer Sciences, Purdue University, 1989-93
- Visiting Associate Professor of Computer Sciences, Cornell University, 1990-91
- Professor of Computer Sciences, Purdue University, 1993-97
- Director of Image Analysis and Visualization Center, Purdue University, 1996-97
- CAM (Comp. Appd. Math) Chair of Visualization, University of Texas at Austin, 1997- Present
- Professor of Computer Sciences, University of Texas at Austin, 1997- Present
- Director of Computational Visualization Center, University of Texas at Austin, 1997- Present

HONORS, AWARDS & MEMBERSHIP IN PROFESSIONAL SOCIETIES

- National Science Talent Scholarship, 1975. Dean's Honor Roll, IIT Delhi, 1975-1980
- Scholastic Merit Award, (B. Tech. DGPA of 10.00/10.00)
- Member of National Science Foundation (NSF) Panels on Advanced Computational Research, Geometric, Symbolic and Numeric Computing, Major Research Instrumentation, 1990 – 2006
- Frame Technology Excellence in Publishing Award, 1993
- Purdue University, Provost's Research Center Initiation Award, 1994
- Association of Computing Machinery, Student Chapter, Appreciation Certificate 2001
- Member of National Institute of Health, Special Emphasis Study Sections, 2001, 2004
- Association of Computing Machinery, Recognition of Service Award, 2002
- University of Texas, Faculty Research Award 2004, Dean Research Assignment Award 2004
- Member of the Austrian Science Foundation (FWF), Scientific Evaluation Committee 2005 - Present
- Best paper award at Computer Aided Design (CAD) 2006
- Invited Jacques Morgenstern Colloquium INRIA- Sophia Antipolis, France, 2006, William Mong Distinguished Colloquium, Hong Kong University, 2012, Barrs Distinguished Colloquium, U of Florida, 2013
- Elected Member of Sigma Xi and Upsilon Pi Epsilon Honor Societies. Member of Association of Computing Machinery (ACM), Institute of Electrical and Electronic Engineers (IEEE), Biophysical Society, Society of Industrial and Applied Mathematics (SIAM), American Association for Advancement of Sciences (AAAS).

- Panel Member of the National Academy of Sciences, Vietnam Education Foundation, 2006, 2007
- Member of the NSF-CISE Board of Visitors, 2004, ETH Zurich, CS Dept Evaluation Committee (2004), INRIA Evaluation Committee 2007
- Chair Search Committee, King Abdullah University of Science and Technology (KAUST) Center Director 2008
- Member of Consolider Scientific Committee of the Spanish Ministerio de Ciencia e Innovacion, 2008, 2009
- Member of the NIH-NCRR National Biomedical Computation Resource Advisory Committee, 2006 – Present
- American Association for the Advancement of Science- Fellow - 2008
- Member of Mol. Structure Function (MSFD), Study Section, National Institute of Health, 2008 – 2010
- Chairperson of Mol. Structure Function (MSFD) Study Section, National Institute of Health, 2011 – 2014
- The 2010 Visions of Computing Lecture Series, UT-CS Austin, November 2010
- University of Texas-ICES-Moncrief Grand Challenge Faculty Research Award, 2009, 2012, 2016
- Fellow of the University of Texas Institute for Cellular and Molecular Biology (ICMB) 2009
- Fellow of The American Association for the Advancement of Science (AAAS), 2008 –, Association for Computing Machinery (ACM), 2009- , 2010-, Institute of Electrical and Electronic Engineers (IEEE), 2013 –; Fellow of the Society of Industrial and Applied Mathematics (SIAM) Aug, 2016 –
- Best Paper Award at ACM Symposium on Solid and Physical Modeling, 2010, Haifa, Israel
- Program Co-Chair, SIAM/ACM Geometric and Physical Modeling Conference, Orlando, Florida – 2011
- Conference Co-Chair of Pacific Graphics 2016, Okinawa Institute of Science and Technology (OIST), Naha, Okinawa, Japan, October 2016
- 1. Keynote Addresses at SIAM Computational Science (2000), Pacific Computer Graphics (2002), Volume Graphics (2004), EuroGraphics (2004), Computational Algebra (2004), Cyberworlds (2005), Institute of Mathematics and its Applications –IMA (2007), HSEMB Conference (2007), CAD Conference (2009), Physics/Biology Interface (2009), CompImage (2010), ACM Solid Physical Modeling (2010), Symposium on Geometry Processing (2011), IEEE Pacific Vis (2012), Intl Conf. On Contemporary Computing (2012), Advances in Comp. Mechanics, (2013), 22nd Meshing Roundtable (2013), NSF CyberBridges Workshop (2013), MBI-OSU Large Data Visualization Workshop (2014), Banff EM Workshop (BIRS) (2014), Computer Methods in Biomechanics and Biomedical Engineering, Imaging and Visualization, CMBBE (2015), Innovative Modelling Techniques for Predictive Medicine (2015), "Statistical Bio-Modeling for Predictive Medicine", UT Austin/Portugal CoLab-Advanced Computing research, Innovative Modeling Techniques for Predictive Medicine Workshop, 2015, IST, Lisbon, Portugal, Workshop on Mathematical Modeling and Analysis of Protein Cages, OIST, Jan 16, 2016, Invited Speaker, Cryo-EM Workshop, August 8-9, 2018, New York, New York.
- 2. ChinaGraph, November 9-11, 2018, Guangzhou, China, International Conference on Machine Learning and Data Science (ICML & DS 2018), December 21-22, 2018, Invited Speaker, "Spatio-Spectral Tensor Super-resolution" New York University, NY, January 24, 2019, Invited Speaker, "Spatio-Spectral Tensor Super-resolution" Stony Brook University, NY, January 25, 2019, Invited Speaker "Spatio-Spectral Tensor Super-Resolution with Chemical Priors" SIAM Conference on Computational Science and Engineering, February 25–March 1, 2019, Spokane, Washington "Are Spline Kernels Useful", University of Chicago, May 15-May 19, 2019, "Learning to Sample and Sampling to Learn", Amazon, Seattle, June 8-16, 2019, "Computation, Mathematics, and Statistics for Visual Search Applications", University of Peking- Beijing, China, July 2019, "Computation, Mathematics, and Statistics for Visual Search Applications", July 1-13, 2019, University of Peking- Beijing, China, ALBERT: A digital Pathology Electronic Assistant, August 2-4, 2019, UT Southwestern Medical center- Dallas and Univ of Oklahoma [Plenary] Statistical Deep Learning for Automatic 2D and 3D Cytotyping of tumor tissue-. Cold Spring Harbor- Asia conference, Shanghai, China, September 4, 2019, "Learning to Sense, Model. And Predict". Shanghai Jai Tong University- Shanghai, China, September 6, 2019, [Plenary] "Learning the Koopman Operator for Dynamic Simulations", Workshop on Digital Twins, University of Luxembourg, September 9-13, 2019, "Deep Learning Koopman Operator for Dynamic Data", Georgia Tech at Atlanta, Ga. Sept 17, 18, 2019, "Deep Learning for Static and Dynamic Data" Colloquium talk, NYU Data Sciences, Sept 27, 2019, "Deep Learning Koopman Modes for Dynamic Data" Colloquium talk, Princeton University, Sept 30, 2019, Learning to Correct Form and Function with Reinforcement, The 2nd TBSI Workshop on Learning Theory (TBSI-WOLT'20) July 20-22, 2020, Deep Learning to Correct Form and Function with Reinforcement, New Jersey Institute of Tech, December 9, 2020, Hyderabad, India, Numerical Geometry, Grid Generation and Scientific Computing, Moscow, November 2020
- Invited Presentations at BIRS, Dagstuhl, Oberwolfach
- Collaborative Teaching Grant Award (Dr. D. Briscoe) for BIO-(In)formatic Architecture Modeling in Architectural Design (ARC350R/ARC386M/CS378, Spring 2016, Funded by Learning Sciences, Provost Teaching Fellows.

- Member of BIMOS Scientific Advisory Board, Berlin Germany 2015 –
- Society for Industrial and Applied Mathematics- Fellow-2016
- Pioneer Award on Solid Modeling from Solid Modeling Association, July, 2016
- Distinguished Alumni Award, Indian Institute of Technology, Delhi, Aug, 2016
- Moncrief Grand Challenge Faculty Award, Institute for Computational Engineering and Sciences, 2014, 2016
- Member of Scientific Advisory board, Indian Institute of Technology, Delhi, 2018 –
- Honored with a Bountiful Tree at Trees for Tigers, Panna Tiger Reserve, Madhya Pradesh, India for delivering the talk during the IEEE CS-BITS GOA APPCAIR joint Webinar Series- 2021

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ACADEMIC ACTIVITIES

My current research is on the computer science and computational mathematics foundations of statistical and dynamic decision making, actionable intelligence and exploratory visualization. I develop classical and quantum, machine learning and geometric optimization algorithms for applications in the physical, chemical and environmental data sciences, medicine and neuro-morphic computing. I revisit my past research in modeling multi-scale form and function, through the lens of inferential data sciences,. My current research projects include (a) forward and inverse optimization problems in microscopy, spectroscopy, electro-magnetic and electro-optical wide spectrum imaging; (b) generative shape and new material design for spatially realistic and phenomenological models; (c) learning from nature and generating models and mechanisms with accelerated and emergent properties. I teach an undergraduate course titled “Geometric Foundations of Data Sciences” and a graduate course titled “Predictive Machine Learning”. I have courtesy appointments and supervise undergraduates, M.S. and Ph.D. students from several UT departments, including biomedical and electrical engineering, neuroscience, and mathematics.

The following is a link is to my most cited publications :

[http://scholar.google.com/citations?user=gyL3CZ0AAAAJ"&user=gyL3CZ0AAAAJ](http://scholar.google.com/citations?user=gyL3CZ0AAAAJ)

