

UNITED STATES PATENT AND TRADEMARK OFFICE

BEFORE THE PATENT TRIAL AND APPEAL BOARD

SONY INTERACTIVE ENTERTAINMENT LLC,
Petitioner,

v.

INTELLECTUAL PIXELS LIMITED,
Patent Owner.

Case No. IPR2021-00237
U.S. Patent No. 10,681,109

**DECLARATION OF DR. JOHN C. HART IN SUPPORT OF
PATENT OWNER'S RESPONSE TO PETITION FOR
INTER PARTES REVIEW**

I, Dr. John C. Hart, hereby declare as follows:

I. INTRODUCTION

1. I have prepared this Declaration in connection with Patent Owner's Response to the Petition for *Inter Partes* Review of U.S. Patent No. 10,681,109 ("the '109 Patent").

2. In the course of preparing this Declaration, I reviewed the '109 Patent, its prosecution file history, as well as the other documents discussed in this Declaration.

3. I have been retained by Intellectual Pixels Limited ("IPL" or "Patent Owner") as an expert in the field of computer graphics. I am being compensated at my normal consulting rate for my time. My compensation is not dependent on and in no way affects the substance of my statements in this Declaration. I have no financial interest in IPL, the '109 Patent or the owner of the '109 Patent.

II. BACKGROUND AND QUALIFICATIONS

4. I am a tenured full Professor of Computer Science in the Department of Computer Science at the University of Illinois at Urbana-Champaign. I have been researching computer graphics since 1987, with over a hundred papers, videos, patents and other contributions to the field of computer graphics. My work in computer graphics has been funded by Adobe, Intel, Microsoft, Nokia and Nvidia as well as the National Science Foundation (NSF) and the Defense Advanced Research

Projects Agency (DARPA). One of my most recent contributions is on the topic of displaying text on the video screen of a VR headset, in collaboration with Oculus. This paper, “Real-Time Analytic Antialiased Text for 3-D Environments,” was selected as one of the best papers at the 2019 High-Performance Graphics Conference in Strasbourg France.

5. I received my Ph.D. in Electrical Engineering and Computer Science in 1991 from the Department of Electrical Engineering and Computer Science at the University of Illinois at Chicago for my studies and research in computer graphics at its Electronic Visualization Laboratory.

6. I am an internationally recognized leader in the field of computer graphics. From 2002-08 I was the longest-serving Editor-in-Chief of the top journal in computer graphics, the Association for Computing Machinery (ACM) Transactions on Graphics. From 1994-1999 I served on the executive committee of the main organization of computer graphics practitioners, the ACM Special Interest Group on Computer Graphics and Interactive Techniques (SIGGRAPH). I continue to oversee the peer review of major papers in the field through service as chair and member of various paper review committees. I am also a founding member of the editorial board of ACM Books, and the area editor for computer graphics.

7. As an educator for the past three decades, I have taught courses in computer graphics and related areas to thousands of students. I also strive to provide

opportunities for the general public to learn more about computing. For example, in 1999 I oversaw the production of the documentary “The Story of Computer Graphics.” I also teach an open course on data visualization on Coursera that has reached over 360,000 learners worldwide since 2016.

8. In 2016, I redesigned the online offering of the MCS degree program to make it more flexible and affordable for students that could not afford to leave their job to pursue a degree full-time. Under my leadership, this degree program quickly grew to the second largest graduate program offered by the University of Illinois at Urbana-Champaign, and contributed significantly to the campus-wide proportion of underrepresented minorities enrolled in the institution. The tech company C3.ai found this online degree so desirable, it pays its employees’ tuition and, upon completion, gives them a bonus, a raise and stock options. In 2021, I received the Excellence in Online & Distance Education Award from the University of Illinois at Urbana-Champaign. I also served as the Executive Associate Dean of the Graduate College of the University of Illinois at Urbana-Champaign from 2015-21, where I developed a new post-baccalaureate certificate credential at Illinois to provide the recently unemployed with a rapid educational opportunity to transition their skills to areas of greater prosperity. In Aug. 2021, the University of Illinois established a new Office of Professional Education and named me its first director.

9. At the January 24, 2001 priority date of the '109 Patent, I had researched so-called “fractal” compression methods in computer graphics, which were a form of self-referential vector quantization, including publications in the IEEE journals “Transactions on Visualization and Computer Graphics” and “Computer Graphics and Applications,” a poster presentation at the 1997 IEEE Data Compression Conference and invited attendance to a 1995 NATO Advanced Study Institute on compression. In 2002, shortly after the priority date, I collaborated with Microsoft on a project titled “Precomputed Radiance Transfer Compression” which applied a vector-quantization compression method to reflectance functions to efficiently store them at the vertices of geometric meshed models in the Xbox 360 video game system and in the DirectX graphics library, presenting the results at the 2003 ACM SIGGRAPH Annual Conference and published in the ACM Transactions on Graphics.

10. Further details regarding my qualifications, including my employment and academic history, are set forth in my curriculum vitae, attached as Appendix A.

III. MATERIALS CONSIDERED

11. I have reviewed the '109 Patent (EX1001) and its file history. Additionally, and in addition to any other documents cited or referenced herein, I have reviewed the following materials in preparing this Declaration:

- a. Petition for *Inter Partes* Review of U.S. Patent No. 10,681,109

- b. Declaration of Dr. Henry Fuchs (EX1002)
- c. Wiltshire, U.S. Patent No. 6,409,602 (EX1004)
- d. Saha, U.S. Patent No. 6,404,817 (EX1005)
- e. Chen (EX1006)
- f. PC Magazine, September 1999 (EX1007)
- g. Excerpt from IEEE Dictionary (7th ed. 2000) (EX2002)
- h. Excerpt from Microsoft Computer Dictionary (5th ed. 2002) (EX2003)
- i. File History of U.S. Patent No. 10,681,109 (EX2004)
- j. Yamada, U.S. Patent No. 6,929,549 (EX2005)
- k. Kitabatake, U.S. Patent No. 6,266,930 (EX2006)
- l. Excerpts from Discovering Computers: Fundamentals (4th ed. 2008)
(EX2007)
- m. Frameless Rendering: Double Buffering Considered Harmful (1994)
(EX2008)
- n. August 17, 2021 Final Transcript of Deposition of Dr. Henry Fuchs
(EX2010)
- o. McVeigh et al., A Software-Based Real-Time MPEG-2 Video Encoder,
IEEE Transactions on Circuits and Systems for Video Technology
10(7), Oct. 2000, pp. 1178-1184 (EX2012)

- p. H.261 Standard, https://www.itu.int/rec/dologin_pub.asp?lang=e&id=T-REC-H.261-198811-S!!PDF-E&type=items (EX2013)
- q. “Beyond the Desktop Metaphor: Toward More Effective Display, Interaction, and Telecollaboration in the Office of the Future via a Multitude of Sensors and Displays” by Henry Fuchs in Proc. International Conference on Advanced Multimedia Content Processing, Nov. 9, 1998, pp. 30-43, <https://www.cs.unc.edu/~fuchs/publications/Fuchs1998.pdf> (EX2014).
- r. MPEG-2 Video standard, <https://mpeg.chiariglione.org/standards/mpeg-2/video> (EX2015)
- s. ITU-T Rec. H.262 recommendation (EX2016), available at <https://www.itu.int/rec/T-REC-H.262-199507-S/en>

IV. RELEVANT LAW

12. I am not an attorney. For the purposes of this Declaration, I have been informed about certain aspects of the law that are relevant to my opinions. My understanding of the law is summarized below.

13. I have been informed and understand that determining whether a patent claim is valid requires a two-step analysis. First, the claim must be construed. Second, the properly construed claim must be compared to the prior art.

14. I have been informed and understand that claim construction is a matter of law and that the final claim constructions for this proceeding will be determined by the Patent Trial and Appeal Board.

15. I have been informed and understand that in the context of an *inter partes* review, claims are construed from the perspective of a person of ordinary skill in the art at the time of the purported invention (which is approximated based on the earliest priority date of the patent). I understand that absent disclaimer or express definition, claim terms are given their plain and ordinary meaning to a person of ordinary skill in the art in view of the specification and file history and knowledge of a person of skill in the art.

16. I have been informed and understand that a patent claim is invalid if it is anticipated by the prior art (*i.e.*, lacks novelty). I understand that anticipation requires the disclosure in a single prior art reference of every limitation of the claim, expressly or inherently, with the limitations arranged as specified in the claim.

17. I have been informed and understand that, although not expressly disclosed, subject matter may be inherently disclosed in a prior art reference where that subject matter is necessarily present in the expressly disclosed subject matter and would be understood to be so by those of ordinary skill in the art. I understand that the fact that a certain result or characteristic may occur or be present in the prior art is not sufficient to establish the inherency of that result or characteristic.

18. I have been informed and understand that a patent claim is obvious and therefore invalid if the claimed subject matter, as a whole, would have been obvious to a person of ordinary skill in the art as of the priority date of the patent based on one or more prior art references and/or the knowledge of one of ordinary skill in the art. I understand that an obviousness analysis must consider (1) the scope and content of the prior art, (2) the differences between the claims and the prior art, (3) the level of ordinary skill in the pertinent art, and (4) secondary considerations, if any, of non-obviousness (such as unexpected results, industry praise, commercial success, long-felt but unmet need, failure of others, copying by others, and skepticism of experts).

19. I understand that a prior art reference may be combined with other references to disclose each element of the invention under 35 U.S.C. § 103. I understand that a reference may also be combined with the knowledge of a person of ordinary skill in the art, and that this knowledge may be used to combine multiple references. I further understand that a person of ordinary skill in the art is presumed to know the relevant prior art. I understand that the obviousness analysis may take into account the inferences and creative steps that a person of ordinary skill in the art would employ.

20. In determining whether a prior art reference could have been combined with other prior art or other information known to a person having ordinary skill in the art, I understand that the following principles may be considered:

- a. A combination of familiar elements according to known methods is likely to be obvious if it yields predictable results;
- b. The substitution of one known element for another is likely to be obvious if it yields predictable results;
- c. The use of a known technique to improve similar items or methods in the same way is likely to be obvious if it yields predictable results;
- d. The application of a known technique to a prior art reference that is ready for improvement, to yield predictable results;
- e. Any need or problem known in the field and addressed by the reference can provide a reason for combining the elements in the manner claimed;
- f. A person of ordinary skill often will be able to fit the teachings of multiple references together like a puzzle; and
- g. The proper analysis of obviousness requires a determination of whether a person of ordinary skill in the art would have a “reasonable expectation of success” – not “absolute predictability” of success – in achieving the claimed invention by combining prior art references.

21. I am informed that whether a prior art reference invalidates a patent claim as obvious is determined from the perspective of a person of ordinary skill in the art. While there is no requirement that the prior art contain an express suggestion to combine known elements to achieve the claimed invention, a suggestion to combine known elements to achieve the claimed invention may come from the prior art as a whole, or individually, as filtered through the knowledge of one skilled in the art. In addition, the inferences and creative steps a person of ordinary skill in the art would employ are also relevant to the determination of obviousness.

22. When a work is available in one field, design alternatives and other market forces can prompt variations of it, either in the same field or in another. If a person of ordinary skill in the art can implement a predictable variation and would see the benefit of doing so, that variation is likely to be obvious. In many fields, there may be little discussion of obvious combinations, and in these fields market demand – not scientific literature – may drive design trends. When there is a design need or market pressure and there are a finite number of predictable solutions, a person of ordinary skill in the art has good reason to pursue those known options.

23. It is my understanding that there is no rigid rule that a reference or combination of references must contain a “teaching, suggestion, or motivation” to combine references. But, I understand that the “teaching, suggestion, or motivation” test can be a useful guide in establishing a rationale for combining elements of the

prior art. This test poses the question as to whether there is an express or implied teaching, suggestion, or motivation to combine prior art elements in a way that realizes the claimed invention, and it seeks to counter impermissible hindsight analysis.

V. LEVEL OF ORDINARY SKILL IN THE ART

24. Dr. Fuchs proposes that “a person of ordinary skill in the art at the time of the alleged invention would have had at least (1) an undergraduate degree in computer science, electrical engineering, or an equivalent subject, together with two years of post-graduate experience in computer graphics; or (2) a master’s degree in computer science, electrical engineering, or equivalent subject, together with one year of post-graduate experience in computer graphics.” EX1002, ¶ 23.

25. I agree with this characterization of a person of ordinary skill in the art (“POSITA”). I was at least a POSITA under this definition by January 24, 2001, the priority date of the ’109 Patent. My opinions throughout this declaration are from the perspective of this hypothetical person of ordinary skill in the art as of January 2001.