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2. 9/1/86 - 6/30/88 "Experimental Laboratory for Electronic Prototyping and Geometric Modeling", (\$117,000), National Science Foundation, CCR-8612590, (with M. Atallah, C. Hoffmann)
3. 7/1/87 - 6/30/88 "Algorithmic Robotics: Geometric Modeling and Motion Planning", (\$10,200), Purdue Research Foundation, David Ross Grant
4. 1/1/88 - 6/30/88 "Algebraic Methods in Solid Modeling", (\$26,500), Computer Aided Manufacturing - International, Contract No. H928/C
5. 7/1/88 - 6/30/89 "Algorithmic Robotics: Geometric Modeling and Motion Planning", (\$10,200), Purdue Research Foundation, David Ross Grant
6. 10/1/88 - 9/31/89 "An Experimental Laboratory for Computational Algebraic Geometry", (\$75,000), Defense University Research Instrumentation Program, DAAL03-88-G-0068, (with S. Abhyankar)
7. 1/1/88 - 6/30/90 "Computational Algebraic Geometry and Geometric Modeling", (\$150,000), Army Research Office/ Cornell MSI, DAAG29-85-C-0018, (with S. Abhyankar)
8. 7/15/88 - 9/31/90 "Modular Algorithms in Computational Algebraic Geometry", (\$217,000), Office of Naval Research, N00014-88-0402, (with S. Abhyankar)
9. 8/14/89 - 8/13/90 "Surface Fitting using Algebraic Surfaces", (\$10,200), Purdue Research Foundation, David Ross Grant
10. 5/15/89 - 9/31/91 "Algorithmic Algebraic Geometry", (\$160,000), National Science Foundation, DMS-8816286, (with S. Abhyankar)
11. 8/14/90 - 8/13/91 "Polyhedral Decomposition Algorithms", (\$10,200), Purdue Research Foundation, David Ross Grant
12. 7/1/91 - 12/31/91 "Efficient Algorithms and Data Structures for Geometric Design", (\$30,000), Air Force Office of Scientific Research, AFOSR-91-0276
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32. 1/1/96 - "Center on Image Analysis and Data Visualization", \$100,000 per year, Purdue University
33. 3/1/96 - 2/28/97 "Repetitive Contact Modeling, Analysis & Visualization", (\$139,760), National Science Foundation, CDA-9529499, (with B. Hillberry, and E. Sacks)
34. 8/14/96 - 8/13/97 "Deformable Modeling", (\$9,900), Purdue Research Foundation, Davis Ross Grant
35. 6/1/96 - 5/31/97 "Distributed Analysis and Visualization of Spinal Cord Injuries", (\$39,800) per year, Canadian Spinal Research Organization, Award No: 3409670
36. 6/1/96 - 2/28/97 "Flexible Constraint Management in CSCW", (\$26,500), National Institute of Standards and Testing, NIST grant No: 60NANB4D1645
37. 3/1/97 - 2/28/98 "Interrogative Virtual Reality", (\$126,818), Office of Naval Research N0014-97-1-0398
38. 4/1/97 - 12/31/97 "Visualization of Scalar, Vector and Tensor Field Data", (\$126,882), Air Force Office of Scientific Research, F 49620-97-1-0278
39. 6/1/97 - 4/30/98 "Prostate Image Characterization", (\$13,475), Indiana Center for Advanced Research, Award No: 6712868
40. 8/1/98 - 7/31/00 "Modeling and Visualization with Algebraic Surfaces and Splines", (\$150,000), National Science Foundation, CCR-9732306
41. 8/25/98 - 8/24/00 "Data Intensive, Display Intensive Visualization", (\$400,000), Sandia National Labs and Lawrence Livermore National Labs BD-4485
42. 7/1/98 - 6/3/00 "Data Intensive Visualization", (\$113,328), National Aeronautics and Space Administration NCC2-5276
43. 9/1/98 - 8/31/01 "Multiscale Physics-Based Simulation of Fluid Flow for Energy and Environmental Applications", (\$1,700,000) National Science Foundation, DMS-9873326 (with J. Wheeler, T. Arbogast, S. Bryant, Dawson)
44. 2/24/99 - 9/30/00 "Structural Simulation Using Multiresolution Material Models", (\$400,000) Sandia National Labs (with T. Oden, I. Babuska, G. Rodin)
45. 10/1/99 - 9/30/00 "Interaction Environments", (\$105,000) National Partnership for Advanced Computing Infrastructure (NSF-NPACI)

46. 10/15/99 - 9/30/02 "Terascale Data Visualization", (\$593,536) National Science Foundation ACI-9982297
47. 1/1/00 - 12/31/01 "MetaBuffer: Combining Realtime Parallel Graphics and Multiresolution VR Display", (\$161,040) Texas Higher Education Coordinating Board (with Donald Fussell)
48. 6/1/00 - 5/31/03 "Interrogative Synthetic Environments", (\$51,000) National Science Foundation INT-9987409
49. 10/1/00 - 9/30/01 "Interaction Environments", (\$308,000) National Partnership for Advanced Computing Infrastructure (NSF-NPACI)
50. 9/1/00 - 3/31/04 "Formal Methods Visualization", (\$493,177) National Science Foundation CCR-9988357 (with J. Moore)
51. 06/30/99 to 06/29/02 "Research in the Area of Computational and Applied Mathematics", (\$12,402), Lucent Technologies
52. 10/01/01 - 09/30/02 "Interaction Environments", (\$316,000), National Partnership for Computational Infrastructure (NSF-NPACI) Sub Contract from SDSC
53. 10/01/01 to 09/31/04 "Data Intensive and Display Intensive Computing", (\$400,000), Lawrence Livermore National Laboratory
54. 10/1/02- 9/30/05 "ITR: Large Scale Simulations of Emulsions", (\$400,000) National Science Foundation, ACI: 0220037 (with G. Rodin, R. Bonneau)
55. 10/01/02 - 09/30/03 "Interaction Environments", (\$315,000), National Partnership for Computational Infrastructure (NSF-NPACI) Sub Contract from SDSC
56. 9/1/03 to 8/31/04 "4D Deformable Anatomy Models for Radiation Therapy" (\$19,000) Whitaker-Biomed (with L. Dong)
57. 10/01/03 - 04/30/05 "Interaction Environments", (\$275,000). National Partnership for Computational Infrastructure (NSF-NPACI) Sub Contract from UCSD-SDSC
58. 9/15/03 - 8/30/07 "ITR: Subnanometer Structure Based Fold Determination of Biological Complexes", (\$2,250,000) National Science Foundation, EIA: 032550 (with Wah Chiu and Andrej Sali)
59. 09/1/03 - 08/31/08 "Mastadon: A High Throughput Simulation Infrastructure", (\$1,238,471) National Science Foundation (with R. Mikkulainen, D. Burger, K. McKinley and V. Ramachandran)
60. 06/1/04 - 05/31/08 "Towards a Computational Center for Biomolecular Complexes", (\$2,263,996) National Institutes of Health, P20-RR020647, (with W. Chiu (Baylor College of Medicine), H. Baker (Rutgers University), A. Olson (The Scripps Research Institute))
61. 04/1/05 - 03/31/2010 "Hierarchical Methods for Bio-Molecular Complexes", (\$718,065) National Institutes of Health, R01-GM074258
62. 10/01/05 - 09/30/10 "A Dynamic Data Driven System for Laser Treatment of Cancer", (\$805,930), National Science Foundation, CNS-0540033, (with T. Oden (PI), K. Diller, J. Browne)
63. 03/1/06 - 02/28/10 "A New Approach to Rapid Protein-Protein Docking", (\$850,000) National Institutes of Health, R01-GM07308
64. 09/01/06 - 08/31/09 MRI: "Acquisition of a High Performance Computing System for Online Simulation", National Science Foundation Equipment Grant (\$800,000), CNS-0619838, (with O. Ghattas, T. Oden, J. Boisseau, M. Wheeler)
65. 08/15/06 - 08/14/07 UT- Austin, Texas Institute for Drug Diagnostics Development - TI3D, (\$100,000), Post-Doctoral Student Grant
66. 03/01/07 - 02/28/13 "Software Maintenance for Biomolecular Complexes", (\$900,000), National Institutes of Health, R01-EB004873
67. 09/01/09 - 08/31/12 "Advanced Computing: Patient Specific Cardiovascular Modeling and Analysis", with T. Hughes of UT and Adelia Sequeira, et al, of Portugal, (\$175,000), Portuguese Science and Technology Foundation
68. 09/01/12 - 08/31/13 "Collaborative Research: Conceptualizing an Institute For Using Inter-domain Abstractions to Support Inter-disciplinary Applications", National Science Foundation OCI-1216701, (\$1,170,737), with S. Midkiff, D. Padua, K. Pingali, M. Kulkarni, R. Elber, J. Caruthers, A. Prakash, P. H Geubelle, J. Hart, V. Pai.
69. 04/01/14 - 09/30/16 "Global Optimization and Fourier Studies with application to Higher Order Meshing", Sandia National Labs Contract #1439100, (\$498,000)
70. 08/01/15 - 08/31/21 "Mathematical Chemical Imaging with Uncertainty Quantifications", BioMath (NSF/NIH) R01-GM117594-01, -02, -03 (\$1,539,212) with Pradeep Ravikumar (UT Austin) and Rohit Bhargava (UIUC)
71. 08/01/15 - 08/31/19 "Mathematical Chemical Imaging with Uncertainty Quantifications", BioMath (NSF/NIH) Supplement, 5R01GM117594 (\$35,750)
72. 06/01/2016 - 08/31/2017 "Virtual Surgical Atlas: Medical Modeling of the Pediatric Skull", Dell Medical School, (\$75,140) with Dr. Raymond J. Harshbarger, III, MD, Dell Medical School, Seton Family of Hospitals, OSP# 201602388, Project# CR-14-051

73. 08/15/15 – 12/31/17 “A-MOP – Algorithms for Macro-Molecular Pocket Identification”, INESC-ID/University of Lisboa (Portugal)(UTAP-EXPL/QEQ-COM/0019/2014), (\$14,935)
74. 06/06/2016 - 12/31/2017 “Polar Sampling and Optimization of Protein-Ligand Cocrystal Structures”, NIH of General Medical Sciences, Small Business Technology Transfer Program, GFREE BIO, LLC, Grant No: 1R41GM116300-01, (\$224,934) with Charles Reynolds (GFREE BIO)
75. 09/30/2020-09/29/2021- Intelligent Machine Learning for Real- Time Processing of Hyperspectral Video Streams- Army Futures Command-DOD-ARMY- Project Number W911NF1920333, PO7 (\$648,000.00)
76. 2/1/2021-01/31/2022- A Deep Learning Framework for Event Based Anomaly Detection- IFML-UT Austin, Univ of Wash, Wichita State and Microsoft- (\$50,000)
77. 7/1/2021-6/30/2023- “Deep Learning of Pancreas MRI to Predict Progression of T1D” NIH- 1R03DK12997901 (\$317,000) with Jack Virostko(UT- Computational Oncology- University of Texas at Austin)
78. (9/01/2021-)- Beatson Foundation
79. 9/1/2021-8/31/2022- Development of advanced machine (deep) learning algorithms to rapidly detect and accurately estimate the percentage of melanocytes expressing Mart1-Ki67 in borderline melanocytic lesions, and PDL1-in tumor cells, using double staining with tumor specific makers- MD Anderson Cancer Center and (TACC)- \$50,000(direct costs) with Phyu Aung(MD Anderson)- (split 25,000 each)

MULTIMEDIA

1. A. Abdelkader, C. Bajaj, M. Ebeida, A. Mahmoud, S. Mitchell, J. Owens, A. Rushdi “VoroCrust Illustrated: Theory and Challenges”. 2018 , pp. 77:1-77:4, 99

PATENTS

1. Encoding Images of 3-D Objects with Improved Rendering Time and Transmission Process. August 2002, US Patent 6438266

PROGRAM COMMITTEE MEMBER

1. Fourth Annual ACM Symposium on Computational Geometry, Urbana-Champaign, Illinois (1988)
2. HICCS Conference, Emerging Technologies - Simulation and Modeling, Kona, Hawaii (1991)
3. Seventh Annual ACM Symposium on Computational Geometry, New Hampshire (1991)
4. Third IEEE Workshop on Enabling Technologies for Concurrent Engineering, West Virginia (1994)
5. Graphics Interface 1995, Quebec City, Canada (1995)
6. Pacific Graphics 1995, 1996, 1997, 1998, 1999, 2000
7. Implicit Surfaces 1995, 1996
8. Eurographics 1995, 1996
9. IEEE Workshop on Enabling Technologies for Concurrent Engineering, West Virginia (1995, 1996)
10. Workshop on Algorithms and Data Structures (WADS) (1995)
11. Computer Graphics International (1996, 1997, 1998, 1999, 2000)
12. Workshop on Algorithms and Data Structures (WADS), Halifax, Canada 1997
13. IEEE Visualization Conference 1997, 1999
14. Fifth Intl. Conference on Computer-Aided Design and Computer Graphics, Shenzhen, China, December 1997
15. ACM Symposium on Computational Geometry (Theory) Minneapolis, MN, June 1998
16. IMA Math of Surfaces VIII, Birmingham, UK, August 1998
17. ACM SIGGRAPH, 1999
18. Chair, Intl. Symposium on Symbolic and Algebraic Computation (ISSAC) St. Andrew, Scotland, UK, 2000
19. Chair, ACM Annual Symposium on Computational Geometry (Applied Track) 2002
20. Program Committee Chair, ACM Annual Symposium on Computational Geometry, (Applied Track), 2002
21. Co-Chair of Visualization of Large Biomolecular Complexes Workshop, UCSD-Scripps, San Diego, 2006
22. Chair of an NIH Workshop on the Molecular-Cell Project, Austin, TX, 2006
23. International Computer Vision, Graphics and Image Processing (ICVGIP) 2006
24. 5th Workshop on Volume Graphics, (VG 2006), Boston MA