VI. BACKGROUND OF TECHNOLOGY

A. Three-Dimensional Computer Graphics

26. Three-dimensional computer graphics for real-time applications such as video games at the priority date of ’109 Patent were produced by a rasterization-

based rendering pipeline. Three-dimensional geometric models of shapes are represented by 3-D vertex positions connected together into a mesh of polygonal faces. A common and general rasterization-based graphics pipeline was well known at the time. This pipeline began with a first set of vertex-processing stages that transformed the shapes from their configurations in a 3-D scene to their positions on a 2-D display screen according to a given viewpoint, illuminated by one or more light sources in the 3-D scene. Then a second set of rasterization stages would begin by scan converting the mesh polygons from their representation as 2-D colored screen vertices into a collection of the display screen pixels representing the mesh polygon, followed by stages that further process the colors and visibility of these pixels. These pixels are then stored in a frame buffer, which consists of memory locations shared by the graphics pipeline processor and the display processor where the latter can access them rapidly as it continually refreshes the display screen.

27. The embodiments of the “visual server” of the ’109 Patent were designed to accept “image modifying data” to control a rasterization-based renderer that would produce “image data” in the frame buffer that would be transmitted to a client over a network. “The Visual Server runs standard software, such as games, that are the same as versions running on standard personal computers.” EX1001 at 3:43-45.

B. Networked Multimedia Systems

28. The '109 Patent refers to networked client-server systems. Such systems allow a network connection to provide one or more client systems lacking resources to access those resources from one or more resource-rich server systems. In the context of the '109 Patent, these multimedia resources available from the server are images and video, and include the computational power to generate media through three dimensional computer graphics rendering.

29. For real-time applications such as video games, the ability for the server to provide resources also depends on both the network bandwidth and latency incurred to receive a request for resources, then the time it takes for the server to process and provide the requested resource, and then the network bandwidth and latency incurred to transmit the requested resource to the client. The network bandwidth measures the network's capacity in terms of the maximum amount of information (bits) that can be transmitted in a given time (second). The network latency measures the delays incurred by the network transmission of information.

C. Compression and Decompression

30. Networked multimedia systems at the priority date of the '109 Patent sometimes relied on compression and decompression to overcome delays incurred by network bandwidth and latency for interactive client-server applications. Compression can be lossless such that the decompressed data is identical to the

original data, or lossy such that the decompressed data is in the same format as the original data but only approximates the original data.

31. The JPEG standard for compressing image data, as mentioned in the '109 Patent specification, includes the following steps. First the image data is converted from the RGB color space to a chroma subsampled YUV 4:2:2 color space. Then the image is diced into an array of 8x8 blocks. Then a discrete cosine transform (DCT) is applied to each 8x8 block to convert it to an equivalent frequency space representation. Then the coefficients of this frequency space representation are quantized (rounded to a smaller set of values) and compressed. The transformations from RGB to YUV to DCT convert the image to a representation that can then be compressed, such that the artifacts due to lossy compression happen in the frequency domain. These artifacts are less objectionable to the human visual system than if the same compression were applied to the RGB or YUV versions of the image without the DCT step.

32. The MPEG standard for compression of video data, as mentioned in the '109 Patent specification, includes the following steps. First, the individual video frames are converted from the RGB color space to a chroma subsampled YUV 4:2:0 color space with full resolution Y but the resolution of the chroma channels U and V is reduced by one fourth, such that each chroma U and V value is blurred across four neighboring pixels. Then each frame is encoded either as an intra (I) frame, a

predicted (P) frame, or a bidirectional interpolated (B) frame. The I frames are sent periodically (e.g. every 15 frames) and are encoded using the DCT similar to a JPEG image, whereas the remaining frames are P and B frames and use motion prediction to provide better compression than if they were handled as individual I frames. Both P and B frames each consist of a grid of 16x16 pixel macroblocks. Each macroblock of a P frame is encoded as the location of a 16x16 region in a previous I or P frame. Each macroblock of a B frame is encoded as the location of a 16x16 region in a previous or subsequent I or P frame. The motion prediction that searches other frames for matching macroblocks is the most expensive part of the MPEG encoding process. (“It is well known that motion estimation often consumes the largest percentage of processing cycles for an MPEG-2 video encoder.” EX2012 at p. 2.)

33. A POSITA would have understood the MPEG-2 video standard, as documented e.g. by the ITU-T Rec. H.262 (1995 E) recommendation (EX2016) freely available at: <https://www.itu.int/rec/T-REC-H.262-199507-S/en>. “The text of the MPEG-2 Video standard is common with ITU-T Rec. H.262.” *See, e.g.,* <https://mpeg.chiariglione.org/standards/mpeg-2/video>. At p. v., it provides the following description, characterization and motivation of the use of motion prediction in the task of MPEG compression of video.

Because of the conflicting requirements of random access and highly efficient compression, three main picture types are defined. Intra Coded

Pictures (I-Pictures) are coded without reference to other pictures. They provide access points to the coded sequence where decoding can begin, but are coded with only moderate compression. Predictive Coded Pictures (P-Pictures) are coded more efficiently using motion compensated prediction from a past intra or predictive coded picture and are generally used as a reference for further prediction. Bidirectionally-predictive Coded Pictures (B-Pictures) provide the highest degree of compression but require both past and future reference pictures for motion compensation. Bidirectionally-predictive coded pictures are never used as references for prediction (except in the case that the resulting picture is used as a reference in a spatially scalable enhancement layer). The organisation of the three picture types in a sequence is very flexible. The choice is left to the encoder and will depend on the requirements of the application. Figure Intro. 1 illustrates an example of the relationship among the three different picture types.

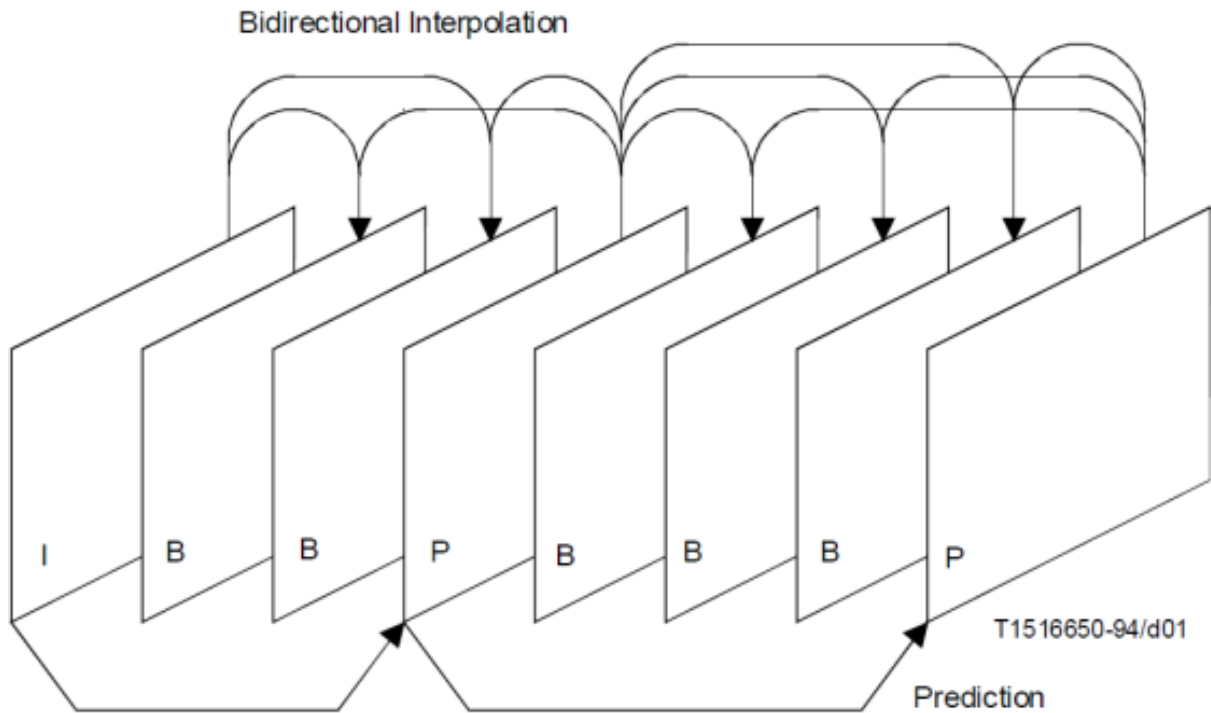


Figure Intro. 1 – Example of temporal picture structure

ITU-T Rec. H.262 (1995 E) at p. v.

VII. OVERVIEW OF THE '109 PATENT

34. The '109 Patent is titled “Image Display System with Visual Server.” I understand that the '109 Patent issued on June 9, 2020 from U.S. Patent Application No. 15/638,020, filed on June 29, 2017, which claims priority to Provisional Application No. 60/263,854, filed on January 24, 2001.

35. The '109 Patent discloses a networked client-server system in which one or more client computers are in communication with a remote visual server that receives image-modifying data from a client computer, generates a modified image

based on the image-modifying data, and transmits the modified image as compressed data to the client. '109 Patent (EX1001), Abstract. The '109 Patent system is configured to allow a client to use the remote server's resources to execute an application, *e.g.*, a video game, and for the server to generate complex graphical images. *Id.*, 3:41-48, 4:66-5:2.

36. In the '109 Patent, the client computer includes an input device through which input signals are generated to control a user's interaction with the image currently displayed at the client. *Id.*, 3:58-61, 4:17-21. The client collects the input control signals and transmits them to the server over a network, which receives those input signals and passes them to the application to modify the existing state of the game. *Id.*, 3:51-57, 4:17-32, 6:38-43. The server generates a modified or updated image and transmits that image as compressed data back to the client. *Id.*, 3:54-57. In one embodiment, the step of transmitting the updated image from the server comprises transmitting the updated image as a compressed frame. *Id.*, 4:48-52, 6:64-66, 8:42-47. The client computer decompresses the image data and displays the image frame. *Id.*, 3:67-4:3. This process is repeated many times per second allowing the user at the client to play a 3D video game in real-time according to the target frame rate of the system. *Id.*, 6:23-28, 6:63-7:7.

VIII. CLAIM CONSTRUCTION

37. I have used the following constructions of claim terms in forming my opinions.

Claim Term	Construction Used
“compressing the at least one updated image” (Claims 1 & 8)	The “compressing” happens after the “generating” step and operates on the “at least one updated image” produced by the “generating” step.
“transmitting the compressed updated image” (Claims 1 & 8)	The “transmitting” happens after the “compressing” step and operates on the compressed, updated image that results from the “compressing” step.
“frame” (Claims 1 & 8)	“a single instance of the display”
“mobile device” (Claims 6, 11, 12)	“handheld computing device”

38. My analysis of how a POSITA would have understood each of these claim term constructions is provided as follows.

A. Compressing and Transmitting The At Least One Updated Image

39. Claims 1 and 8 include the phrase “compressing the at least one updated image” in their limitations. ’109 Patent at 9:65, 10:39. The “updated image”

references the antecedent “updated image” generated by the server to reflect the update of the state of the interactive software application in response to the user input signals it received from the client device. *Id.* at 9:58-64, 10:31-38.

40. A POSITA would have understood from Claims 1 and 8 a specific order of steps performed by the server. The first “**receiving**” step receives user input signals from the client. ’109 Patent at 9:58-61, 10:31-34. The second “**generating**” step generates an updated image in response to these user input signals (specifically to reflect the new state of the interactive software application updated according to the user input signals). *Id.* at 9:62-64, 10:35-38. Only then can the third “**compressing**” step operate on the updated image produced by the second “generating” step. *Id.* at 9:65, 10:39. Similarly, the fourth “**transmitting**” step, which occurs after the “compressing” step, involves transmitting to the client device the compressed, updated image that results from the “compressing” step. *Id.* at 9:65-66, 10:39-40. Because of the dependency of each subsequent step on the prior performance of the preceding step, a POSITA would have understood these steps to be required to be performed in the order recited in the claim.

41. A POSITA would have understood Figs. 2B and 2D of the ’109 Patent to illustrate this specific order of steps in Claims 1 and 8 executed by the server. (*See, e.g.*, ’109 Patent at 5:24-29, 7:43-46, 7:61-8:14.) “Receive image-modifying data” (box 58 in Fig. 2B) represents the “receiving” step of Claims 1 and 8. The

sequence in Fig. 2B then flows from box 58 to box 60 then to box 62. “Generate the corresponding image for the image-modifying data” (box 62 in Fig. 2B) represents the “generating” step of Claims 1 and 8. The sequence in Fig. 2B then flows from box 62 to box 64 then to connector “D.” This same sequence continues in Fig. 2D which begins by showing connector “D” and resumes the sequence with box 66. “Compress the image data” (box 66 in Fig. 2D) represents the “compressing” step of Claims 1 and 8. The sequence in Fig. 2D then flows from box 66 to box 68. “Transmit the compressed image” (box 68 in Fig. 2D) represents the “transmitting” step of Claims 1 and 8. Figs. 2B and 2D confirm a POSITA’s understanding from the language of Claims 1 and 8 as to the need for these steps (receive image-modifying data, generate the corresponding image, compress the image data, and transmit the compressed image) to occur in the order recited in Claims 1 and 8.

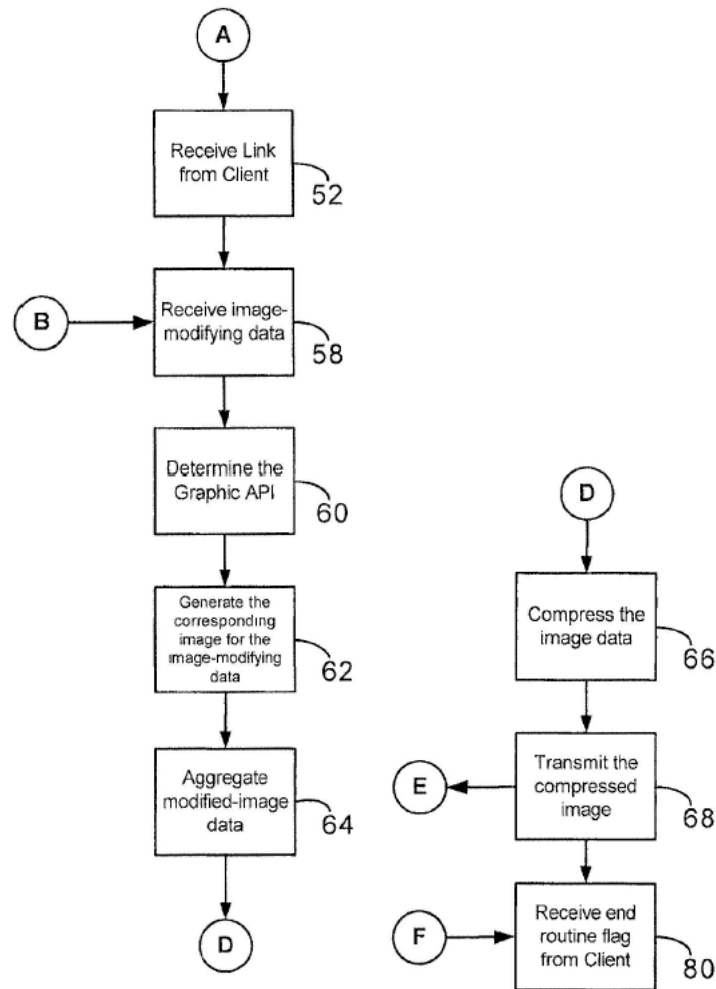


Fig. 2B

Fig. 2D

42. The “compressing” step is specifically addressed in the ’109 Patent at 8:10-12, which states that “the visual server 12 compresses the image data in a predetermined format, such as MPEG, as shown at step 66.” (The “aggregation” step shown at box 64 of Fig. 2B represents the integration of any additional data to “complete the image” (’109 Patent at 8:6-8).)

43. Hence a POSITA would have understood “compressing the at least one updated image” to mean that the “compressing” happens after the “generating” step and operates on the “at least one updated image” produced by the “generating” step. Similarly, a POSITA would have understood “transmitting the compressed updated image” to mean that the “transmitting” happens after the “compressing” step and operates on the compressed, updated image that results from the “compressing” step.

B. Frame

44. Claim 1 includes the requirement “wherein the server transmits the updated image as a compressed *frame* that can be decompressed and displayed as an updated image at the client device.” ’109 Patent at 9:67-10:2 (emphasis added). Similarly, Claim 8 includes the requirement “wherein the server transmits the updated image as a *frame* and wherein the client device is configured for decompressing of the compressed updated image and displaying the updated image on a display coupled to the client device.” *Id.* at 10:41-45 (emphasis added). As used in Claims 1 and 8 of the ’109 Patent, a POSITA would have understood “frame” to mean “a single instance of the display,” which I understand is the construction Patent Owner has proposed in this IPR. I agree with that construction and adopt it and use it in the opinions I have provided throughout this declaration.

45. The claim term “frame” differs from the claim term “image” and Saha’s definition of a “frame” as a “picture.” Saha’s definition of a “frame” as a “picture”

(*see, e.g.*, Saha at 2:21-23) is made in the context of a frame as a single still image in a video sequence of images, but Saha is only concerned with an MPEG stream of images, and not the source or ultimate use of those images. By contrast, the use of the term “frame” in Claims 1 and 8 of the ’109 Patent also refers to the additional context of a “frame” representing the visual output of an interactive software application. *See, e.g.*, ’109 Patent at 9:62-64 (Claim 1: “generating at least one updated image at the server in response to updating the state of the interactive software application”), 10:35-38 (Claim 8: “generating at least one updated image at the server in response to updating the state of the interactive software application running on the server by the user input signals”). Thus, a POSITA would have understood the term “frame” as used in the ’109 Patent to mean something more than simply an “image” or a “picture.”

46. For example, the term “frame” would have been understood by a POSITA reading the claims in the context of the ’109 Patent specification to refer to the *entire* display and not a first portion of the display to be combined with a second portion of the display. The ’109 Patent Description of the Related Art discloses a specific example from the prior art where a first portion of the display is produced by a server and combined with a second portion of the display produced by the client.

The client unit contains only a low level-of-detail geometric database and renders this database for each *frame*, and the difference image

computed on the server is compressed and transmitted to the client in real-time which decompresses and *composites* it together with the image generated by the client from the low level-of-detail database.

'109 Patent at 2:9-14 (emphases added). The term “frame” in this passage refers to the full resolution image generated by the “rendering” step of a “software application.” '109 Patent at 1:37-57.

47. The ordinary meaning of “frame” as “a single instance of the display” is consistent with how the term “frame” is defined in technical dictionaries. For example, the IEEE Dictionary (EX2002) at p. 3 defines “display frame” as “A *single display image* analogous to a frame in a motion picture.” (emphasis added). Similarly, the Microsoft Computer Dictionary (EX2003) at p. 3 defines frame as “A *single screen-sized image* that can be displayed in sequence with other, slightly different, images to create animated drawings.” (emphasis added).

48. The term “display” used in the proposed construction for “frame” refers specifically to the full image generated by the application at any given instance in time, whether running on a standard personal computer or running on a visual server, that is displayed to the user. A POSITA would have understood that an application displays information to the user, and this display of information is what is compressed and transmitted to the client for decompression and display in Claims 1 and 8. This display of information to the user would be equivalently generated by

the application when run on a standard personal computer. Even if the '109 Patent's "client" augments the frame with additional decorations, such as a window frame, a POSITA would have understood that these decorations were not part of the original application and hence did not constitute any part of the "frame."

49. The term "display" in the proposed construction of "frame" is therefore also an acknowledgement that the entire display image is produced by an application running on a visual server.

The Visual Server runs *standard software, such as games, that are the same as versions running on standard personal computers*. The Visual Server has certain support software modified to enable control of the *application* from the client and the delivery of the *result of 3D drawing to the client*.

'109 Patent at 3:43-48 (emphases added). From this passage, a POSITA would have understood an "application" to be "standard software" that runs on a "standard personal computer." Given this understanding of "application," the '109 Patent at 2:9-14 is specifically differentiating itself from prior art where an application is distributed across two pieces of software, one running on the client and one running on the server, and instead is proposing a visual server that runs the application as a single program.

50. The file history of the '109 Patent also supports that the term "frame" as used in the '109 Patent means more than simply an "image" as that term is used

in the MPEG context as discussed above. During prosecution of the '109 Patent application, the patent examiner rejected certain claims based on U.S. Patent No. 6,929,549 to Yamada. '109 Patent File History (EX2004) at p. 289. The pending claim recited “wherein the server transmits the updated image as a compressed *frame* that can be decompressed and displayed as an updated image at the client device.” EX2004 at p. 289 (emphasis added). The patent examiner relied on Yamada’s disclosure at col. 19, lines 33-35, which states, “The MPEG decoder 52 decompresses image data such as a background image and a character image used in the game, supplied from the STB 6 via the wireless communication.” EX2004 at p. 289. In response to the rejection, the applicant argued that Yamada’s disclosure did not show a “frame” and that “there is nothing to suggest that Yamada first generates a frame of image data and then compresses that frame prior to transmitting it to a remote client device.” EX2004 at p. 273. The patent examiner “fully considered” the applicant’s arguments and noted that they were “persuasive.” EX2004 at p. 235.

51. The related art example provided by the '109 Patent at 2:9-14 does not satisfy Claims 1 and 8 because the application is duplicated, running at full resolution on the server and at reduced resolution on the client. Both applications generate a display image, and the display image generated by the server application is compressed and transmitted to the client, where it is combined with the client

application's display image, and the result is displayed to the user. Claims 1 and 8 could allow a second version of the application to run on the client, but not one that generates a display image that is combined with the server's display image for presentation to the user as the display of the application, because Claims 1 and 8 require the capability for the compressed frame from the server to be decompressed on the client and *displayed as an updated image of the interactive software application running at the server.* '109 Patent at 9:67-10:2 (Claim 1: "wherein the server transmits the updated image as a compressed frame that can be decompressed and displayed as an updated image at the client device"), 10:41-45 (Claim 8: "wherein the server transmits the updated image as a frame and wherein the client device is configured for decompressing of the compressed updated image and displaying the updated image on a display coupled to the client device"). In other words, the term "frame" in Claims 1 and 8 makes clear that the server transmits "a single instance of the display" to the client.

C. Mobile Device

52. Claims 6 and 11 require that "the client device is a mobile device." '109 Patent at 10:19-20, 10:55-56. Similarly, Claim 12 requires that "at least one of the plurality of client devices is a mobile device." *Id.* at 10:58-59. As used in Claims 6, 11, and 12 of the '109 Patent, a POSITA would have understood "mobile device" to mean a "handheld computing device," which I understand is the construction Patent

Owner has proposed in this IPR. I agree with that construction and adopt it and use it in the opinions I have provided throughout this declaration.

53. The '109 Patent specification provides examples of “consumer client devices such as personal digital assistants (PDAs) [and] mobile telephones” ('109 Patent at 3:28-29) and explains that “exemplary clients are PDA” such as a “Palm Pilot” and “cellular telephone” (*id.* at 5:51-53). A POSITA would have understood that these devices are mobile devices because they are handheld computing devices.

54. A POSITA would have understood “mobile device” to have a different meaning than “portable device.” A POSITA would have understood that a mobile device is small enough to be held in one’s hand, while a portable device is a device, such as a laptop computer, that can be carried from one place to another.

55. The computer textbook, *Discovering Computers: Fundamentals* (EX2007), states at pp. 24-25 that “a mobile device is a computing device small enough to hold in your hand” and “small enough to carry in a pocket.” Consistent with that description, it states at p. 25 that “[t]hree popular types of mobile devices are handheld computers, PDAs, and smart phones.” The *Discovering Computers* textbook distinguishes between mobile devices and mobile computers and states at p. 24 that “[a] mobile computer is a personal computer you can carry from place to place” and that “[a] notebook computer, also called a laptop computer, is a portable, personal computer designed to fit on your lap.” On p. 24, it further states that: “These

[notebook] computers weigh on average between 2.5 and 9 pounds, which allows users to easily transport the computers from place to place.” I agree with these descriptions of a mobile device and a mobile computer.

56. Dr. Fuchs at ¶ 216 of his declaration describes the Apple iBook laptop computer as “portable.” I agree with Dr. Fuchs that a laptop computer is a portable device.

IX. VALIDITY

A. Claims 1 and 3-12 are valid, even in view of Wiltshire and Saha (Ground 1)

57. Dr. Fuchs at ¶ 100 of his declaration concludes that Claim 1 is unpatentable over Wiltshire combined with Saha. I disagree.

58. Dr. Fuchs’s conclusion at ¶ 100 relies necessarily on his opinion at ¶ 80 of his declaration that the combination of Wiltshire and Saha discloses the limitation “and compressing the at least one updated image and transmitting the compressed updated image to the client device, wherein the server transmits the updated image as a compressed frame that can be decompressed and displayed as an updated image at the client device.” I disagree.

59. Similarly, for Claim 8, Dr. Fuchs relies on his opinion regarding Claim 1 to assert that the combination of Wiltshire and Saha discloses the Claim 8 limitation “compressing the at least one updated image and transmitting the compressed updated image to the client device, wherein the server transmits the

updated image as a frame and wherein the client device is configured for decompressing of the compressed updated image and displaying the updated image on a display coupled to the client device.” *See* Fuchs declaration at ¶¶ 135-138. For the same reasons I discuss with respect to Claim 1, I disagree.

1. Wiltshire does not disclose “compressing the at least one updated image and transmitting the compressed updated image to the client device”

60. Dr. Fuchs at ¶ 81 of his declaration opines that Wiltshire alone discloses “compressing the at least one updated image and transmitting the compressed updated image to the client device.” Dr. Fuchs provides no opinion in his declaration that anything in addition to, or in combination with, Wiltshire discloses “compressing the at least one updated image and transmitting the compressed updated image to the client device.”

61. Dr. Fuchs at ¶ 83 opines that “Wiltshire discloses that the updated images may be transmitted to the client as a ‘compressed video MPEG stream.’” The term “updated image(s)” appears nowhere in Wiltshire. Wiltshire at 8:2-7 states the following.