25. Pacific Conference on Computer Graphics and Applications, (PG 2007), Maui, Hawaii
26. Special Year on Algebraic Geometry at the IMA, 2006-2007
27. Geometric Modeling and Processing Conference, (GMP 2008), Hang Zhou, China.
28. ACM Symposium on Solid Modeling and Applications, (SPM 2008), Stony Brook, NY
29. Pacific Graphics, (PG 2008), Tokyo, Japan
30. International Conference on Cyberworlds, (Cyberworlds 2008), Hang Zhou, China
31. Workshop "Medical Imaging Systems", (EUROMEDIA 2008), Porto, Portugal
32. SIAM/ACM Joint Conference on Geometric and Physical Modeling, San Francisco, 2009
33. Geometric Modeling and Processing (GMP), Castro Urdiales, Spain, 2010
34. UT Austin - Portugal Summer School and Workshop, (CoLab 2010), Coimbra, Portugal
35. Ohio State University, Mathematical BioSciences Institute Workshop on "Analysis and Visualization of Large Collections of Imaging Data", (with P. Keller, M. Maggioni, A. Tanenbaum), Columbus, Ohio, February 2014
36. Chair of the PhD Admissions Committee, and Member of the Promotions Committee, Computer Science, 2015
37. Mathematics of Soft Matter Minisymposium, Okinawa Institute of Science and Technology (OIST), Okinawa, Japan, January 2016
38. Invited International Member of K1-Centre Consortium review team, "Competence K-1 Center in VrVis Visual Computing, The Austrian Research Promotion Agency, Vienna, Austria, June 2016
39. Member of BIMOS Scientific Advisory Board to assist with further design and development of the BIMOS Program, Berlin, Germany, June 20-21, 2016
40. NIH BD2K Trainee Selection Committee for Computational Sciences, Engineering, Mathematics and Computer Science, 2016
41. Budget Council 2016, Computer Science
42. Member, Selection Panel for Simons Foundation, Simons Investigators in the Mathematical Modeling of Living Systems (MMLS) internal competition, Vice President for Research, September 2016
43. Program Co-Chair, Pacific Graphics 2016, 25th Pacific Conference on Computer Graphics and Applications, (with T. Ertl, T Nishita), Okinawa Institute of Science and Technology (OIST), Okinawa, Japan, October 2016
44. Member, International Program Committee for the 2017 Symposium on Solid and Physical Modeling (SPM 2017), Berkeley, CA, USA, [June 19-21, 2017](#) (see: Member, International Program Committee for the 2017 Symposium on Solid and Physical Modeling (SPM 2017), Berkeley, CA, USA, [June 19-21, 2017](#) (see: <https://s3pm.icsi.berkeley.edu/s3pm/>))
45. Member, International Program Committee for the 2017 Symposium on Visualization (SOV 2017), Bangkok, Thailand, SIGGRAPH ASIA 2017 (<https://sa2017.siggraph.org/attendees/symposium-on-visualization>)
46. Berlin International Graduate School in Model and Simulation based Research- Scientific Advisory Board 2019, November 25th and 26th, 2019.
47. Data Science Faculty Recruiting committee- December 5, 2019
48. Ad Hoc Committees- 2019/20- Press
49. Ad Hoc Committee- 2019/20Vouga
50. CNS committee- 2019- NTT P&T committee
51. CSEM Admissions committee- 20-21
52. Moncrief recruiting committee- 20-21
53. Data Science Chair- 20-21
54. CS Student Assessment committee- 20-21
55. Computing Survey committee- 20-21
56. Committee member of the multidisciplinary Mid-Term Review Panel-Canadian Institute of Health Research(CIHR), (Natural Sciences and Engineering Research Council(NSERC) and Humanities Research Council(SSHR)- April 21-23, 2021-
57. Chair the CFREF Review Panel for York University(Spring 2021)
58. Faculty Mentor for CSE Certification program-2021
 - a) Deep Structured Inference Networks: Predictions and Actions for Improved Outcomes from Multi-modal Time Series and Imaging (e.g Intelligent Reconnaissance, Intelligent Health)
 - b) Learning to Optimally Control Stochastic Dynamical Systems (eg. Learn to Fold a Protein Faster than Nature, Inverse Game Theory)
 - c) Learning Shape Optimization through Reinforcement Learning (e.g Designing Stealth and Cloaking Devices, Meta-materials)

ORGANIZER

1. Special Course on Computational Algebraic Geometry and Geometric Modeling, Fifteenth Annual ACM SIGGRAPH Conference on Computer Graphics and Interactive Techniques, Atlanta, Georgia, 1988
2. Minisymposium on Computational Algebraic Geometry and Geometric Modeling, SIAM Conference on Geometric Design, Tempe, Arizona, 1989
3. Conference on Algebraic Geometry and its Applications, Purdue University, 1990
4. (Co-organizer), Special Course titled Unifying Parametric and Implicit Representations of Surfaces for Computer Graphics, Seventeenth Annual ACM SIGGRAPH Conference on Computer Graphics and Interactive Techniques, Dallas, Texas, 1990
5. Special Session on Algebraic Surfaces in Modeling and Visualization, IMACS 94, Atlanta, Georgia, 1994
6. Special Course titled "Representations of Geometry for Computer Graphics", Annual ACM SIGGRAPH Conference on Computer Graphics and Interactive Techniques, Orlando, Florida, 1994
7. (Co-Organizer with G. Farin, H. Edelsbrunner), Workshop on Voronoi Diagrams, Triangulations and Splines, Arizona State University, Feb 19 - 21, 1997
8. NIH Workshop on Visualization of Large Biomolecular Complexes, (with A. Olson) August, 2006, The Scripps Research Institute, San Diego, August 2006
9. Minisymposia on Geometry and Analysis, (with T. Hughes), World Congress in Computational Mechanics, Los Angeles, July 2006
10. Minisymposia on Geometry and Analysis, (with T. Hughes and Y. Bazilevs), US National Congress in Computational Mechanics, San Francisco, July 2007
11. MAA/AMS Workshop on Molecular Structure and Function, (with A. Gillette), Washington, DC, Jan 2009
12. COLAB UT-Portugal, Workshop on Biomedical Imaging and Visualization, (with L. Caffarelli, A. Gillette), Austin, Texas, March-April, 2009
13. Ohio State University, Mathematical BioSciences Institute Workshop on "Analysis and Visualization of Large Collections of Imaging Data", (with P. Keller, M. Maggioni, A. Tanenbaum), Columbus, Ohio, February 2014
14. Program Co-Chair, Pacific Graphics 2016, 25th Pacific Conference on Computer Graphics and Applications, (with T. Ertl, T. Nishita), Okinawa Institute of Science and Technology (OIST), Okinawa, Japan, Jan 2016
15. Co-Organizer, Mathematics of Soft Matter Minisymposium, (with E. Fried, P. Podio-Guidugli), Okinawa Institute of Science and Technology (OIST), Okinawa, Japan, January 2016

OTHER ACADEMIC ACTIVITIES

1. NSF panel member in Numeric and Symbolic Computation, for Small Business Industrial Research Grants, 1989
2. External Ph.D. examiner, Department of Computer Science, 1991
3. Invited panel member, "Toward Multimedia Computing" in the International Conference on Software and Knowledge Engineering, 1992
4. NSF panel member in Numeric, Symbolic and Geometric Computation, for Small Business Industrial Research Grants, 1993
5. IEEE Multimedia Technical Committee Member, 1993 - 1995
6. NSF panel member in Numeric, Symbolic and Geometric Computation, for Small Business Industrial Research Grants, 1994
7. NSF site visitor as part of an NSF-CISE Infrastructure team, 1995
8. MPEG-4 SNHC Geometric Compression Sub-Committee, 1996
9. Associate editor, ACM Transactions on Graphics, 1996 – 2005
10. Associate editor, SIAM Journal on Imaging Sciences, 2007 – 2011
11. Associate editor, International Journal of Computational Geometry and Applications, 1996 - *Present*
12. NSF panel member in New Technologies, 1998
13. Site visit team for Accelerated Strategic Computing Initiatives (ASCI), 1999
14. NSF panel member in Numeric, Symbolic and Geometric Computation, 1999
15. NSF panel member in Experimental Systems, 1999, 2000
16. NSF panel member in Advanced Computational Research, 2000
17. Associate editor, ACM Computing Surveys, 2003 – *Present*
18. Review Panel member, Austrian Science Foundation, 2006

19. Educational Panel Member for the Vietnam Education Foundation research fellowship committee, 2006-2007
20. KAUST Center Director Search Committee, 2008
21. Review Panel member, Austrian Science Foundation, 2008
22. CONSOLIDER Committee, 2008- 2012
23. Member of NIH Molecular Structure Function (MSFD) Computational BioPhysics Study Section, 2009 –2014
24. Member of National Biomedical Computation Resource(NBCR) Advisory Committee, 2010 - *Present*
25. Austrian Science Foundation, 2010
26. Editor, Chapman and Hall ICRC Mathematical and Computational Imaging Sciences Series, 2009 –*Present*
27. Editorial advisory board member of Lecture Notes in Computational Vision and Biomechanics, Springer Verlag, 2010 – *Present*
28. Advisory Board Member, Berlin International Graduate School in Model and Simulation Based Research (BIMoS at Technische University Berlin, Berlin, Germany 2015- *Present*
29. “Computer Science Vs. Cancer”, Invited UT Computer Science Alumni Talk, Oct 29, 2015, University of Texas at Austin
30. Invited reviewer for K1-Centre Consortium, “Competence Center in Polymer Engineering and Science (PCCL-K1), for The Austrian Research Promotion Agency, Consortium hearing June 15, 2016, Vienna, Austria
31. Invited guest speaker for 2016 USACM Conference on Isogeometric Analysis and Meshfree Methods, Oct 10-12, 2016
32. NIH BD2K Trainee Selection Committee for Computational Sciences, Engineering, and Mathematics and Computer science, 2016

COURSES TAUGHT AT PURDUE UNIVERSITY

1. CS414 Introduction to Numerical Analysis, Spring 1987
2. CS435 Computer Graphics, Fall 1993, Fall 1994, Fall 1995, Spring 1996, Fall 1996
3. CS482 Introduction to Design and Analysis of Algorithms, Spring 1986
4. CS484 Introduction to Theory of Computation, Spring 1985
5. CS541 Files and Database Structures and Systems, Fall 1984
6. CS572 Introduction to Artificial Intelligence, Spring 1989, Spring 1993
7. CS574 Advanced Computer Graphics, Fall 1989
8. CS580 Design and Analysis of Algorithms, Fall 1985, Spring 1992
9. CS584 Theory of Computation and Computational Complexity, Spring 1988, Spring 1994
10. CS586 Algorithmic Robotics, Fall 1991, Fall 1992, Spring 1996
11. CS590R Geometric Modeling and Motion Planning, Fall 1986, Spring 1988, Fall 1988
12. CS590Z Introduction to Scientific Data Visualization, Spring 1994, Spring 1997