In some embodiments, to further reduce the amount of network bandwidth required for the operation of computer gaming system 100, image updates (once an image has been displayed) are limited to areas of the screen that are actually modified rather than full screen refreshes.

Here, Wiltshire refers to “image updates” as an update to an “image [that] has [already] been displayed.” This reference is within the context of Wiltshire at 7:57-8:14 which outlines several strategies for reducing the bandwidth requirements of transmitting an image update. These include caching previously displayed images on the client (7:65-8:2) and preloading images on the client (8:8-11). This section specifically addresses decreasing the bandwidth requirement of the embodiments, but does not make any mention of applying MPEG compression, or any streaming video compression, to the image generated by the game program running on the server/host computer to reduce the bandwidth required for transferring it to the client/terminal computers.

62. In fact, nowhere in the entirety of Wiltshire does it disclose the application of MPEG compression, or any streaming video compression, to the image generated by the game program running on the server/host computer. Wiltshire’s only disclosure of video stream compression is in its description of stage 230 at 7:13-18.

In stage 230, an image is sent from server/host computer 110 to client/terminal computer 120. The image may include any type of graphical information including a bitmap, a JPEG file, a TIFF file or even an encoded audio/video stream such as a compressed video MPEG stream.

The next line (7:18-19) states that the “image is generated by game computer program” but the above quoted passage states that this image “may *include* any type of graphical information” and this graphical information could include “a JPEG *file*” or “a TIFF *file*.” A POSITA would have understood Wiltshire to disclose that the “image [] generated by the game computer program” could include the contents of a pre-existing compressed image file.

63. A POSITA would have understood two ways to include the contents of a pre-existing compressed image file in the context of Wiltshire’s disclosure. One way would be to decompress the file on the server/host and combine the decompressed image with any other image elements generated by the game program. Another way would be to somehow attach the compressed image file to the generated image for transfer from the server/host to the client/terminal. Either way, a POSITA would not have understood Wiltshire to disclose the on-the-fly compression of the image generated by the game computer program, because Wiltshire specifically refers to a *file*.

64. Similarly, a POSITA would have understood Wiltshire’s reference to “or even an encoded audio/video stream such as a compressed video MPEG stream” (7:16-18) to mean a pre-stored encoded audio/video stream, such as an MPEG file, that could be included in the image generated by the game program to provide, for example, a short video segment in the display.

65. A POSITA would have understood “encoded” here to mean a previously encoded video stream. Wiltshire at Fig. 2 refers to Step 230 as “Send video stream to client” as the process applied to the output of Step 220 “Display/update image” when the image is updated. When Wiltshire at 7:13-18 refers to “or even *an* encoded audio/video stream such as a compressed video MPEG stream” as something that may be “include[d]” in the image transmitted to the client, a POSITA would have understood this to mean an additional encoded audio/video stream, because Fig. 2 already refers to a specific “video stream” consisting of the updated images. If Wiltshire had meant to communicate to a POSITA that the video stream of Fig. 2 could be compressed using MPEG or any other technique, a POSITA would have expected an additional step showing something of the form “encoding the video stream” or even a reference in Step 230 to “encoding the video stream” of updated images coming from Step 220. But Wiltshire does not include any disclosure suggesting that the updated images coming from Step 220 are encoded or compressed.

66. A POSITA would have understood “an encoded audio/video stream” in Wiltshire at 7:13-18 to refer to an additional encoded audio/video stream other than the updated images coming from Step 220 in Fig. 2. This understanding is further supported by Wiltshire’s disclosed embodiments. Wiltshire demonstrates at Fig. 4A an “attract mode” (3:20-21) that a POSITA would have understood was intended to

attract the attention of an observer. A POSITA would have understood that a still image would not attract attention as well as a video with moving and flashing elements. A POSITA would have also understood that these moving and flashing elements need not be generated in real-time and an efficient implementation would have used a premade video file for these elements.

67. Figs. 4B, 8A, and 9A of Wiltshire all include imagery of people in a casino environment. A POSITA would have understood that the inclusion of real people in a real-time synthetic computer graphics environment would have required significant resources that would have been unnecessary for the task as disclosed. A POSITA would have understood that the appropriate way to depict real people in a welcoming environment would have been to use a video recording of these people in the environment, and the proper way to include a video in an image that also includes user interface elements such as the buttons shown would have been to store a pre-encoded MPEG file that would be utilized for the display.

68. Finally, Wiltshire provides neither motivation nor means for performing any kind of on-the-fly compression step to the updated image in order to transmit a compressed video stream to the client/terminal. At ¶ 84 of his declaration, Dr. Fuchs suggests that a “POSITA would already have known that a compressed MPEG stream consists of compressed frames, and that to display a compressed MPEG stream at the client, the client would decompress the received stream to

display the video stream at the client... .” Indeed a POSITA would have understood MPEG compression and decompression, but a POSITA would have also understood that the MPEG format for compressed video includes frames that are interpolated and such frames are not possible for a live stream without introducing lag, latency and other delays that would have impeded interactivity. A POSITA would not have been motivated to introduce such delays and impediments to interactivity without a reason, and neither Wiltshire nor Dr. Fuchs provides one.

2. Wiltshire combined with Saha does not disclose “compressing the at least one updated image and transmitting the compressed updated image to the client device”

69. Dr. Fuchs at ¶¶ 87-88 of his declaration opines that a POSITA, based on Saha, would have understood an MPEG stream to consist of “three types of pictures,” the so-called “intra” (I) frame, “predicted” (P) frame and “bi-directional interpolated” (B) frame.

An MPEG stream includes three types of pictures, referred to as the Intra (I) frame, the Predicted (P) frame, and the Bi-directional Interpolated (B) frame. The I (intra) frames contain the video data for the entire frame of video and are typically placed every 10 to 15 frames. Intraframes provide entry points into the file for random access, and are generally only moderately compressed. Predicted frames are encoded with reference to a past frame, i.e., a prior Intraframe or Predicted frame. Thus P frames only include changes relative to prior I or P frames. In general, P frames receive a fairly high amount of

compression and are used as references for future P frames. Thus, both I and P frames are used as references for subsequent frames. Bi-directional pictures include the greatest amount of compression and require both a past and a future reference in order to be encoded. Bi-directional frames are never used as references for other frames.

Saha at 2:21-38.

70. Saha at 2:47-4:7 discloses the process of MPEG encoding a video file or a bitstream. Saha states that “the MPEG encoder generally first creates the I frames” (2:47-49) where the I frames “are typically placed every 10 to 15 frames” (2:26). Each of the frames between these periodic I frames is either a P frame or a B frame. A P frame is subdivided into 16x16 pixel “macroblocks.” Instead of representing all 16x16 pixels of the macroblock, the MPEG encoder instead searches for a similar 16x16 block of pixels somewhere in a prior frame, so once found, it can represent this entire 16x16 block of pixels in the current P frame by a single reference to its location in a prior frame. A B frame is similarly processed, but can search for matching 16x16 blocks of pixels in both prior and subsequent frames.

71. Dr. Fuchs does not provide an opinion on the composition of his supposed MPEG stream produced by Wiltshire combined with Saha. Is it entirely I-frames? Does it include P-frames? If so, how much effort would have been spent by Wiltshire to predict motion?

72. Dr. Fuchs does not mention that B frames would be impossible in a live stream without introducing significant latency. This is because a B frame would search both prior *and subsequent* frames. If an MPEG stream were being used in the live display of an interactive application, then how could a B frame search for a matching macroblock in a future frame without knowing what interactive action may come from the user that could alter that future frame?

73. A POSITA would also have understood that the analysis and computation needed to perform the macroblock searches to create an MPEG video is considerable, and in the absence of any express mention of it, a POSITA would not simply assume Wiltshire intended on-the-fly MPEG compression. Instead, Wiltshire discloses caching and prestorage of visual elements on the client/terminal as the preferred method to reduce bandwidth, and Wiltshire's examples of reducing bandwidth do not make any mention of compression.

74. Dr. Fuchs at ¶¶ 91-92 of his declaration misleadingly opines that “a POSITA would have understood that MPEG was well known and widely used to compress and decompress image or video data years before the '109 patent” and “would thus have understood Wiltshire's disclosure of ‘a compressed video MPEG stream’ as teaching compression of images frames by ‘server/host computer 110’” This conclusion is flawed because the MPEG compression described by Saha and used in Dr. Fuchs's opinions relies on off-line processing of a pre-existing file

or bitstream. For example, Saha at 2:60 reminds us that in an MPEG encoder, “[f]or a target B frame, the encoder searches in a prior and subsequent I or P frame,” but if Wiltshire is combined with Saha, then how is a *subsequent* I or P frame available in a live encoding? Dr. Fuchs does not provide any evidence of or citation to on-the-fly real-time MPEG compression of a live video stream, as would have been required if Wiltshire had actually taught the MPEG compression of its updated image video stream.

75. Dr. Fuchs at ¶ 84 of his declaration concedes that “Wiltshire does not discuss the details of decompressing the compressed frames at the client” because “Wiltshire is written for a POSITA” who “would already have known that a compressed MPEG stream consists of compressed frames... .” But in doing so, Dr. Fuchs makes no distinction between the MPEG compression of an existing video in its entirety versus a live stream generated by a server requiring low latency to support the needs of remote client interaction.

76. Dr. Fuchs continues at ¶ 85 of his declaration by suggesting that “the ’109 patent does not describe the details of the MPEG standard” and “[i]nstead, like Wiltshire, the ’109 patent merely mentions the MPEG standard... .” In this comparison, Dr. Fuchs overlooks several key details of the ’109 Patent that would inform a POSITA on how to apply compression to a live stream of rendered images.

77. First, the '109 Patent expressly acknowledges that “[t]hrough the use of adequate bandwidth, substantial image data can be transmitted from the visual server 12 to the client 16,18,20, approaching real-time speeds which can allow multimedia applications to be displayed on the clients 16,18,20, such as games and other graphic-intensive applications.” ’109 Patent at 6:23-28. Thus, the '109 Patent specifically discloses that the goal is real-time interactivity, which requires real-time compression. *See, e.g.*, ’109 Patent at 2:19-23 (describing as “Related Art” an example and observing that “[w]hile this method can decrease the computational load of the client and reduce the communication costs, it requires both real-time image compression and decompression and further requires that special image compositing be added to the pipeline”).

78. Second, the '109 Patent discloses not only MPEG, but also H.261. While MPEG can support real-time encoding, a POSITA would have understood it to be used offline for encoding video files. A POSITA would have understood the real-time MPEG encoding of live streams would have required an additional hardware subsystem, though software encoding was just becoming available in research laboratory settings at the time¹. For real-time low-latency encoding, a

¹ *See, e.g.*, McVeigh et al., A Software-Based Real-Time MPEG-2 Video Encoder, IEEE Transactions on Circuits and Systems for Video Technology 10(7),

POSITA would have expected a videoconferencing codec, such as H.261, to be the more appropriate choice. The H.261 standard² states in its first line that the standard is motivated by a “a significant customer demand for videoconference service,” and identified a single, primary use for its specification, when it stated it “should be used for international videoconference connections.”

79. These details of the ’109 Patent that inform a POSITA on compression of a live stream of rendered images are completely absent from Wiltshire. Wiltshire did not need these details because Wiltshire discloses the use of a pre-encoded MPEG video file as an item that can be included with an updated image, and that would have been understood by a POSITA.

Oct. 2000, pp. 1178-1184 (EX2012) (explaining that “dedicated high-cost hardware encoders typically are used in broadcast ... systems” and that “[d]ue to increases in clock frequency, the introduction of video-specific instruction sets..., and the availability of low-cost storage devices, the personal computer is now well suited to meet the requirements of these emerging applications.”).

² https://www.itu.int/rec/dologin_pub.asp?lang=e&id=T-REC-H.261-198811-S!!PDF-E&type=items (EX2013).