ADMINISTRATIVE POSITIONS AT THE UNIVERSITY OF TEXAS

1. GSSC CAM Admissions Committee (TICAM), 1997-2000
2. CAM Research Fellowship Committee (TICAM), 1997-2002
3. Chair and Infrastructure Committee (TICAM), 1997-2000
4. Festivals and Publicity Committee (CS), 1997-1999
5. HPPC Vision and Strategy Task Force Committee (UT Vice President for Research), 1998-2000
6. Chair Committee (CS), 1998-2000
7. Graduate Admissions Committee (CS), 1998-2000
8. Chair Recruiting Committee (CS), 2000-2001
9. Faculty Evaluation Committee (CS), 2000-2002 (Chair, 2001-2002)
10. Chair Recruiting Committee (TICAM), 2000-2002
11. Computational Applied Mathematics, GSSC (TICAM), 2000-2002
12. CISE Committee (CS), 2004-2007
13. Faculty Recruitment Committee for Imaging Resources Center, 2005-2006
14. Search Committee for ICES Chair in Life Sciences, Chair, 2005-2006
15. ICES Advisory Board, 2005 – 2008
16. JTO Fellowship Award Committee (ICES), 2005 - 2008
17. CAM Graduate Studies Committee (ICES), 2006-2007
18. ICES Board of Advisers, 2008

19. GSC (CS), 1997 - Present
20. GSSC (ICES), 1997- Present
21. GSC (EE), 2000 - Present
22. GSC (Biomed), 2004 - Present
23. GSC (ICMB), 2005 - Present
24. GSC (Neurosciences), 2007 - Present
25. GSC (Mathematics), 2007 - Present
26. Neurosciences Graduate Curriculum Committee (Neurobiology), 2007 - Present
27. Faculty Recruiting Committee (CS), 2007 - 2008
28. Master Admissions Committee (CS), 2008 - 2010
29. Institute of Neurosciences Executive Committee, 2008 - 2012
30. SBES/Moncrief Search Committee on Molecular Sciences, 2009 - 2010
31. SBES/Moncrief Search Committee on Cardiovascular Engineering, 2009 - 2010
32. ICES Core Course B Curriculum Committee, 2009 – 2010
33. VP of Research representative to UT's International Oversight Committee, 2010-2011
34. Member of the Hamilton Book Awards Committee, 2013-2014
35. Doctoral Admissions Committee, 2013-2014, 2015-2016
36. Interdisciplinary Hiring Ad Hoc Committee, 2014-2015
37. Faculty Promotions Committee, Computer Science, 2015-2016, 2016-17
38. Moncrief Data Analytics Search Committee, 2016-17
39. Ad Hoc Budget Council for Alex Huth, 8/2017 -2018
40. CS Peer Evaluation for Etienne Vouga, April 2017
41. BD2KT32 Admissions Committee, Spring 2017
42. TOTAL High Performance Computing Group - Campus Visit Feb. 2
43. Computer Sceince, Engineering & Mathematics (CSEM) Admissions Committee 2017-2018

COURSES TAUGHT AT THE UNIVERSITY OF TEXAS

1. CS395T, Graphics, Modeling, Visualization, Fall 1998, Spring and Fall 1999, Spring and Fall 2000, Spring 2002
2. CS395T, Physically Based Geometric Modeling, Fall 2002
3. CS395T Multi-Scale Bio-Modeling and Visualization, Fall 2005, Fall 2006
4. CS354/BME 345, Intro. to Computer Graphics, Fall 1999, Spring 2001, Fall 2003, Spring 2004, Fall 2005, Fall 2006, Fall 2007, Fall 2008, Spring 2010, Fall 2010, Fall 2013, Spring 2014
5. CS384G/CAM 395T, Computer Graphics, Spring and Fall 1999, Fall 2000, Fall 2007, Fall 2008
6. CS384R, Geometric Bio-Modeling and Visualization, Fall 2007, Fall 2008, Fall 2010, Fall 2013
7. CSE 383M/CS 395T, "Statistical and Discrete Methods for Scientific Computation / Bioinformatics" Spring 2015
8. ARC350R/ARC386M/CS378 "BIO-(In)formatic Architecture Modeling in Architectural Design", Spring 2016
9. CS378 Geometric Foundations of Data Sciences, Fall 2017
10. CS383M Statistical and Discrete Methods for Data Analysis, Spring 2018
11. CS378 Geometric Foundations of Data Science, Fall 2018
12. Fall 2018 C S 399W Dissertation (Graduate)
13. Fall 2018 CSE 370 Individual Reading & Research (Undergraduate)
14. Fall 2018 CSE 392 Geometric Fndtns Of Data Sci (Graduate)
15. Fall 2018 CSE 698A Thesis (Graduate)
16. Fall 2018 M 392C Geometric Fndtns Of Data Sci (Graduate)
17. Spring 2019 C S 379H Computer Science Honors Thesis (Undergraduate)
18. Spring 2019 C S 395T Comp Stat Appl In Data Sci (Graduate)
19. Spring 2019 C S 399W Dissertation (Graduate)
20. Spring 2019 CSE 370 Individual Reading & Research (Undergraduate)
21. Spring 2019 CSE 383M Stat/Discrete Meths Sci Comput (Graduate)
22. Spring 2019 CSE 698B Thesis (Graduate)
23. Spring 2019 E E 697C Research Problems (Graduate)
24. Spring 2019 M 393C Stat/Discrete Mthd Sci Comp (Graduate)
25. Spring 2019 SDS 389R Graduate Research (Graduate)
26. Summer 2019 C S W379H Computer Science Honors Thesis (Undergraduate)

27. Summer 2019 CSE W390 Individual Research (Graduate)
28. Fall 2019 CS 379H Computer Science Honors Thesis
29. Fall 2019 CS 399W Dissertation
30. Fall 2019 EE 398R- Master's Report-Se-
31. Fall 2019 CSE 370- Individual Reading and Research
32. Spring 2020 CSE 370F- Undergraduate Research & Writing
33. Spring 2020-CS 378-Geometric Fndtns of Data Sci
34. Spring 2020- CS395T-Machine Learn in Data SCIS
35. Spring 2020-M 392C Geometric Fndtns of Data Sci
36. Spring 2020-M 393C Stat/Discrete Mthd Sci Comp
37. Spring 2020-CSE 383M Stat/Discrete Meths Sci Compu
38. Spring 2020- CS 395T- Comp Stat Appl In Data Sci
39. Spring 2020- CS 399W- Dissertation
40. Spring 2020- CSE 370 Undergrad Reading and Research
41. Spring 2020- CS 390 Individual Reading(Grad)
42. Spring 2020-PHY 341 Geometric Foundations of Data Science
43. Spring 2020- M375- Conference course (undergraduate)
44. Summer 2020 CSE 370- Individual Reading and Research(undergrad)
45. Summer 2020 CSW 395- Conference Course
46. Summer 2020 CSE S370- Individual Reading and Research
47. Fall 2020- CSE 390-Individual Reading
48. Fall 2020- CSE 392- Foundations of Predictive Machine Learning
49. Fall 2020- CSE 392- Geometric Foundations of Data Science-Wb
50. Fall 2020- M-392C- Geometric Foundations of Data Science
51. Fall 2020- M-392C- Foundations of Predictive Machine Learning
52. Fall 2020- Phy 341- Geometric Foundations of Data Science
53. Fall 2020- SDS 379R- Undergraduate research
54. Spring 2021- CSE 390-Individual Reading
55. Spring 2021- CSE 392- Foundations of Predictive Machine Learning
56. Spring 2021- CSE 392- Geometric Foundations of Data Science-Wb
57. Spring 2021- M-392C- Geometric Foundations of Data Science
58. Spring 2021- M-392C- Foundations of Predictive Machine Learning
59. Spring 2021- Phy 341- Geometric Foundations of Data Science
60. Spring 2021- SDS 379R- Undergraduate research
61. Spring 2021- CSE 398R- Master's Report
62. Summer 2021- CSE W 390- Individual Research

Ph.D. STUDENTS

Completed Ph.D. Students (Chair)

1. Myung-Soo Kim, December 1988, (Professor Seoul National University, Seoul, Korea)
2. Tamal Dey, August 1991, (Professor Ohio State University, USA)
3. Insung Ihm, August 1991, (Professor Sogang National University, Seoul, Korea)
4. Andrew Royappa, December 1992, (Professor Mississippi State University, USA)
5. Vinod Anupam, June 1994, (Senior Research Scientist, Google Inc, Mountain View, USA)
6. Jindong Chen, December 1995, (Senior Research Scientist, Google Inc, Mountain View, USA)
7. Fausto Bernardini, December 1996, (Senior Research Scientist, IBM Research Yorktown Heights, USA)
8. Kwun-nan Lin, December 1996, (Private Entrepreneur, Taipei, Taiwan)
9. Dan Schikore, August 1997, (Senior Research Scientist, CEI International, North Carolina, USA)
10. Peinan Zhang, December 1997, (Research Scientist, SUN Microsystems, California, USA)
11. Guozhong Zhang, May 1999, (Research Scientist, Intel Research, Portland, USA)
12. Steve Cutchin, August 1999, (Director, San Diego Super Computer Visualization Center,)
13. Valerio Pascucci, May 2000, (Professor, University of Utah, Salt Lake City, UT)
14. Susan Evans, August 2001, (Research Scientist, Xerox Corporation, California, USA)
15. William Blanke, December 2001, (Professor University of Fiji, Fiji Island)
16. Xiaoyu Zhang, December 2001, (Professor of California State University, California,)

17. Bong-Soo Sohn, August 2005, (Professor of Kyungpook National University, Daegu, Korea)
18. Yongjie Zhang, August 2005, (Assistant Professor at Carnegie Mellon University)
19. Zeyun Yu, August 2006, (Assistant Professor, University of Wisconsin, Milwaukee, WI)
20. Sangmin Park, December 2006 (Research Scientist, Siemens Research Center, Princeton, NJ)
21. Vinay Siddahanavalli, December 2006 (Research Scientist, Google Inc, Mountain View, CA)
22. Wenqi Zhao December 2008 (Research Instructor, Bowling Green University)
23. Shun Chuan “Albert” Chen, December 2009 (Research Scientist, Google Inc, Mountain View, CA)
24. Andrew Gillette, May 2011 (PostDoc, University of California, San Diego, CA)
25. Radhakrishna Bettadapura August 2012 (Research Scientist at Strand Life Sciences)
26. John Edwards, May 2013 (Postdoctoral Fellow, University of Utah)
27. Muhibur Rasheed, August 2014 (Research Scientist at CD-Adapco, Austin, Texas)
28. Supawit Chockchawat- graduated 2021- now in University of Illinois PhD Program
29. Avik Roy-PhD- Graduated Summer 2021- Physics- Developing and Implementing physics informed deep learning architectures
- 30.