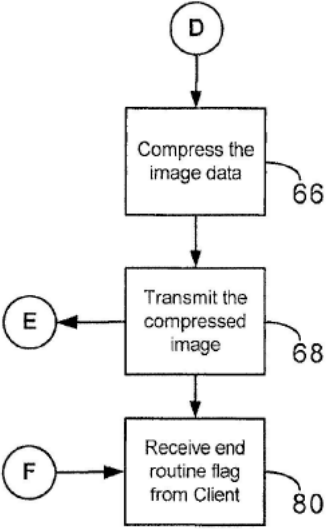
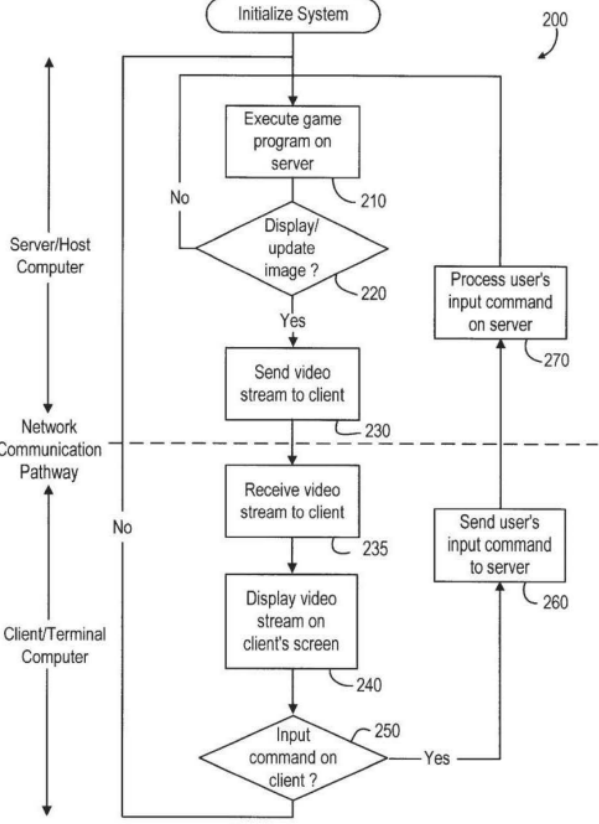
3. Wiltshire combined with Saha does not disclose “wherein the server transmits the updated image as a compressed frame that can be decompressed and displayed as an updated image at the client device”

80. Dr. Fuchs at ¶ 82 of his declaration opines that Wiltshire combined with Saha discloses “wherein the server transmits the updated image as a compressed frame that can be decompressed and displayed as an updated image at the client device.” I disagree.

81. One reason is that neither Wiltshire alone nor its combination with Saha disclose “wherein the server transmits the updated image as a compressed frame” and so there is nothing for the client device *to decompress* to display as an updated image. First, I have shown above that Wiltshire alone does not disclose that “the server transmits the updated image as a compressed frame.” Second, Dr. Fuchs does not provide any opinion that Saha cures this deficiency in Wiltshire.

82. Furthermore, as shown in the table below comparing the disclosure of the '109 Patent to Wiltshire, Wiltshire includes no reference to the inclusion of a component performing compression of an updated image. As mentioned above, when Wiltshire was filed in 1998, a POSITA would have understood a low-latency real-time MPEG encoder capable of supporting user interaction of a remote application would have required a dedicated hardware component. Where in

Wiltshire would a POSITA have been informed of the existence, placement and configuration of such a dedicated hardware component?

Fig. 2D of the '109 Patent, showing Box 66 is a necessary component of its design to “Compress the image data.”	Fig. 2 of Wiltshire, showing Box 230 “Send video stream to client” without any mention or inclusion of a compression component.
 Fig. 2D	 Fig. 2

4. Wiltshire combined with Saha does not disclose or suggest “wherein the server transmits the updated image as a ... frame”

83. Using the construction of “frame” provided above in my declaration, Dr. Fuchs does not show that Wiltshire combined with Saha discloses a server that transmits the updated image as a frame.

84. As shown above in my declaration, a POSITA would have understood “frame” in the context of Claims 1 and 8 of the ’109 Patent to mean “a single instance of the display.” As shown above, the “display” is the entire visual output of the application running on the server.

85. Wiltshire teaches at 8:4-7 a preference for embodiments where “image updates (once an image has been displayed) are limited to areas of the screen that are actually modified rather than full screen refreshes.” Wiltshire provides the context for this teaching by first stating at 7:57-59 that “a very limited amount of information needs to be transferred over communication pathways 130 between server/host computer 110 and client/terminal computers 120... .” A POSITA would have understood Wiltshire’s “very limited amount of information” to mean avoiding sending the frame (a single instance of the entire displayed output of the server application) when only a small portion of the screen was updated.

86. Dr. Fuchs at ¶ 31 of his declaration opines that “Both MPEG-1 and MPEG-2 (collectively ‘MPEG’) provide compression by generating compressed

‘frames’ from video data.” Dr. Fuchs explains that “frames represent the still images that are ordered in a sequence to produce a video or animated sequence.” As I understand Dr. Fuchs, he is simply stating that MPEG produces a series of compressed images that are called “frames” in MPEG terminology. At ¶ 88 of his declaration, Dr. Fuchs states, “Saha discloses that in these MPEG standards, an encoded MPEG stream is a sequence of compressed ‘frames’ (also called ‘pictures’).” I understand Dr. Fuchs to be using the word “frame” to simply mean picture or image. As he explains at ¶ 89, “A POSITA would understand that a video stream is a sequence of frames (or pictures), where each frame is an image of a video sequence.”

87. Dr. Fuchs at ¶ 91 of his declaration concludes that “a POSITA would have known that MPEG includes ‘compressed frames’ and provides a method for both compression of frames and decompression of compressed frames.” However, because Dr. Fuchs understands “frame” to simply mean picture or image, his opinion does not address whether MPEG generates compressed “frames” as required by the claims of the ’109 Patent. MPEG simply compresses the series of images that are input to the algorithm. As such, MPEG does not change the nature of the input images that are not “frames” into “frames” through compression. If a series of images that are not “frames” are input to the MPEG algorithm, they will not be “compressed frames” at the output. I disagree that MPEG alone generates

compressed “frames” as that term is used in the ’109 Patent without regard to whether the input images are “frames.”

5. Claims 6, 11, and 12 are not obvious over Wiltshire combined with Saha (Ground 1)

88. Claim 6 of the ’109 Patent recites: “The method as recited in claim 1, wherein the client device is a mobile device.” ’109 Patent at 10:19-20.

89. As explained above, the “mobile device” referred to in Claim 6 of the ’109 Patent would have been understood by a POSITA to mean “a handheld computing device.” Wiltshire in combination with Saha does not disclose the method as recited in Claim 1 wherein the client device is a mobile device. I also disagree with the opinions in the declaration of Dr. Fuchs that state Wiltshire combined with Saha makes such a disclosure.

90. Dr. Fuchs at ¶ 119 of his declaration suggests that Wiltshire at Abstract discloses “allow[ing] a patron to participate in a mobile gaming environment” but this phrase is produced out of context. The full sentence of the abstract states: “By using a stereo head-mounted display together with a joystick input device and wireless communication pathways, the present invention allows a patron to participate in a mobile gaming environment.” A POSITA would not have considered a stereo head-mounted display to be a handheld computing device. Wiltshire was filed in 1998 and a POSITA at that time would have understood a stereo head-

mounted display to require a sophisticated workstation-class computer with dedicated graphics capabilities as well as a dedicated head-tracking system to support a stereo head-mounted display.

91. In fact, in 1998 head-mounted displays were not “well enough developed ... to give a comfortable, stable image with sufficient image quality” even using high-end graphics VR laboratory computing equipment of the time. p. 32 of “Beyond the Desktop Metaphor: Toward More Effective Display, Interaction, and Telecollaboration in the Office of the Future via a Multitude of Sensors and Displays” by Henry Fuchs in Proc. International Conference on Advanced Multimedia Content Processing, Nov. 9, 1998, pp. 30-43, <https://www.cs.unc.edu/~fuchs/publications/Fuchs1998.pdf> (EX2014).

92. Dr. Fuchs at ¶ 120 of his declaration suggests that “laptops could be used in a ‘mobile gaming environment’ as Wiltshire describes.” First, Wiltshire does not mention or suggest using a laptop computer, and Dr. Fuchs points to no such disclosure or suggestion in either Wiltshire or Saha. The fact that laptop computers were known is not a reason in and of itself to use one in Wiltshire’s system. For example, as I explained above regarding Wiltshire’s stereo head-mounted display (the very system that Dr. Fuchs suggests would motivate the use of a laptop (¶ 119)), a POSITA would have understood that a laptop computer could not be expected to support such a system. Second, as shown in my above construction of “mobile

device,” a laptop computer would not have been understood by a POSITA to be a “handheld computing device.”

93. Like Claim 6, Claim 11 requires that “the client device is a mobile device.” ’109 Patent at 10:55-56. Similarly, Claim 12 requires that “at least one of the plurality of client devices is a mobile device.” *Id.* at 10:58-59. For the same reasons I discuss with respect to Claim 6, I disagree with the opinions in the declaration of Dr. Fuchs that state Wiltshire combined with Saha discloses a client device that is a mobile device.

B. Claim 2 is valid, even in view of Wiltshire, Saha and Chen (Ground 2)

94. As Dr. Fuchs explains at ¶ 192 of his declaration, Claim 2 depends on Claim 1, and his Ground 1 analysis is incorporated into his Ground 2 analysis. I disagree with these incorporated opinions of Dr. Fuchs on Ground 2 for the same reasons I disagreed with them above for Ground 1.

1. A POSITA would not have been motivated to combine Wiltshire, Saha and Chen

95. Dr. Fuchs at ¶¶ 196-202 of his declaration suggests four reasons that would have somehow motivated a POSITA reading Wiltshire (alone or in combination with Saha) to have considered combining it with Chen. I disagree for the following reasons.

96. First, Dr. Fuchs at ¶ 197 of his declaration suggests that because both Wiltshire and Chen mention the “Internet,” they “thus teach toward one another.” But the mere fact that both Wiltshire and Chen mention the Internet would not have necessarily led a POSITA to combine Wiltshire and Chen.

97. Second, Dr. Fuchs at ¶ 198 of his declaration contrives the notion that “Wiltshire’s system provides a form of ‘video-on-demand.’” Dr. Fuchs opines that Chen explains that “ADSL is well suited for video-on-demand.” However, a POSITA would have understood “video-on-demand” to mean “providing pre-encoded video at a time requested by the viewer.” A POSITA would have understood pre-encoded video could include bidirectional frames, variable rate encoding and offline analysis to reduce the bandwidth necessary. A POSITA would have understood such techniques are not available if Wiltshire disclosed the real-time live embodiments that Dr. Fuchs opines that it does. Finally, a POSITA would have understood the difference between Chen’s pre-encoded MPEG videos and the transmission of updated images allegedly disclosed by Wiltshire. (Alternatively, Dr. Fuchs may be admitting here that Wiltshire discloses that pre-encoded MPEG video files are attached to updated images and both are transmitted to the client/terminal.)

98. Third, Dr. Fuchs at ¶ 201 of his declaration opines that the number of known options for providing Internet connectivity was finite. Dr. Fuchs then suggests there were “typically” only two options: “*ADSL* or cable networks,”

quoting a passage from PC Magazine (EX1007) that “[c]able modems and **DSL** lines are proliferating faster than anyone predicted...” (emphasis added to both quotes to differentiate Dr. Fuchs’s “ADSL” from PC Magazine’s “DSL”). A POSITA would have understood the distinction between DSL and ADSL, but Dr. Fuchs seeks to confound the terminology and equate DSL and ADSL. In doing so, Dr. Fuchs ignores the second paragraph of Chen (on p. 4 of 8) which states “[s]ince there are so many different versions of DSL systems, people have used the name xDSL, where x stands for any version” and goes on to recite (original) DSL, HDSL, ADSL and SHDSL, as well as IDSL, SDSL and RADSL.

99. Furthermore, at ¶ 201 of his declaration Dr. Fuchs seems to incorporate what a POSITA would have understood from PC Magazine in an argument that did not include a combination with PC Magazine.

100. Fourth, Dr. Fuchs at ¶ 202 of his declaration suggests that “a POSITA would have had a reasonable expectation of success with the combination of Chen with Wiltshire and Saha,” but only justifies this opinion with the argument that “Wiltshire describes using a communication pathway such as the Internet” and “Chen discloses that ADSL is ideal for providing Internet access.” A POSITA would have required more explicit details and requirements for a network configuration to have a reasonable expectation of success.

2. Dr. Fuchs does not show how a POSITA would combine Wiltshire and Saha with Chen

101. Dr. Fuchs at ¶ 196 opines that a POSITA would have combined Wiltshire and Saha with Chen, with a reasonable expectation for success, and then provides four reasons. However, none of these reasons describe *how* a POSITA would combine Wiltshire and Saha with Chen.

102. For example, Wiltshire at 5:30-44 describes element 130 of Fig. 1D as “communication pathways” which could include “the Internet.” This section further refers to a “network interface 115” that connects “server/host computer 110 to client/terminal computers 120,” all diagrammed in Fig. 1A. Dr. Fuchs does not indicate how a POSITA would have mapped Chen to these networking components that are explicitly disclosed by Wiltshire.

103. Dr. Fuchs does provide bandwidth details at ¶ 195, indicating that Chen’s ADSL was capable of 1.544 Mb/s, and further quotes Chen at ¶ 200 that this would be sufficient to support *one* MPEG video stream at 1.3 Mb/s.

104. Wiltshire at 2:45-65 motivates the use of a server/host computer because (1) fairness and regulatory compliance can be continuously monitored by duly authorized regulators, (2) improving reliability and availability due to regular server maintenance, and (3) the ability to modify and upgrade the computer gaming programs from a central location. A POSITA would have understood from this

motivation that Wiltshire was suggesting a server/host located at a computer server farm facility that could be outside the casino housing the client machines. A POSITA would further have understood that the Internet would be used as the communications pathway from 110 to 115, and 115 would have been the network router connecting all of the client/terminal computers at the casino to the single Internet connection. This POSITA understanding is consistent with Wiltshire's disclosure of the network interface 115 at 5:32-37. However, a POSITA would not have a reasonable expectation of success with that embodiment using Dr. Fuchs's proposed Chen ADSL as the Internet connection, because as Dr. Fuchs showed, the ADSL would only be capable of a single MPEG video stream and thus would not be capable of transmitting such video stream to the more than one client/terminals prescribed by Wiltshire.