Ph.D. Students in Progress (Chair-Supervisor)

Nathan Clement, 2015-

Yi Wang- CSEM ,PhD- 2018-present-

Chase Tessmer - CSEM- PhD-taking a break-Spring 2019 –Summer 2021-

Ryan Farrell(Operational Research and Industrial Engineering)- Fall 2021-AFC/Equinox Research Fellowship

Minh Nguyen- Fall 20-21-PhD-Math

Taemin Heo- CS- 2021 Masters- Computational Science Certificate-Graduated- now in PhD program

Juntao Wang- Doctoral (Fall 2020- Spring 2021)- CSEM- left UT in Spring 2021

Ph.D. Students (Committee Member)

Jeff Manning, ECE-2017 – 2020- Graaduated Spring 2020-

Xiangru Huang, CS Fall 2019 -

Jiong Zhang- CSE-Spring 2019-

Dilin Wang, CS- 2018 -2020- Graduated Summer 2020

Shu-Wei Tsao-Physics- Spring 2020-

Therese Eileen Paoletta- Physics- Spring 2021

Jong Won Ma-CE- Spring 2021

Sumit Sinha-PhD-Fall 2020- Present- Physics and Machine Learning

POST-DOCTORAL STUDENTS

Completed Post-Docs

Dr. Sanghun Park 1998-2000 (Currently Professor at Dongguk University, Seoul, Korea)

Dr. Ariel Shamir 1999-2001 (Currently .Professor at Herziliya University, Israel)

Dr. Julio Castrillon-Candas 2003-2005

Dr. Yongjie Zhang 2005-2007 (Currently Professor at Carnegie Mellon University)

Dr. Samrat Goswami, 2006 – 2008 (Currently at CAD , Boston)

Dr. R. Inkulu, 2007 – 2008

Dr. Wenqi Zhao, 2008 – 2009 (Currently Assoc. Professor at Michigan State University)

Dr. Cliff Rumsey, 2008 – 2010

Dr. Rezaul Chowdhury, 2007 – 2010 (Currently Asst. Professor at StonyBrook University)

Dr. Alex Rand, 2009 – 2012 (Currently Research Scientist at CD Adapco, Austin, Texas)

Dr. Qin Zhang, 2008 – 2012 (Currently Research Scientist at Houston)

Dr. Deukhyun Cha, 2010 – 2013 (Currently Research Scientist at Houston)

Dr. Ahmad Rushdi 2014 – 2016 (Currently Research Scientist at Sandia National Lab.)

Dr. Muhibur Rasheed 2014-2015 (Currently Research Scientist at CD-Adapco, Austin, Texas)
Dr. Tianming Wang 2018-2020 (Currently Asso. Prof in Southwestern Univ of Finance and Econ in Chengdu of China)

PostDoc Students in Progress

Dr. Ahmed Abdelrazek (Sept 2020-Present)

Research Fellows:

Mohamed Abouhawwash- Oct 2021-

Completed MS STUDENTS

Katherine Clarridge, (BME), May 2006
Alex Mollere, (CSEM), May 2009
Jesse Sweet, (Math), May 2008
Bharadwaj Subramaniam, (CSEM), May 2010
Yu Lu (Physics) Dec 2018
Haoran Zhang 2019-2020
Richard Matthews- Fall 2020- CS- Master's thesis
Akshay Varanasi (CSEM), 2018-2019
Taemin Heo- CS- 2021 Masters- Computational Science Certificate-Graduated- now in PhD program

MS Students in Progress

Shijing Zhong- CSE-Spring 2020-
Michael Andrew Davis- ECE-Fall 2019-
Yorick Sanders- Masters 2020-2021- Computer Science-Rectifying connections between observable biomedical variables regarding Type 1 Diabetes and elucidating latent information from the original data through learned transformations
Rochan Avlur-Masters-Spring '21 Computer Science- Developing sample efficient and uncertainly bounded methods to solve rank-ordered search and score tasks in time critical domains with extremely large search spaces
Yunhao Yang-Masters- Fall 2020- CS/Math- to graduate in May 2022- Learning latent subspaces for image denoising
Sean Zanyk McLean- Master's Fall 2021- present- CSEM

UNDERGRADUATE RESEARCH STUDENTS (Chair)

Completed Undergraduate Students

Nona Sirakova (CS) August 2012
David Moench (CS), August 2014
Suchith Vuppala (CS), May 2014
Pragati Prasad (CS), August 2014
Holim Lee (CS) <date>
Huijin Kim (CS) <date>
Chetan Kumar, (BME) <date>
Keerthana Kumar (CS) <date>
Chand John (CS) <date>
Balaz Kustar (Mathematics) Independent study-August 2019-Turing Scholar Thesis
Benny Meltzer (Math) Graduated- Dec 2019- Turing Scholar Thesis
Supawit Chockchowwat (CS) Graduated-May 2020- Turing Scholar Thesis

Current Undergraduate Students

2019

Andrew Davis (ECE) Dec 2019, Demetrius Rowland (ECE), Dec 2019,

2020- Summer

Minghan Yu(Math)- 2020, Binglin Zhang(Math) 2020, Eshani Kaul(CS)- 2020, Shijing Zhong- 2020

Yunhao Yang- 2020 (Summer Moncrief Student), Tarun Thummala(CS), Tyler Parker (CSEM) May 2020, Matt Hall- 2020, Abhijit Raman- 2020, Aditya Gadiyar- 2020, Benjamin Beal(CS) , David Benny, Jonathan Randall-(CS), Kevin Jin- Conrad Li(CS), Nithin Anumala(CS), Pranav Eswaran(CS), Kevin Jin, Shamira Kabir, Shikhar Gupta(CS), Yuhang Zheng, Tyler Miller

Fall 2020:

Conrad Li- (CS), Benjamin Beal-(CS), Joshua Prupes, Nithin Anumala-2020, Pranav Eswaran-2020

Ryan Bethke-(CS and Spanish), William Gross(CS), Abhishek Dayal(CS/Math), Shikhar Gupta(CS), Eshani Kaul, Arman Maesumi, Theodore Morales(CS), Mingkang Zhu, Abrar Anwar(CS), Binglin Zhang

Spring 2021:- not teaching this semester- all below are research assistants

Conrad Li-(CS)-AFC, Benjamin Beal-(CS)-AFC, Harrison White(ME), Nikhil Ajjarapu(CS)-AFC, Joseph Chen, Minghan Yu, Binglin Zhang(Math), Edward Zhou(Math)

Summer 2021: Below are research assistants

Rochan Chan(CS), Ryan Farell (ORIE), Minh Nguyen(Math), Avik Roy, Yorick Sanders(CS), Sean Zanyk McLean(CSEM), Conrad Li(CS), Taemin Heo(CSEM), Luke McLennan(Moncrief Summer Intern), Omatharv Vaidya, Yash Totlani, Sumit Sinha(physics), Vineet Yang, Edward Zhou(Math), Soumil Chopra(Biomedical engineering-indep study), Zachary Endres, Yunhao Zheng, Akash Suruvu, Ariaan Ghatate(HS), Dangyan Zhang, Krishna Reddy(CS), Priyansh Kedia(UG-India), Thomas Ghorbania, Sebastian Rutherford, Supawit Chockhowat, Amrutha Srinivasan(Biomedical Engineering)

MEMBER OF MS/PhD Committee

Peter March of ME, (Ph.D. chair Dr. Delbert Tesar)
Darlan Girao of Math, (Ph.D. Chair Dr. Alan Reid)
Yul Young Park, INS (Ph.D. chair Dr. Dan Johnston)
Ming Ming Wu, Neurobiology (Ph.D. Chair Dr. Harold Zakon)
Rui Mao, CS (Ph.D. Chair Dr. Dan Miranker)
Matthew Alden, CS, (Ph.D. chair Dr. Risto Mikkulainen)
Ligang Long, Math, (Ph.D. chair Dr. Dr. Cameron Gordon)
Ann M. Clemens, Neuroscience (Ph.D. Chair Dr Daniel Johnston)
James Delfeld, Math. (Ph.D. Chair Dr. Ronald Hadani)
Itamar Gal (Ph.D. Chair Dr. Rachel Ward)
Jeff Manning (Ph.D. Chair Ross Baldick, ECE), 2019
Jiong Zhang (Ph.D. Chair Inderjit Dhillon, CS), 2018
Madeline Folkerts (MS. Supervisor, BME), 2018

Oden Institute/Computational Visualization Center Visitors

18-19: Dr. Krzysztof Gajowniczek, Warsaw University of Life Sciences (Spring 2019)
18-19: Dr. Bong-Soo Sohn, Chung-Ang University, (JTO, 2019)
18-19- Benjamin Berkels and Bong-Woo Sohn.O
17-18 Ruslan Akhmetvaleev, Moscow (Fulbright 2018)
17-18: Dr. Chand John, Stanford University, (Summer 2018)
17-18: Bernard Mourrain, Gerrit Welper, Paolo Podio-Guidugli, Bong Soo Sohn, Abel Gomes
16-17: Gerrit Welper, Benjamin Berkels

15-16: Bernard Mourrain, Paolo Podio-Guidugli, Eliot Fried, Tamal Dey
 14-15: Gitta Kutyniok, Bernard Mourrain, Antje Vollrath, John Edwards
 13-14: Rohit Bhargava, Jaydeep Bardhan
 12-13: Antje Vollrath, Bernard Mourrain, Laureano Gonzalez-Vega, Paolo Podio-Guidugli, Antonio Di Carlo, Andrea Micheletti, Paolo Podio-Guidugli, Charles Reynolds
 11-12: Wenping Wang, Andrew Gilette, Michael Holst, Paolo Cermelli, Paolo Podio-Guidugli, Yunrong Zhu
 10-11: Ozan Oktem, Antje Vollrath, Wenping Wang
 09-10: Guoliang Xu, Paolo Podio-Guidugli, Luciano Teresi, Sergey Bereg
 08-09: Laureano Gonzalez-Vega, Alberto Paoluzzi, Ozan Oktem, Amabile Tatone, Xiaoyu Zhang, Guoliang Xu, Zeyun Yu, Paolo Podio-Guidugli, Antonio DiCarlo
 07-08: Insung Ihm, Na Lei, Annie Raoult, Yoel Shkolnisky, Carlos Oscar Sanchez Sorzano, Guoliang Xu, Zeyun Yu
 06-07: Alberto Paoluzzi, Sanghun Park, Jorg Peters, Ulrich Reif, Theofanis Strouboulis, Luciano Teresi, Guoliang Xu
 05-06: Alberto Paoluzzi, Vladik Kreinovich, Denis Zorin, Tao Ju, David Goodsell, Bong Soo Sohn, Tomoyuki Nishita, Guoliang Xu
 04-05: Guoliang Xu, Karol Miller, Shigeru Owada, Xiaoyu Zhang, Insung Ihm, Alberto Paoluzzi

SUPERVISION/TRAINING OF SUMMER INTERNS

Andre, Nuno (2010), Ana Jantadarna (2011), Thomas Kelleher (2012,2013), Bruno Araújo, José Ricardo Ribeiro, Joao Silva and Tiago Martins, Bruno da Silva, Jorge Oliveira (2014), Filip Drowsdowski (2014), Jialin Wu (2016), Amisha Jhanji (2016), Abinav Chandar (2016), Zachary Walters (2016 with Dr. Danelle Briscoe, Architecture), KAUST Gifted Summer Research Program, July 12 - August 11, 2016: Rawan Al Yahya, Sara Alshaik Hussain, Khuzam Al Shubbar (2016); Young Min Kim Visiting Research Scholar (June 28, 2016-February 28, 2018); Moncrief Undergrad Summer Intern-Stephen Davis Owen (June 5-Aug 11, 2017); Xiaolong Zhang, Visiting Researcher Scholar, China; Arjun Karpur, (2017); Zhou Lu (Peking math, June 27, 2017) Summer internship; Zihao Wei (July, 2017) Summer internship; Yufeng Zhang (USTC math, July, 2017); Xi Ye (2017); Mythreya Kuricheti (2018); Abhilash Karpurapu (2018), Aditya Gupta (2018), Jahnvi Vikrama (2018); Maryam Aljeshi (2018); Mohammad Subah (2018); Khalid Aldawood (2018); Simiao Zuo, Moncrief; Charles K. Tusa, Moncrief (2018), Yukang Cao (2019)

INVITED CONFERENCE/WORKSHOP/ PLENARY/KEYNOTE PRESENTATIONS

3. "Applying Galois Methods to Geometric Optimization Problems", SIAM Conference on Geometric Modeling and Robotics, Albany, New York, July 1985
4. "Generalized Unfoldings for Shortest Paths", SIAM Conference on Geometric Modeling and Robotics, Albany, New York, July 1985
5. "Efficient Generation of Conguration Spaces", Army Robotics Workshop, Rennselear, Troy, New York, June 1986
6. "Automatic Rational Parameterization of Curves and Surfaces", Army Robotics Workshop, Rennselear, Troy, New York, June 1986
7. "The Parameterization of Rational Curves and Surfaces", Computers and Mathematics Conference, Stanford, California, July 1986
8. "Geometric Modeling Research, Computer Aided Manufacturing", International, Geometric Modeling Group, San Jose, California, January 1987
9. "Genus is a Birational Invariant", Midwest Theory Conference, University of Illinois, Urbana, Illinois, April 1987
10. "Algorithmic Implicitization and Parameterization: The Known and the Unknown", Research Conference on Geometric Design, Detroit, Michigan, May 1987
11. "Algebraic Methods in Geometric Modeling, Computer Aided Manufacturing", International Geometric Modeling Group, Boston, Massachusetts, May 1987
12. "Geometric Modeling Research", Tata Research and Development Center, Pune, India, June 1987
13. "Geometric Modeling and Robotics", Computer Maintenance Corporation, Hyderabad, India, June 1987
14. "Motion Planning with Algebraic Objects", First International Conference on Industrial and Applied Mathematics, ICIAM'87, Paris, France, June 1987

15. "Genus is a Birational Invariant: Parameterizing Algebraic Space Curves", SIAM Conference on Applied Geometry, Albany, New York, July 1987
16. "Convex Decompositions and Gaussian Approximations of Curved Objects", SIAM Conference on Applied Geometry, Albany, New York, July 1987
17. "Algorithms for Algebraic Curve and Surface Parameterization" workshop on Algebraic Computational Geometry, Bellairs Research Institute of McGill University, Holetown, Barbados, 1988
18. Workshop on Algorithmic Aspects of Geometry and Algebra, Mathematical Sciences Institute, Cornell University, Ithaca, NY, 1988
19. Invited keynote speaker, Third IMA Conference on the Mathematics of Surfaces, Keble College, Oxford University, 1988
20. ONR Workshop on Geometric Design, Moscow, Idaho, 1989
21. Special Session on "Mathematical Questions in Computational Geometry", American Mathematical Society, Boulder, Colorado, 1989
22. Workshop on Practical Issues in Computational Geometry, DIMACS, Princeton University, Princeton, 1990
23. Workshop on Algebraic Issues in Computational Geometry, DIMACS, Princeton University, Princeton, 1990
24. I.CO. GRAPHICS'91 Conference in Milan, Italy, February 1991
25. Special Year on Symbolic Computation at the Nankai Institute of Mathematics, Tianjin, China, April 1991
26. Dagstuhl-Seminar on Algorithmic Geometry, Saarbrücken, West Germany, October 1991
27. Curves and Surfaces in Computer Vision and Graphics II, SPIE Conference, Boston, MA, November 1991
28. "Multivariate Interpolation and Approximation", Presentation, 7th Texas Approximation Theory Conference, Austin, Texas, January 1992
29. "Experiments in Distributed and Collaborative Design", DARPA workshop on Manufacturing, Salt Lake City, Utah, January 1992
30. "Algebraic Surface Design and Finite Element Meshes", Presentation, NASA Workshop on Software Systems for Surface Modeling and Grid Generation, Langley Research Center, Hampton, Virginia, April 1992
31. "Parameterization in Finite Precision", Presentation, Graphics Interface '92, Vancouver, British Columbia, Canada, May 1992
32. "Multimedia Computing (What now in User Interfaces)", Invited Presentation at a Panel, Fourth International Conference on Software Engineering and Knowledge Engineering, Capri, Italy, June 1992
33. "Implicit Algebraic Splines and Applications", Tenth Army Mathematics Conference, West Point, New York, June 1992
34. "Generalized Hermite Interpolation for Algebraic Varieties", Invited Presentation, International Workshop on Mathematics Mechanization, Institute of System Sciences, Beijing, China, July 1992
35. International Workshop on Algebraic Approaches to Geometric Reasoning, RISC-LINZ, Austria, August 1992
36. International Conference on Computer Graphics, Bombay, India, February 1993
37. Dagstuhl-Seminar on Computational Geometry, Saarbrücken, West Germany, March 1993
38. "Virtual Reality and Virtual Environments", ONR Workshop, Research Triangle Park, North Carolina, May 1993
39. Siggraph 1993 Course on Implicit Surfaces, Anaheim, California, August 1993
40. Minisymposia at 1993 SIAM Conference on Geometric Design, Tempe, Arizona, November 1993
41. International Conference on Computer Aided Geometric Design, Penang, Malaysia, July 1994
42. Workshop on "Human-Computer Interaction and Virtual Environments", University of Virginia, Hampton, VA, May 1995
43. "Mathematics of numerical analysis: real number algorithms", SIAM, Park City Utah, July 1995
44. Annual Pacific Graphics Conference, Seoul, Korea, August 1995
45. Minisymposium on Surface-on-Surfaces at the Geometric Design Conference, Nashville, Tennessee, November 1995
46. "Modeling Surfaces and Associated Fields" Dagstuhl-Seminar on Geometric Modeling, Schloss Dagstuhl, West Germany, May 1996
47. Invited Talk on "High Performance Scientific Computing" (C3AD), Brazil, July 1. 1996
48. Course on "Representations of Geometry", SIGGRAPH 96, New Orleans, July 1996
49. Course on "Implicit Surfaces", SIGGRAPH 96, New Orleans, July 1996
50. Canadian Conference on Computational Geometry, Ottawa, Canada, August 1996
51. IMA Conference on the Mathematics of Surfaces, Dundee, Scotland, UK, September 1996
52. "Progressive Compression of Arbitrary Triangular Meshes", Conference on Hierarchical Methods in Computer Graphics, Dagstuhl-Seminar on Scientific Visualization, Schloss Dagstuhl, West Germany, May 1997

53. Minisymposium on Reverse Engineering, Conference on Computer Aided Geometric Design, Lillehammer, Norway, July 1997
54. IMACS conference on Problem Solving Environments Berlin, Germany, August 1997
55. The Laredo Course on Applications of Symbolic Computing, Laredo, Spain, September 1997
56. Tutorial at Eurographics '97, Budapest, Hungary, September 1997
57. "Hierarchical Free Form Modeling Using A-patches", Dagstuhl Germany, Workshop on Hierarchical Methods in Computer Graphics, Dagstuhl Germany, November 1998
58. Conference on Computer Aided Geometric Design, , ETH Zurich, "Multi Resolution Modeling & Visualization", July 1998
59. The Conference on New Themes in Computer Aided Geometric Modeling, Tel-Aviv, Israel, February 1998
60. "Freeform Modeling on Vector Fields for Interrogative Visualization", Oberwolfach Germany, Conference on Free Form Surfaces, at the Mathematisches Forschungsinstitut Oberwolfach Seminar , June 1998
61. NSF Large Data Visualization Workshop, Salt Lake City, UT, "Terascale Visualization", May 1999
62. "Vector Topology in Geometric Modeling and Visualization", Symbolic Numeric Computation Conference, Hagenberg, Austria, August 1999
63. Conference on Algebra and Algebraic Geometry with Applications, "Abhyankar Festschrift", Purdue University, Lafayette, Indiana, June 2000
64. [Keynote] "Higher Performance Visualization", First SIAM Conference on Computational Science & Engineering, Washington, DC, September 2000
65. Panel Presentation, "The Transfer Function Bake-Off Challenge", IEEE Visualization Conference, Salt Lake City, UT, October 2000
66. Panel Presentation "The Next Steps in Scalable Visualization", NPACI, All Hands Meeting, San Diego, CA, February 2001
67. UC San Diego - Advisory Member of Dr. Mark Ellisman's National Center on Microscopy Research, San Diego, CA, April 2001
68. "Subdivision Based Finite Element Solution of Anisotropic Diffusion Equations", IMA Workshop on Geometric Modeling, Minneapolis, MN, April 2001
69. "Scalable Rendering on COTS Clusters", IMA Workshop on Computer Graphics, Minneapolis, MN, May 2001
70. "Remote Visualization", TEXGRAPH 01, Houston, TX, May 2001
71. "Anisotropic Diffusion in 3D Image Processing", IPAM Workshop on Geometric Diffusion and Image Processing, Los Angeles, CA, May 2001
72. "Geometry Processing and Visualization in Hierarchical Modeling in Heterogeneous Materials", Sandia National Lab, Project Grantee Workshop, Albuquerque, NM, May 2001
73. "High Performance Visualization Techniques", WSCG2002 Conference, Plzen, Czech Republic, February 2002
74. "Algebraic Geometry of Molecular CAD", Symbolic Computation Workshop, Catania, Italy, March 2002
75. "Algebraic Geometry Computation and Applications", Workshop, Hefei, China, April 2002
76. "Active Visualization", Eurographics Workshop on Virtual Environments, Barcelona, Spain, May 2002
77. "Molecular Modeling and Visualization" Gordon Conference on Diffraction Methods, Connecticut, July 2002
78. "Molecular Modeling and Visualization" IUCR World Congress on Crystallography, Geneva, Switzerland, August 2002
79. [Keynote] "Volumetric Filtering Modeling and Visualization for Nano-Medicine", Eurographics 2003, Granada, Spain
80. "Quantitative Visualization of Static and Dynamic Macromolecular Complexes", Workshop on Visualization of Large Macromolecular Complexes, Berkeley, CA, October 2003
81. Invited Altenberg Lecture "Visual Representations in Biology", Konrad Lorenz Institute of Theoretical Biology, Vienna, Austria. February 2004
82. Invited McGovern Lecture "Image Processing and Visualization for Structural Biology", University of Texas Health Sciences, Houston. February 2004
83. Invited Presentation, "Cubic A-Patches and Twenty Seven Lines on a Cubic", Algebraic Geometry and Geometric Modeling Workshop, Science Research Institute, Berkeley, California. April 2004
84. Invited Talk, "Flexible Chain Complex Models for Cryo-EM Maps and Atomic Macromolecular Structures", Scripps Research Institute, San Diego. April 2004
85. "Quality Meshing of Large Biomolecular Complexes", Japan Society of Industrial and Applied Mathematics, Tokyo. September 2004
86. "Ultrastructure Elucidation from 3D Electron Microscopy at the Gordon Conference in 3D Electron Microscopy, New London, New Hampshire, July 2005