105. Dr. Fuchs at ¶ 201 concludes that a "POSITA would have known that ADSL was a widespread and common choice for broadband Internet access in the 1998-2000 time frame" based on his citation of a PC Magazine article. That particular PC Magazine article "Affordable Networking: Share your cable or DSL modem across your small network with the BeadleNet SOHO 2000" (EX1007 at p.17/20) refers to "DSL" not "ADSL," contradicting Dr. Fuchs's assertion. As the second paragraph of Chen (on p. 4 of 8) stated, "[s]ince there are so many different versions of DSL systems, people have used the name xDSL, where x stands for any

version” and goes on to recite (original) DSL, HDSL, ADSL and SHDSL, as well as IDSL, SDSL and RADSL. Dr. Fuchs’s assertion that “DSL” means “ADSL” is contradicted by Chen. The PC Magazine article also encourages the reader to purchase a router to be able to connect multiple computers to their Internet connection. If a BeadleNet SOHO 2000 (or any other router) connected multiple computers to a Chen ADSL Internet connection, by Dr. Fuchs’s ¶ 195 math only one of these computers would be able to receive an MPEG video stream and be able to access the Wiltshire server/host as a client/terminal. Dr. Fuchs justified the use of Chen’s ADSL with Wiltshire’s Slim Terminal Gaming System using a PC Magazine article about a device that, when purchased, would impede additional client/terminals to function as prescribed by Wiltshire. In short, a POSITA would not have had a reasonable expectation of success from such a configuration.

C. Claims 6, 11 and 12 are valid, even in view of Wiltshire, Saha and PC Magazine (Ground 3)

106. Claim 6 of the ’109 Patent recites: “The method as recited in claim 1, wherein the client device is a mobile device.” ’109 Patent at 10:19-20. Dr. Fuchs at ¶¶ 215-236 opines that a POSITA would have understood an Apple iBook to have met the requirements of a “mobile device” because it was a portable device that could operate with wireless technology allowing it to “roam up to 150 feet from its base station.”

107. As explained above, the “mobile device” referred to in Claim 6 of the ’109 Patent would have been understood by a POSITA to mean “a handheld computing device.” Wiltshire and Saha in combination with PC Magazine do not disclose the method as recited in Claims 6, 11 and 12 wherein the client device is a mobile device. I also disagree with the opinions in the declaration of Dr. Fuchs that state Wiltshire and Saha combined with PC Magazine make such a disclosure.

108. Dr. Fuchs at ¶ 119 of his declaration suggests that Wiltshire at Abstract discloses “allow[ing] a patron to participate in a mobile gaming environment” but this phrase is produced out of context. The full sentence of the abstract states: “By using a stereo head-mounted display together with a joystick input device and wireless communication pathways, the present invention allows a patron to participate in a mobile gaming environment.” As I explained above, a POSITA would not have considered a stereo head-mounted display to be a handheld computing device. Wiltshire was filed in 1998 and a POSITA at that time would have understood a stereo head-mounted display to require a sophisticated workstation-class computer with dedicated graphics capabilities as well as a dedicated head-tracking system to support a stereo head-mounted display.

109. In fact, in 1998 head-mounted displays were not “well enough developed ... to give a comfortable, stable image with sufficient image quality” even using high-end graphics VR laboratory computing equipment of the time. p. 32 of

“Beyond the Desktop Metaphor: Toward More Effective Display, Interaction, and Telecollaboration in the Office of the Future via a Multitude of Sensors and Displays” by Henry Fuchs in Proc. International Conference on Advanced Multimedia Content Processing, Nov. 9, 1998, pp. 30-43, <https://www.cs.unc.edu/~fuchs/publications/Fuchs1998.pdf> (EX2014).

110. Dr. Fuchs at ¶ 120 of his declaration suggests that “laptops could be used in a ‘mobile gaming environment’ as Wiltshire describes.” However, as shown in my above construction of “mobile device,” a laptop computer would not have been understood by a POSITA to be a “handheld computing device.”

111. Also, Wiltshire discloses a specific context for its invention. It states that “[t]he terms ‘game’ and ‘gaming,’ as used herein, include all type of electronic, electromechanical or mechanical gambling and casino game facsimiles” Wiltshire at 1:26-28. Although Wiltshire goes on to describe a broad array of game types, Wiltshire concludes with the following:

Embodiments described above illustrate but do not limit the invention. In particular, the invention is not limited to any particular game. In fact, *any casino game or other non-casino games where players play against each other for money* with the house taking a percentage of the stake for providing the game.

Wiltshire at 12:8-13 (emphasis added). Wiltshire’s disclosure is focused on gambling and in particular commercial gambling operations provided by a “house”

or a casino. That is why Wiltshire's Fig. 1D shows "Wager-Acceptor" devices on each client computer.

112. A POSITA would not have been motivated to use a laptop computer in a commercial gambling environment. Commercial gaming environments of any type, such as arcades, focus on durability and security. That is why arcade games even today are large devices that are not easily tampered with. Casinos, however, are even more focused on security because exchanging money (and potentially large sums of it) are what the devices are intended to do as shown by Wiltshire's "Wager-Acceptor" attached to each client device in Fig. 1D. Like ATMs, for example, a POSITA would be heavily focused on the security of the device. U.S. Patent No. 6,266,930 (EX2006) was filed on October 15, 1999 and is entitled, "Safeguard Structure and Transaction Device." It explains:

A variety of security and burglarproof mechanisms have conventionally been proposed, especially to those automatic transaction devices which carry cash, such as vending machines and ATMs [D]ue to the development of the burglarproof mechanisms, burglars tend to prefer stealing a vending machine entirely In particular, the recent trend in miniature equipment has facilitated to carry [sic] the entire machine.

'930 Patent at 1:14-30. A POSITA would have understood that any device accepting money needs to be secured. Dr. Fuchs does not offer any explanation for why a

POSITA would employ a laptop in such an application. It would be far easier for a patron to carry off a laptop computer than an ATM machine.

113. Like Claim 6, Claim 11 requires that “the client device is a mobile device.” ’109 Patent at 10:55-56. Similarly, Claim 12 requires that “at least one of the plurality of client devices is a mobile device.” *Id.* at 10:58-59. For the same reasons I discuss with respect to Claim 6, I disagree with the opinions in the declaration of Dr. Fuchs that state Wiltshire combined with Saha discloses a client device that is a mobile device.

X. CONCLUSION

114. Based on the foregoing, it is my opinion that Petitioner has failed to establish by a preponderance of the evidence that the Challenged Claims of the ’109 Patent are unpatentable over the cited references.

115. 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 called upon to testify in deposition or before the Patent Trial and Appeal Board. If called upon to testify, I would testify truthfully and competently to all matters stated in this Declaration.

116. I reserve the right to supplement my opinions in the future to respond to any arguments that Petitioner raises and to take into account new information as it becomes available to me.

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

Dated: September 3, 2021



Dr. John C. Hart

APPENDIX A

Curriculum Vitæ

John C. Hart

Director of Professional Education
and
Professor of Computer Science
University of Illinois at Urbana Champaign

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∞ Experience ∞

Education

- **Ph.D.** Electrical Engineering and Computer Science Dept., University of Illinois at Chicago, 1991. Thesis title: "Computer Display of Linear Fractal Surfaces." Advisor: Thomas A. DeFanti.
- **M.S.** EECS Dept., University of Illinois at Chicago, 1989. Thesis title: "Image Space Algorithms for Visualizing Quaternion Julia Sets." Advisor: Thomas A. DeFanti.
- **B.S.** College of Liberal Arts and Science, Aurora University, 1987. Major: Computer Science.

Academic Positions

- **Director of Professional Education**, University of Illinois at Urbana-Champaign, 2021-.
- **Director of Online Programs**, Dept. of Computer Science, 2018-2021.
- **Director**, Master of Computer Science in Data Science program, 2016-2017.
- **Executive Associate Dean**, Graduate College, University of Illinois, 2015-2021.
- **Associate Dean**, Graduate College, University of Illinois, 2014-2015.
- **Director for Graduate Studies**, Dept. of Computer Science. 2013.
- **Full Professor**, Dept. of Computer Science, University of Illinois, 2006-.
- **Associate Professor**, Dept. of Computer Science, University of Illinois, 2000-2006.
- **Associate Professor**, School of Electrical Engineering and Computer Science, Washington State University, 1998-2000.
- **Assistant Professor**, School of Electrical Engineering and Computer Science, Washington State University, 1992-1998.
- **Postdoctoral Research Associate**, Electronic Visualization Laboratory, University of Illinois at Chicago, and National Center for Supercomputing Applications, University of Illinois at Urbana-Champaign, 1991-1992.
- **Research Assistant**, Electronic Visualization Laboratory, Electrical Engineering and Computer Science Dept., University of Illinois at Chicago, 1988-1991.

- **Teaching Assistant.** Analog & digital circuit design courses, EECS Dept. University of Illinois at Chicago, 1987-1988.

Awards and Honors

- **The Excellence in Online & Distance Teaching Award.** University of Illinois at Urbana-Champaign, 2021.
- **Fellow.** Academic Leadership Program, Big Ten Academic Alliance, 2016-2017.
- **Outstanding Advisor.** College of Engineering, 2010 and 2015.
- **Winner.** 2004 Fantasy Graphics League.
- **Listed.** *International Who's Who of Professionals*, 1997.
- **Champion.** SIGGRAPH Bowl II, SIGGRAPH 94. Captain of the EVL Alumni Team.
- **NSF Research Initiation Award.** "Modeling, Rendering and Animation of Implicit Surfaces," to support the generalization of methods developed for the visualization of fractal models to the more common implicit surfaces used in CAGD and entertainment, 1993.
- **First Runner-Up.** Truevision Videographics Competition, SIGGRAPH 90.
- **Graduate Fellowship.** Graduate College, University of Illinois at Chicago, 1990-1991.

Industry Consulting

- **Intrinsic Medical Imaging LLC**, Bloomfield Hills, MI. Consultant, 2012-13. Mesh construction and simulation of coronary arterial blood flow.
- **Pratt & Whitney**, Hartford, CT. Consultant, 2011. Flux estimation in a lensed system.
- **Science Applications International Corp. (SAIC)**, Champaign, IL. Consultant, 2008. Ray-NURBS intersection.
- **Adobe Systems, Inc.**, Seattle, WA. Visiting Researcher, 2007. Project: Rendering meshed objects as stylized vector art.
- **The Teaching Company**, Chantilly, VA. Consultant, 2003. Produced custom educational video elements on the platonic solids.
- **Evans & Sutherland Computer Corp.**, Salt Lake City, Utah. Consultant, 1999-2000. Project: Design of the Evans & Sutherland Multi-Texturing Language.
- **Blue Sky | VIFX, Inc.**, Culver City, California. Consultant, 1998. Project: development of a custom software plug-in for the Houdini procedural animation package to polygonize a feature film villain modeled as a complex implicit surface.
- **Evans & Sutherland Computer Corp.**, (group formerly known as Silicon Reality, Inc.) Federal Way, Washington. Consultant, 1997-8. Project: design of graphics hardware to support antialiased procedural solid texturing.
- **Kleiser-Walczak Construction Company (a visual effects production company)**. Lennox, Massachusetts. Consultant, 1992-1993. Project: development of a new fractal-based video transition effect for an attraction at the Luxor Hotel, Las Vegas.
- **AT&T Pixel Machines.** AT&T Bell Laboratories, Holmdel, New Jersey. Summer Intern, 1990.
- **IBM T.J. Watson Research Center.** Hawthorne, New York. Summer Intern, 1989.

Expert Testimony

(Only includes disclosed engagements.)