87. Invited Presentation on “Ultrastructure Elucidation from 3D Electron Microscopy”, Computational Structural Biology, Data Mining Workshop, Stanford University, Stanford, August 2005
88. Invited Talk on “Visualization of Large Biomolecular Complexes”, Workshop, UCSD-Scripps, September, 2005
89. Invited Colloquium on “Geometric and Signal Processing of 3D Electron Microscopy“, Courant Institute, New York University, October 2005
90. Invited Jacques Morgenstern Colloquium on “Geometric and Signal Processing for Biomolecular Interactions ”, INRIA- Sophia Antipolis, France, April, 2006
91. Invited Talk on “Geometric and Signal Processing for 3D Electron Microscopy”, The IMA Workshop on Imaging Science, Minneapolis, May 2006.
92. Invited Minisymposium on “Efficient Computation of Molecular Surfaces, Energetics, Forces”, Minisymposium at World Congress on Computational Mechanics, Los Angeles, July 2006
93. Invited Talk on “Static and Time Dependent Meshing from Imaging”, Annual Meeting of the National Bio-Medical Center, San Diego, August, 2006.
94. VEF Review, Hanoi, Invited Talk on "Computer Science Research in Computational Biology", September 2006
95. Invited Talk on “Algebraic Geometric Methods in Engineering”, IMA Conference, Minneapolis, September 2006
96. [Keynote] “In Silico Methods in Cellular Engineering”, 24th Annual HSEMB Conference, Houston, February 2007
97. Invited Colloquium on “Applications of Approximation Theory”, International Conference in Approximation Theory, San Antonio TX, March 2007
98. Invited Talk on “Flexibility of Virus Capsids Via Elastic Models”, NRP Workshop on “Mathematical Models for Materials Science”, Rome, March 2007
99. Invited Minisymposium Presentation on “Automatic Structure Interpretation of single particle Cryo-Electron Microscopy: From Images to Psuedo-Atomic Models” 2007 IEEE International Symposium on Biomedical Imaging, from Nano to Macro, Washington, DC, March 2007, <http://tinyurl.com/PMC2678009>, PMCID: PMC2678009
100. Invited Talk on “Fast Algorithms for Protein-Protein Energetic Interactions”, Workshop on Macro-Molecules and Proteins, Lincei Academy, Rome, March 2007
101. [Keynote] “Molecular Structure and Properties Elucidation from 3D Electron Microscopy” at the Multi-Scale Imaging “Gulliver” Workshop, LBNL, Berkeley, CA, May 2007.
102. Invited Talk on “Algebraic Splines for Molecular Modeling”, IMA Annual Workshop, St. Paul, Minnesota, May 2007
103. Invited Talk on “Visualizing Physical Phenomena Using Interactive Media”, Gordon Research Center, Smithfield Rhode Island, July 2007
104. [Keynote] “Cardiovasculature Modeling and Visualization”, USNCCM 9th Annual Congress, San Francisco, July 2007
105. Invited Minisymposium Presentation “Viral Capsids as Deformable Shells”, for Tinsley Oden’s 70th Birthday Minisymposium, USNCCM 9th Annual Congress, San Francisco, July 2007
106. Invited Minisymposium Talk on “Algebraic Splines and Analysis”, USNCCM 9th Annual Congress, San Francisco, July 2007
107. Invited Minisymposium Presentation on “Union of Algebraic Spline Models”, SIAM Conference on Geometric Design, San Antonio, November 2007
108. Invited Talk “Molecular Electron Microscopy to Biophysical Modeling and Analysis”, Workshop on Image Analysis Challenges in Molecular Microscopy, IPAM-UCLA, Los Angeles, January 2008
109. [Plenary] “Geometric Flow for Quality Surface/Volumetric Modeling”, 1st Workshop on Computational Engineering and Fluid Dynamics, Lisbon, Portugal, July 2008
110. [Plenary] “Modeling Two Phase Flow Dynamics for Deformable Interfaces in Biology”, 1st Workshop on Computational Engineering and Fluid Dynamics, Lisbon, Portugal, July 2008
111. Invited Minisymposium Talk, “Multiscale Molecular Modeling for Drug Discovery”, SIMAI Conference, Rome Italy, September 2008
112. Invited Minicourse on “Computational Structural Biology”, Chinese Academy of Sciences, Beijing, February 2009
113. Invited talk, “Mathematics/Computer Sciences and Art”, Dean’s Advisory Council, March 2009
114. Invited talk, “Characterizing Electromagnetic Molecular Interaction Force Fields Using the Hodge Decomposition”, ACE (Advanced Computational Electromagnetics) 2009, Rome, April 2009
115. Invited Minicourse on “Molecular Modeling for Simulations”, University of Cantabria, Santander, Spain, May 2009
116. [Keynote] “Spatially Realistic CAD from Multi-Scale Bio-Imaging”, CAD Conference, Reno, NV, July 2009

117. Invited Plenary talk, "Variational Higher-Order Level-Set Methods for Image Segmentation", Image Segmentation in Materials Science Conference, Pittsburgh, PA, November 2008
118. Invited talk, "Discovering Nature's Gadgets and Gizmos", at Workshop in Honor of John Hopcroft's 70th Birthday, Cornell University, Ithaca, New York, October, 2009
119. [Keynote] "Nature's Forces for Molecular Recognition: models and Computation", at the International Conference on Physics/Biology Interface, Saha Institute of Nuclear Physics, Kolkata, India, December 2009
120. Invited talk "Cohomology Stability Criteria for Mixed Finite Elements", Conference celebrating the 60th birthday of Tomas Recio, Castro Urdiales, Spain, May 2010
121. [Keynote] "Spatially Realistic Multiscale Modeling from Electron Microscopy", CompIMAGE 2010, Buffalo, NY, May 2010
122. Invited Workshop Talk, "Computational Analysis of Protein Interactions for Drug Discovery", 2nd Collaboration Meeting on Applications of Theoretical Physics Methods in Biology, ECT Institute, Trentino, Italy, June 2010
123. Invited talk, "Algebra and Geometry of Algebraic Finite Elements", Conference on Algebra and Algebraic Geometry with Applications: Celebration of the 80th Birthday of Professor Shreeram Abhyankar, Purdue University, July 2010
124. Invited colloquial talk, "Solubility by Radicals and Monodromy of Riemann Surfaces", Conference celebrating the 80th birthday of Prof. Abhyankar, Pune University, December 2010
125. [Keynote] "Computational Mathematics for Protein-Protein Interactions", ACM/SIAM Solid Physical Modeling Conference, 2010, Haifa, Israel, August 2010
126. Invited talk, "Computational Analysis of Protein Interactions for Drug Discovery", 2010 Austin-Portugal International Collaboratory for Emerging Technologies (COLAB), Lisbon, Portugal, September 2010
127. Invited talk, "Computational Analysis of Protein Interactions for Drug Discovery", Meeting on Modeling of Protein Interaction (MPI), Lawrence, Kansas, October 2010
128. Invited Plenary speaker at the 2010 Visions of Computing Lecture Series, Computer Science UT Austin, November 2010
129. Invited participant and presenter, "Computational Analysis of Protein Interactions for Drug Discovery", the National Academies Keck Futures Initiative Conference on Seeing the Future with Imaging Science, Irvine, CA, November 2010
130. Invited talk, "Variational Methods for 3D Reconstruction in Electron Microscopy", Sampling and Reconstruction: Applications and Advances workshop at the Banff International Research Station for Mathematical Innovation and Discovery (BIRS), Vancouver, British Columbia, Canada December 2010
131. Invited talk, "Variational Geometry and Differential Topology Approaches to Structure Modeling from 3D EM Maps", Workshop on Structural Biology, Pacific Symposium on Biocomputing, Waimea, HI, January 2011
132. Invited talk, "Computational Molecular Biology, Modeling, and Visualization", IAMCS Visualization in Biomedical Computation Conference, Texas A&M University, College Station, Texas, February 2011
133. Invited talk "Geometric Modeling and Analysis of Protein Complexes Using Algebraic Splines", Conference held on Geometric Modeling at Schloss Dagstuhl Leibniz-Zentrum Fur Informatik, Dagstuhl, Germany, May 2011
134. [Keynote] "Computational Molecular Biology: Drug Discovery", Ninth Eurographics Symposium on Geometry Processing (SGP-2011), Lausanne, Switzerland, July 2011
135. Invited talk, "Automating the Visualization of Biological Machines", IEEEJ Autumn Conference on Basic and New Development in Visual Computing, University of Tokyo – Komaba Campus, September 2011
136. Invited SIAM minisymposium presentation, "Quality Hexahedral Reparameterization", SIAM Geometric Design and Solid /Physical Modeling Conference, Orlando, Florida, October 2011
137. Invited SIAM minisymposium presentation, "Harmonic Analysis for Protein-Protein Docking", SIAM Geometric Design and Solid /Physical Modeling Conference, Orlando, Florida, October 2011
138. Invited SIAM minisymposium presentation, "Computational Challenges in Bio-Nano-Technology", SIAM Geometric Design and Solid /Physical Modeling Conference, Orlando, Florida, October 2011
139. [Keynote] "Quantitative Visualization in the Computational Biological Sciences", IEEE Pacific Visualization 2012, Songdo, Korea, February 2012
140. Biomedicine in 4D Conference "Statistical Verification and Validation of Drug Targets using 3DEM", Oregon Health and Science University, March 2012.
141. "Automating the Visualization of Biological Machines", Experimental Biology 2012, San Diego, California, April 2012
142. Invited *William Mong Distinguished Lecture*, "Computational Challenges in Accelerated Drug Discovery", Hong Kong University, Hong Kong, May 2012