- **Intellectual Pixels**, Inter Partes Review for Patent 8,667,093. Retained by Armond Wilson. Mar. 2021 – ongoing. Authored declaration. Deposed 18 June 2021.
- **CorePhotonics**, Inter Partes Reviews for Patents 10,225,479 and 10,230,898. Retained by Russ, August & Kabat. Jan. 2021 – ongoing. Authored declarations. Deposed 29 Apr. 2021 and 21 May 2021.
- **LG Electronics Inc.**, US District Court, Central District of California, Western Division. Case No. 2:19-cv-09474-JAK. Retained by Sidley Austin Jan. 2020. Authored Sep 2020 expert report on claim construction. Settled .
- **Align Technology, Inc.**, US District Court for the District of Delaware, C.A. No. 17-1647-LPS-CJB. Retained by Morrison Foerster Mar. 2019. Authored infringement report and reply report on validity. Deposed 19 June 2020.
- **Adsync Technologies**, Middle District of Florida, Orlando Division, Case 6:18-cv-1176-Orl-40TBS. Retained by Akerman Jun. 2019. Declaration in defense of Amended Complaint from Adacel and in support of counter complaint from Adsync. Deposed 24 Jan 2020. Settled favorably for Adsync Jan. 2021.
- **ZiiLabs** (subsidiary of Creative Technology), Certain Graphics Processors and Products Containing the Same, US International Trade Commission Case #337-TA-1099. Retained by Pepper Hamilton Sep. 2017. Deposed 12 Nov. 2018. Settled Feb. 2019.
- **Samsung**, - FotoNation Ltd. et al. v. Samsung Electronics. Co., Ltd., et al., No. 2:17-cv-00669 (E.D. Tex.). Retained by O'Melveny & Myers Oct. 2017. Settled Jan. 2019.
- **Samsung**, Inter Partes Reviews for of patents filed by Image Processing Technologies LLC: 6,717,518, 6,959,293, 7,650,015, 8,805,001, 8,983,134 and 8,989,445. Retained by O'Melveny & Myers Oct. 2016. Deposed Dec. 2017.
- **ZiiLabs** (subsidiary of Creative Technology), Certain Graphics Processors, DDR Memory Controllers, and Products Containing the Same, US International Trade Commission Case #337-TA-1037, for Pepper Hamilton LLP, Sep. 2016 – July 2017. Testified to the International Trade Commission for Markman hearing. Settled.
- **Advanced Silicon Technology**, Certain Computing or Graphics Systems, Components Thereof, and Vehicles Containing Same, US International Trade Commission Case #337-TA-984, for Mintz, Levin, Cohn, Ferris, Glovsky and Popeo PC, Aug. 2015 – Aug. 2016. Testified to the International Trade Commission for Markman hearing and authored validity report. Written declarations submitted for IPR2016-00894, -00897 and 01060). All settled.
- **ZiiLabs** (subsidiary of Creative Technology), Eastern District of Texas, Marshall Division, Case 2:14-cv-00203, for Heim, Payne & Chorush LLP and Susman Godfrey LLP. Sep. 2014 – Dec. 2015. Prepared invalidity rebuttal report for four patents and damages report for nine patents, all on graphics hardware. Deposed over two sequential days on both reports. Settled.
- **Graphics Property Holdings** (formerly SGI), Certain Consumer Electronics with Display and Processing Capabilities, US International Trade Commission Case #337-TA-884, for Mintz, Levin, Cohn, Ferris, Glovsky and Popeo . Graphics hardware expert on floating point rasterization, Authored report on patent validity. Deposed Feb. 2014. Testified to the International Trade Commission Apr. 2014. Judgement for GPH.
- **Microsoft Xbox**, Illinois Northern District Court (Eastern Division) Case #08-C-393, for Sidley Austin LLP. Dec. 2009 – May 2010. Prepared non-infringement rebuttal report and invalidity report. Settled.

- **NVIDIA & AMD (ATI)**, California Northern District Court Case # 3:07-cv-00302, for Cooley Godward Kronish LLP. July 2008 – Sep. 2008. Provided expertise on graphics hardware and insight into the industry-wide process for the deployment of innovative features. Settled.
- **Broadcom**, California Southern District Court Case #06-CV-0660, for McAndrews, Held & Malloy, Ltd, Dec. 2006 – Mar. 2007. Settled.

∞ Research Funding ∞

From Industry

- **Caterpillar**, through the **Digital Manufacturing & Design Innovation Institute**. \$410,000, Co-PI with Placid Ferreira and Shiv Kapoor.
- **Intel**. Intel Illinois Parallelism Center. \$2,500,000, Co-PI, 2011-2012.
- **Intel**. Leveraging Larrabee's Programmable Rasterization. \$130,000, 2009-2011.
- **Intel/Microsoft**. Universal Parallel Computing Research Center. \$18,000,000, Co-PI, 2008-2012.
- **NAVTEQ**. "Surface Classification and Reconstruction from LIDAR and images." \$60,000, 2008.
- **Thomas M. Siebel**. "MethMorph: Visual Simulation of Methamphetamine Addiction." \$35,000, Spring 2006.
- **NVidia Corp.** \$15,000 annually through the UIUC CS Affiliates Program, 2004–, and \$125,000 total to date in Ph.D. student fellowships (\$25K directly to the student to support one year of Ph.D. research): Nate Carr: 2002 & 2003, Jesse Hall: 2003 & 2004, Jared Hoberock: 2005 & 2008.
- **Microsoft Research**. "Precomputed Radiance Transfer Compression." \$15,000, Sep. 2002.
- **Evans & Sutherland Computer Corp.** "Real Time Procedural Solid Texturing." \$83,246, June 1999 – May 2000.
- **Evans & Sutherland Computer Corp. and Washington Technology Center**. "APST: Computer Graphics Hardware for Antialiased Procedural Solid Texturing." \$77,089. Aug. 16, 1998 - Aug. 15, 1999.
- **Intel Natural Data Types Group**. "Procedural Modeling." \$43,000. Aug. 16, 1997 - Aug. 15, 1998.
- **Intel Natural Data Types Group**. "Recurrent Modeling -- Beyond Fractal Block Coding." (Co-PI with P. Flynn.) \$93,000. Apr. 1, 1995 - Mar. 31, 1997.

From Government Agencies

- **NSF**. #OAC-1550554 "SI2-SSI: Collaborative Research: ParaTreet: Parallel Software for Spatial Trees in Simulation & Analysis" (co-PI with Laxmikant Kale), \$170,000, Sep. 2016 – Aug. 2018.
- **NSF**. #OCI-1216788 "Collaborative Research: Conceptualizing an Institute for Using Inter-Domain Abstractions to Support Inter-Disciplinary Applications" (co-PI with David Padua and Philippe Geubelle, and other collaborators at Purdue and UT-Austin), \$135,000, Oct. 2012 – Sep. 2016.
- **NSF**. #EF-1115112 "Collaborative Research: Digitization TCN: InvertNet--An Integrative Platform for Research on Environmental Change, Species Discovery and Identification" (co-PI with Christopher Dietrich, Christopher Taylor, Nahil Sobh and Umberto Ravaioli), \$2,809,463, July 2011-June 2015.
- **NSF**. #OCI-1047764 "SI2-SSE: Collaborative Research: Lagrangian Coherent Structures for Accurate Flow Structure Analysis" (co-PI with Shawn Shadden) \$251,643, Sep. 2010 – Aug. 2013.

- **NSF. #IIS-0534485** “Analysis and Visualization of Complex Graphs” (co-PI with Michael Garland) \$300,000, Sep. 2006 – Aug. 2009.
- **UIUC Critical Research Initiative.** “A New Approach to Bone Replacement.” (Co-PI with Russ Jamison, Michael Goldwasser, Ben Grosser, Matei Stroila and Amy Wagoner Johnson.) \$100,000, Sep. 2005 – Aug. 2006.
- **NSF Small Grant for Exploratory Research.** “Application Directed Surface Parameterization.” \$97,868, Jan. 2005 – Dec. 2005.
- **NSF/DARPA CARGO (Computational and Algorithmic Representations of Geometric Objects) Award.** “Robust Lagrangian Surface Propagation with Topological Control.” (Lead PI, with Michael Heath, Jim Jiao and John Sullivan), \$400,000, May 2003 – May 2006.
- **NSF Information Technology Research. #NSG-0219594** “Making 3D Visibility Practical.” (Co-PI with Steve LaValle, Jeff Erickson, Fredo Durand) \$499,923. Aug. 2002 – Aug. 2005.
- **CNRS (Centre National de la Recherche Scientifique).** Supplement to “Making 3D Visibility Practical” to support UIUC – INRIA collaboration, \$7,000, 2003-5.
- **NSF Information Technology Research. #ACI-0113968** “Multipass Programming for Personal High-Performance Computing.” \$489,671, Aug. 2001 – July 2006.
- **NSF Information Technology Research. #ACI-0121288** “Procedural Representation and Visualization Enabling Personalized Computational Fluid Dynamics.” (Co-PI with David Ebert, David Marcum, Kelly Gaither and Penny Rheingans) \$3,989,773. Aug. 2001 – July 2006.
- **NSF. #NSG-9732379** “Applications of Morse Theory and Catastrophe Theory to Computer Graphics.” (Co-PI with R. Lewis.) \$220,541. Aug. 16, 1997 – Aug. 15 2000.
- **NSF. #CCR-9529809** “Recurrent Modeling.” (Co-PI with P. Flynn.) \$206,435. June 15, 1996 - May 31, 1999. Research Experience for Undergraduates Supplement: \$5,000. Jan. 1, 1998 - May. 31, 1999.
- **NSF Research Initiation Award. #CCR-9309210** “Modeling, Rendering and Animation of Implicit Surfaces.” \$97,925. July 1, 1993 - June 30, 1996. Research Experience for Undergraduates Supplement: \$4,885. Jan. 1, 1995 - Dec. 31, 1995.

Education Projects

- **Nokia University Cooperation Funding.** “Teaching Mobile Augmented Reality on the Windows Phone Platform.” \$11,377.64. 2013.
- **UIUC College of Engineering Strategic Instructional Initiatives Program.** Improvement of key ME courses (Statics, Dynamics and Solid Mechanics), \$450,000, with MechSE Profs. Tortorelli, Dullerud Keane and West, 2012-2014.
- **NSF Special Project. #EIA-9911033** “The Story of Computer Graphics Documentary Project.” \$48,000. Sept. 15, 1999 – Aug. 31, 2000.

Equipment Grants and Donations

- **Nokia.** Two Velodyne LIDAR scanners, 2013.
- **NVidia.** K20 graphics card, 2012.
- **Intel.** Dell XPS 12, \$1,000, 2012.
- **Intel.** Two Knights Ferry development workstations, \$4,940, 2009.
- **NVidia.** Various graphics cards, 2002-4.

- **ATI.** One graphics card, 2002.
- **Tektronix Phaser 340 Color Printer.** Tektronix. \$5,000. Oct. 1995.
- **High-Performance Networking and Computing Infrastructure for Imaging Research.** (Co-PI with T. Fischer, P. Flynn and R. Bamberger.) NSF Research Instrumentation and Infrastructure. CISE Instrumentation Program, Office of Cross-Disciplinary Activities. \$100,000. March 1, 1994 - April 30, 1996. Awarded: Jan. 1995.
- **Silicon Graphics Inc. Workstation Upgrade.** \$9,000. Apr. 1993.
- **XAOS Tools.** Software Donation. Pandemonium and n-title. \$6,500. Feb. 1993.
- **Karen Guzak.** Art Donation. 12 Prints. \$4,800. May 1995.

∞ Publications ∞

Most of the following publications are available online via
<http://graphics.cs.illinois.edu/~jch/papers>.

Reviewed Publications

1. A.I. Ellis, W. Hunt and J.C. Hart. Real-Time Analytic Antialiased Text for 3-D Environments. Proc. High-Performance Graphics, Computer Graphics Forum 38(8), 2019, pp. 23-32.
2. A.J. Christensen, V. Srinivasan, J.C. Hart and A. Marshall-Colon. Use of computational modeling combined with advanced visualization to develop strategies for the design of crop ideotypes to address food security. Nutrition Reviews 76(5), May 2018, pp. 332-347.
3. P-C Wang, A.I. Ellis, J.C. Hart, C-H Hsu. Optimizing next-generation cloud gaming platforms with planar map streaming and distributed rendering. Proc. NetGames (15th Annual Workshop on Network and Systems Support for Games), 2017.
4. A. Marshall-Colon, S.P. Long, D.K. Allen, G. Allen, D.A. Beard, B. Benes, S. von Caemmerer, A.J. Christensen, D.J. Cox, J.C. Hart, P.M. Hirst, K. Kannan, D.S. Katz, J.P. Lynch, A.J. Millar, B. Panneerselvam, N.D. Price, P. Prusinkiewicz, D. Raila, R.G. Shekar, S. Shrivastava, D. Shukla, V. Srinivasan, M. Stitt, M. Turk, E.O. Voit, Y. Wang, X. Yin, X. Zhu. Crops in silico: Generating Virtual Crops Using an Integrative and Multi-scale Modeling Platform. Frontiers in Plant Science, May 2017.
5. M. Chen, J.C. Hart and S. Shadden. Hierarchical Watershed Ridges for Visualizing Lagrangian Coherent Structures. Reviewed, accepted and presented at TopoInVis: Topology-Based Methods in Visualization, 2015. Published in: Topological Methods in Data Analysis and Visualization IV, H. Carr, C. Garth, T. Weinkauff, Eds. Springer Mathematics and Visualization Series, 2017, pp. 237-252.
6. A.I. Ellis, Warren Hunt and J.C. Hart. "SVGPU: Real Time 3D Rendering to Vector Graphics Formats." Proc. High Performance Graphics, 2016.
7. M. Chen, S. Shadden and J.C. Hart. "Fast Coherent Particle Advection through Time-Varying Unstructured Flow Datasets." IEEE Transactions on Visualization and Computer Graphics 22(8), pp. 1959-1972, 2016.
8. J. Kratt, M. Spicker, A. Guayaquil, M. Fiser, S. Pirk, O. Deussen, J.C. Hart, B. Benes. Woodification: User-Controlled Cambial Growth Modeling. Proc. Eurographics, Computer Graphics Forum 23(2), May 2015, pp. 361-372.
9. V. Lu, J.C. Hart. Multicore Construction of k-d Trees for High Dimensional Point Data. Proc. Advances in Big Data Analytics, July 2014.