143. "Variational Methods in Molecular Electron Tomography", SIAM Conference on Imaging Science, Philadelphia, Pennsylvania, May 2012
144. [Keynote] "Quantitative Visualization in the Biological Sciences", International Conference on Contemporary Computing, IC3, New Delhi, India, August 2012
145. "Enhancing Visualization of Multi-scale Biophysical Simulations", Conference on Computational Physics, Kobe, Japan, October 2012
146. "Images to Function: Multiscale Modeling of Electrophysiology in the Hippocampus", Turning Images to Knowledge: Large-Scale 3D Image Annotation, Management, and Visualization, Janelia Farm, Virginia, October 2012
147. "Multi-Protein Docking", Modeling of Protein Interactions MPI 2012, University of Kansas, Lawrence, Kansas, November 2012
148. "Images to Function: Multi-scale Modeling of Electrophysiology in the Hippocampus", Modeling and Simulations of Physiological Systems, Technico Lisboa, Lisbon, Portugal, December 2012
149. "Computational Science Challenges for the 3D Virtual Cell", University of California, San Diego, California, December 2012
150. "Geometric Modeling Tales Born from Two Sciences: Algebra & Geometry", *Algebraic Geometry and Geometric Modeling* workshop at the Banff International Research Station for Mathematical Innovation and Discovery (BIRS), Vancouver, British Columbia, Canada, January 2013
151. "Modeling, Analysis and Validation of Molecular Interactions from Electron Microscopy", Advanced Imaging Methods Workshop, UC Berkeley, California, January 2013
152. [Keynote] "The Geometry and Analysis of Biological Machines", Advances in Computational Mechanics, Celebrating the 70th Birthday of Thomas J.R. Hughes, February 2013
153. "Modeling Analysis and Validation of Molecular Interactions from X-ray and Electron Microscopy", Mathematical Challenges in Biomolecular/Biomedical Imaging and Visualization Workshop, Mathematical Biosciences Institute, Ohio State University, February, 2013
154. [Keynote] "Data Enabled Molecular Modeling, Uncertainty Quantification and Visualization," 2013 NSF CyberBridges Workshop, July 2013
155. [Keynote] "Multi-domain Meshing Challenges for Scalable Biophysical Simulations," 22nd International Meshing Roundtable Conference, October 2013
156. Invited Distinguished Speaker, "Multi-domain Meshing Challenges for Scalable Biophysical Simulations," Barr Systems Distinguished Lecture Series, University of Florida, Gainesville, Florida, October 2013
157. Invited Distinguished Speaker, "Automated Prediction of Molecular Assemblies with Quantified Uncertainty," Carnegie Mellon University, November 2013
158. "Automated Prediction of Molecular Assemblies," 2nd Zing Conference on Protein and RNA Structure Prediction, December 2013
159. Invited Distinguished Speaker, "Automated Prediction of Molecular Assemblies with Quantified Uncertainty," Colloquium Seminar at the University of Virginia, January 2014
160. "Computational Topology, Geometry, and Analysis for Quantitative Relationships Between Biological Form and Function from 3D Electron Microscopy," MBI-OSU, Analysis and Visualization of Large Collections of Imaging Data Workshop, April 2014
161. "Imaging and Modeling in Electron Microscopy—Recent Advances", Banff International Research Station, Workshop, May 2014
162. "Macro-molecular Map and Model Refinement Techniques for Electron Microscopy", Workshop on Imaging and Modeling in Electron Microscopy: Recent Advances, Banff International Research Station for Mathematical Innovation and Discovery, May 2014
163. [Keynote] Okinawa Institute of Science, Technology Workshop on Quasi-Symm. Assemblies (Jan 2015)
164. [Keynote] "Chemical Imaging and Visualization with Uncertainty Quantification" Computer Methods in Biomechanics and Biomedical Engineering Imaging and Visualization, CMBBE (Sep 2015), Montreal, Quebec, Canada
165. Invited Banquet talk, "Nature's Meshes, Models and Simulations", 24th Intl. Meshing Roundtable IMR 2015, Sandia Nat'l Laboratories, The Bullock Texas State History Museum, University of Texas, Austin, Texas, October 13, 2015
166. Invited Alumni Banquet Lecture, "Computer Science versus Cancer", Computer Science Alumni, University of Texas at Austin, Austin, TX, October 29, 2015

167. “Scalable Global Optimization Problems in Imaging and Geometry Processing”, Workshop for Joint Research Exchange between University of Aachen (AICES) and University of Texas (ICES), Aachen, Germany, Nov 5-6, 2015
168. [Plenary] “Statistical Bio-Modeling for Predictive Medicine”, UT Austin/Portugal CoLab-Advanced Computing Research, Innovative Modeling Techniques for Predictive Medicine Workshop, Nov 9-13, 2015, IST, Lisbon, Portugal
169. Invited Colloquium Speaker, “Scalable Geometric Optimization with Applications to Prediction of Assemblies”, TU Berlin (Technische Universität Berlin), June 21, 2016, Berlin, Germany
170. “Disk Density Tuning of a Maximal Random Packing”, The International Geometry Summit 2016 (IGS), Solid and Physical Modeling (SPM), Technische Universität Berlin, June 22, 2016, Berlin, Germany
171. “Algebra and Geometry of Reproducing Hilbert Space Kernels” at Banff International Research Station-Casa Matematica Oaxaca, Computational Algebra and Geometric Modeling Workshop, Aug 7-12, 2016, Oaxaca, Mexico
172. “Reproducing Kernel Hilbert Spaces for Geometry and Material Sciences”, Geometry and Material Sciences (GEMS) at Okinawa Institute of Science and Technology, Oct 15-18, 2017, Okinawa, Japan
173. “Modern Computer Science”, Convocation 2016, Indian Institute of Technology Delhi, Nov 2-12, 2017, New Delhi, India
174. “Multi-Scale Machine Learning for Bio-Image Processing”, 14th Annual Advanced Imaging Methods (AIM) Workshop, Jan 24-27, 2017, Berkeley Cancer Research Laboratory, San Francisco, CA
175. “Multiscale and High Dimensional Techniques for Time Data Analysis”, First Annual Tissue and Microenvironment (TIME) Day at the University of Illinois at Urbana-Champaign, May 15, 2017, Urbana, IL
176. “Sampling and Optimization in Infrared Spectroscopy”, Multiscale and High-Dimensional Problems Conference, March 26-April 2, 2017, Oberwolfach, Germany
177. “Sampling and Optimization for High Dimensional Big Data”, Dagstuhl Seminar on Geometric Modelling, Interoperability and New Challenges, May 28-June 2, 2017, Schloss Dagstuhl, Saarbrücken, Germany
178. “Sampling and Optimization for High Dimensional Big Data”, INRIA Institut National De Recherche En Informatique Et En Automatique, June 2-9, 2017, Nice, France
179. “Optimized Polygonal Meshes for Quadratic Serendipity Finite Elements”, ADMOS 2017 Adaptive Meshing Methods and Applications Mini-symposium, June 25-29, 2017, Verbania, Italy
180. “The Holy Grail for Interactive Simulations”, BIRS-CMO Workshop 17w5008, Geometry and Computation for Interactive Simulation, Sep 24-29, 2017, Banff International Research Station for Mathematical Innovations and Discovery (BIRS) of Casa Matematica Oaxaca (CMO), Oaxaca, Mexico
181. “Mathematics of Heterogeneous Cryo-EM”, BIRS-CMO Workshop 17w5055, Mathematical Advances in Electron Microscopy, Oct 15-20, 2017, Banff International Research Station for Mathematical Innovations and Discovery (BIRS) of Casa Matematica Oaxaca (CMO), Oaxaca, Mexico
182. [Distinguished Speaker], “Classification Problems with FTIR”, Berlin International Graduate School in Model and Simulation based Research (BIMoS), Technische Universität Berlin, Germany.
183. “The Promise of Infrared Spectroscopy”, ICMLDS 2017 (International Conference on Machine Learning and Data Science), Dec 14-15, 2017, Bennett University Campus in Greater Noida, Delhi, India
184. “The Promise of Infrared Spectroscopy” National Conference on Computational Vision, Pattern Recognition, Image Processing and Graphics, December 16-20, 2017, Delhi, India
185. “Learning Models with Data using Optimization” Models & Data, February 22-23, 2018, Columbia, South Carolina
186. “Promise of Infrared Imaging” University of Tokyo, February 27-March 3, 2018, Tokyo, Japan
187. “The Promise of Machine Learning for Infrared Spectroscopy”, TIME Workshop. University of Illinois at Urbana-Champaign, March 30, 2018, Urbana-Champaign, Illinois
188. “Sampling Conditions for Conforming Voronoi Meshing by the Vorocrust Algorithm” Symposium on Computational Geometry (SOCG 2018), June 2018, Budapest, Hungary
189. “Sparse G1 Spline Manifold and Salient Feature Map Approximation with Topological Accuracy” Curves and Surfaces, June 27-July 2, 2018, Arcachon, France
190. Texas Imaging Symposium, October 30, 2018, The University of Texas, Austin, Texas
191. [Keynote] “Making the Invisible Visible” ChinaGraph, November 9-11, 2018, Guangzhou, China
192. “Deep Learning for Infrared Spectroscopy” Colloquium, Tsinghua University, Beijing, China, Nov 13, 2018
193. “Deep Learning for Infrared Spectroscopy” Colloquium, Peking University, Beijing, China, Nov 14, 2018
194. “Mathematics of Infrared Spectroscopy”, Colloquium, Academia Sinica, Beijing, China, Nov 15, 2018

- 195.[Keynote] “Unsupervised Super Resolution Hyperspectral Imaging” International Conference on Machine Learning and Data Science (ICML & DS 2018), December 21-22, 2018, Hyderabad, India
196. Invited Speaker, Cryo-EM Workshop, August 8-9, 2018, New York, New York.
197. Invited Speaker, “Spatio-Spectral Tensor Super-resolution” New York University, NY, January 24, 2019
198. Invited Speaker, “Spatio-Spectral Tensor Super-resolution” Stony Brook University, NY, January 25, 2019
199. Invited Speaker “Spatio-Spectral Tensor Super-Resolution with Chemical Priors” SIAM Conference on Computational Science and Engineering, February 25–March 1, 2019, Spokane, Washington
200. “Are Spline Kernels Useful”, University of Chicago, May 15-May 19, 2019
201. “Learning to Sample and Sampling to Learn”, Amazon, Seattle, June 8-16, 2019
202. “Computation, Mathematics, and Statistics for Visual Search Applications”, University of Peking- Beijing, China, July 2019
203. “Computation, Mathematics, and Statistics for Visual Search Applications”, July 1-13, 2019, University of Peking- Beijing, China
204. ALBERT: A digital Pathology Electronic Assistant, August 2-4, 2019, UT Southwestern Medical center- Dallas and Univ of Oklahoma.
- 205.[Plenary] “Statistical Deep Learning for Automatic 2D and 3D Cytotyping of tumor tissue”. Cold Spring Harbor- Asia conference, Shanghai, China, September 4, 2019
206. “Learning to Sense, Model. And Predict”. Shanghai Jai Tong University- Shanghai, China, September 6, 2019
- 207.[Plenary] “Learning the Koopman Operator for Dynamic Simulations”, Workshop on Digital Twins, University of Luxembourg, September 9-13, 2019
208. “Deep Learning Koopman Operator for Dynamic Data”, Georgia Tech at Atlanta, Ga. Sept 17, 18, 2019
209. “Deep Learning for Static and Dynamic Data” Colloquium talk, NYU Data Sciences, Sept 27, 2019
210. “Deep Learning Koopman Modes for Dynamic Data” Colloquium talk, Princeton University, Sept 30, 2019
211. [Keynote] “Learning to Correct Form and Function with Reinforcement”, The 2nd TBSI Workshop on Learning Theory (TBSI-WOLT’20) July 20-22, 2020
212. Invited Speaker “Deep Learning to Correct Form and Function with Reinforcement”, New Jersey Institute of Tech, December 9, 2020
213. Invited Speaker “Learning Robust Delaunay/Voronoi (Primal-Dual) Meshes with Minimal Uncertainty”, NUMGRID-2020 – Moscow, November 20, 2020
214. Invited Speaker, “Learned Stochastic Decision Making with Applications to Protein Folding”, IEEE- CS- BITS APPCAIR seminar- June 11, 2021
- 215.[Keynote] - “Learning Rank-Ordered Intelligent Search Policies with Minimal Uncertainty” Emerging Techniques in Computational Intelligence, Co-Sponsored by the IEEE Computational Intelligence Society, Ecole Centrale School of Engineering, Mahindra University, Hyderabad, India, August 25-27, 2021
216. Babuska Oden Institute Workshop, October 11, 2021- Can Computers Self-Learn to Model, Verify, Validate and Predict?- Albuquerque, NM for Prof. Ivo Babuška 95th birthday
217. Invited Speaker, Workshop 3- Linz, Austria- November 1-5, 2022, “Inverse Problems on Small Scales” Special Semester on Topography Across the Scales
- 218.