10. P.R. Khorrami, V.V. Le, J.C. Hart, T.S. Huang. A System for Monitoring the Engagement of Remote Online Students using Eye Gaze Estimation. Proc. IEEE ICME Workshop on Emerging Multimedia Systems and Applications, July 2014.
11. V. Lu, I. Endres, M. Stroila and J.C. Hart. Accelerating Arrays of Linear Classifiers Using Approximate Range Queries. Proc. Winter Conference on Applications of Computer Vision, Mar. 2014.
12. D. Mayerich, J.C. Hart, Volume Visualization of Serial Electron Microscopy Images Using Local Variance. Proc. BioVis (IEEE Symposium on Biological Data Visualization), pp. 9-16, Oct. 2012
13. C. Dietrich, J. Hart, D. Raila, U. Ravaioli, N. Sobh, O. Sobh, C. Taylor. InvertNet: a new paradigm for digital access to invertebrate collections. ZooKeys 209, July 2012, pp. 165-181.
14. Y. Jia, M. Garland, and J.C. Hart. Social Network Clustering and Visualization using Hierarchical Edge Bundles. Computer Graphics Forum 30(8), Dec. 2011, pp. 2314-2327.
15. Y. Jia, V. Lu, J. Hoberock, M.J. Garland, J.C. Hart. Edge v. Node Parallelism for Graph Centrality Metrics. GPU Computing Gems – Jade Edition, Oct. 2011, pp 15-28.
16. M. Kamali, F.N. Iandola, H. Fang, J.C. Hart. MethMorph: Simulating Facial Deformation due to Methamphetamine Usage. Proc. International Symposium on Visual Computing. Sep. 2011.
17. M. Kamali, J. Cho, M. Stroila, E. Shaffer, J.C. Hart. Robust Classification of Curvilinear and Surface-like Structures in 3D Point Cloud Data. Proc. International Symposium on Visual Computing. Sep. 2011.
18. M. Kamali, E. Ofek, F. Iandola, I. Omer, J.C. Hart. Linear Clutter Removal from Urban Panoramas. Proc. International Symposium on Visual Computing. Sep. 2011.
19. K. Karsch, J.C. Hart. Snaxels on a Plane. Proc. Non-Photorealistic and Artistic Rendering, Aug. 2011.
20. J. Hoberock, J.C. Hart. Arbitrary Importance Functions for Metropolis Light Transport. Computer Graphics Forum 29(6), 2010, pp. 1993-2003.
21. S. Shi, M. Kamali, K. Nahrstedt, J.C. Hart, R. Campbell. High-Quality Zero-Delay Remote Rendering System for 3D Video. Proc. Multimedia, Oct. 2010.
22. B. Choi, R. Komuravelli, V. Lu, H. Sung, R.L. Bochino, S.V. Adve, J.C. Hart. Parallel SAH k-D Tree Construction. Proc. High Performance Graphics, June. 2010.
23. Y. Jia, X. Ni, E. Lorimer, M. Mullan, R. Whitaker, J.C. Hart. RBF Dipole Surface Evolution. Proc. Shape Modeling International, June 2010.
24. W.-W. Feng, B.-U. Kim, Y. Yu, L. Peng, J.C. Hart, Feature-Preserving Triangular Geometry Images for Level-of-Detail Representation of Static and Skinned Meshes, ACM Transactions on Graphics 29(2), March 2010, Article 11.
25. J. Hoberock, V. Lu, Y. Jia, J.C. Hart. Stream Compaction for Deferred Shading. Proc. High Performance Graphics, Aug. 2009.
26. J.C. Hart. Assistive Technology for the Aesthetically Impaired. Proc. CHI Workshop on Computational Creativity Support, Apr. 2009.
27. J. Hoberock, S. Hornus, J.C. Hart. On Constructing and Visualizing the Topological Structure of the Visibility and Radiance of Architectural Models. Proc. TopoInVis: Topological Methods in Data Analysis and Visualization, Feb. 2009.
28. Y. Jia, J. Hoberock, M. Garland, J.C. Hart. On the Visualization of Social and other Scale-Free Networks. (Proc. Infovis), IEEE Transactions on Visualization and Computer Graphics 14(6), Nov. 2008, pp. 1285-1292.
29. A. Godiyal, J. Hoberock, M. Garland, J.C. Hart. Rapid Multipole Graph Drawing on the GPU. Proc. Graph Drawing, Sep. 2008.
30. E. Eisemann, H. Winnemoller, J.C. Hart, D. Salesin. Stylized Vector Art from 3D Models with Region Support. (Proc. Eurographics Rendering Symposium), Computer Graphics Forum 27(4), June 2008, pp. 1199-1207.

31. M. Stroila, E. Eisemann, J.C. Hart. Clip Art Rendering of Smooth Isosurfaces. IEEE Transactions on Visualization and Computer Graphics 14(1), Jan. 2008, pp. 71-81.
32. H. Fang, J.C. Hart. Detail Preserving Shape Deformation in Image Editing. Proc. SIGGRAPH, ACM Transactions on Graphics 26(3), Aug. 2007, #12.
33. T. Bergstrom, K. Karahalios, J.C. Hart. Isochords: Visualizing Structure in Music. Proc. Graphics Interface, May 2007.
34. H. Fang, J.C. Hart. RotoTexture: Automated Tools for Texturing Raw Video. IEEE Transactions on Visualization and Computer Graphics 12(6), Nov. 2006, pp. 1580-1589.
35. X. Jiao, A. Colombi, X. Ni, J.C. Hart. Anisotropic Mesh Adaptation for Evolving Triangulated Surfaces. Proc. Meshing Roundtable, Sept. 2006, pp. 173-190.
36. S. Dong, P.-T. Bremer, M. Garland, V. Pascucci, J.C. Hart. Spectral Surface Quadrangulation. Proc. SIGGRAPH, ACM Transactions on Graphics 25(3), July 2006, pp. 1057-1066.
37. N.A. Carr, J. Hoberock, K. Crane, J.C. Hart. Rectangular Multi-Chart Geometry Images. Proc. Sym. on Geom. Proc., July 2006, pp. 181-190.
38. N.A. Carr, J. Hoberock, K. Crane, J.C. Hart. Fast GPU Ray Tracing of Dynamic Meshes using Geometry Images. Proc. Graphics Interface, May 2006, pp. 203-209.
39. P.-T. Bremer, J.C. Hart. A Sampling Theorem for MLS Surfaces. Proc. Point Based Graphics, June 2005.
40. J.O. Talton, N.A. Carr, J.C. Hart. Voronoi Rasterization of Sparse Point Sets. Proc. Point Based Graphics, June 2005.
41. W. Su, J.C. Hart, A Programmable Particle System Framework for Shape Modeling, Proc. Shape Modeling International, June 2005.
42. S. Zelinka, H. Fang, M. Garland, J.C. Hart. Interactive Material Replacement in Photographs. Proc. Graphics Interface, May 2005.
43. S. Hornus, J. Hoberock, S. Lefebvre and J.C. Hart. ZP+: Correct Z-pass Stencil Shadows. Proc. ACM Symposium on Interactive 3-D Graphics and Games, Apr. 2005. **(Highest ranked paper according to review score.)**
44. H. Fang, J.C. Hart, "Textureshop: Texture Synthesis as a Photograph Editing Tool," ACM Transactions on Graphics 23(3) (also in Proc. SIGGRAPH 2004), Aug. 2004, pp. 354-359.
45. X. Ni, M. Garland, J.C. Hart, "Fair Morse Functions for Extracting the Topological Structure of a Surface Mesh," ACM Transactions on Graphics 23(3) (also in Proc. SIGGRAPH 2004), Aug. 2004, pp. 613-622. **(Second highest ranked paper according to tertiary review score.)**
46. N. Carr, J.C. Hart, "Painting Detail," ACM Transactions on Graphics 23(3) (also in Proc. SIGGRAPH 2004), Aug. 2004, pp. 845-852.
47. N. Carr, J.C. Hart, "Dynamic Clustering of Meshed Surfaces," Proc. Symposium on Geometry Processing, July 2004.
48. O.S. Lawlor, J.C. Hart, "Bounding Recursive Procedural Models using Convex Optimization," Proceedings of Pacific Graphics 2003, October 2003, pp. 283-292.
49. P-P. Sloan, J. Hall, J. Hart, J. Snyder. Clustered Principal Components for Precomputed Radiance Transfer. (Proc. SIGGRAPH 2003) ACM Transactions on Graphics 22(3), July 2003.
50. N.A. Carr, J.D. Hall and J.C. Hart, GPU Algorithms for Radiosity and Subsurface Scattering, Proc. Graphics Hardware, July 2003.
51. John C. Hart, Jeyprakash Michaelraj, Brent Baker. Structural Simulation of Tree Growth. The Visual Computer 19(2-3), May 2003, pp. 151-163.
52. P. Sherman, J.C. Hart. Direct Manipulation of Recurrent Models. Computers & Graphics 27(1), Feb. 2003, pp. 143-151.

53. A. Sheffer, J.C. Hart. Seamster: Inconspicuous Low-Distortion Texture Seam Layout. *Proc. Visualization 2002*, Oct. 2002.
54. N.A. Carr, J.D. Hall and J.C. Hart. The Ray Engine. *Proc. Graphics Hardware 2002*, Sep. 2002.
55. H. Fang, J. Hart. Randomly Accessible Procedural Animation of Physically Approximate Turbulent Motion. *Proc. Computer Animation 2002*, June 2002.
56. J. Hart, E. Bachta, W. Jarosz, T. Fleury. Using Particles to Sample and Control More Complex Implicit Surfaces. *Proc. Shape Modeling International 2002*, May 2002, pp. 129-136.
57. N. Carr, J. Hart. Meshed Atlases for Real-Time Procedural Solid Texturing. *ACM Transactions on Graphics* 21(2), Apr. 2002.
58. J.C. Hart. Perlin Noise Pixel Shaders. *Proc. Graphics Hardware 2001*, Aug. 2001.
59. W. Cochran, R. Lewis, J. Hart. The Normal of a Fractal Surface. *The Visual Computer* 17(4), 2001, pp. 209-218.
60. J.C. Hart. Using the CW-Complex to Represent the Topological Structure of Implicit Surfaces and Solids. *Proc. Implicit Surfaces '99*, Sept. 1999, pp. 107-112.
61. J.C. Hart, N. Carr, M. Kameya, S.A. Tibbitts, T.J. Coleman. Antialiased Parameterized Solid Texturing Simplified for Consumer-Level Hardware Implementation. *Proc. Graphics Hardware 99*, Aug. 1999, pp. 45-53.
62. J.C. Hart, A. Durr and D. Harsch. Critical points of polynomial metaballs. *Proc. Implicit Surfaces '98*, June 1998, pp. 69-76.
63. J.C. Hart. Morse Theory for Implicit Surface Modeling. In *Mathematical Visualization*, H-C Hege and K. Polthier, Eds., Springer-Verlag, Berlin, Oct. 1998, pp. 257-268. (Reviewed paper presented at VisMath '97, Berlin, 1997.)
64. W.O. Cochran, J.C. Hart, P.J. Flynn. On Approximating Rough Curves with Fractal Functions. *Proc. Graphics Interface '98*, June 1998, pp. 65-72.
65. A.K. Dunker, E. Garner, S. Guilliot, P. Romero, K. Albrecht, J. Hart, Z. Obradovic, C. Kissinger and J.E. Villafranca. Protein Disorder and the Evolution of Molecular Recognition: Theory, Predictions and Observations. *Pacific Symposium on Biocomputing* 3: 435-446, Jan. 1998.
66. B. Stander, J.C. Hart. Guaranteeing the Topology of an Implicit Surface Polygonization. *Computer Graphics Annual Conference Series* (Proc. SIGGRAPH 97) Aug., 1997, pp. 279-286.
67. J.C. Hart. Implicit formulations of rough surfaces. *Computer Graphics Forum* 16(2), June 1997, pp. 91-99.
68. B. Burch, J.C. Hart. Linear Fractal Shape Interpolation. *Proc. Graphics Interface '97*. May, 1997, pp. 155-162.
69. J.C. Hart, P.J. Flynn, W.O. Cochran. Similarity Hashing: A model-based vision solution to the inverse problem of recurrent iterated function systems. *Fractals* 5, Apr. 1997, pp. 39-50.
70. W.O. Cochran, J.C. Hart, P.J. Flynn. Fractal volume compression. *IEEE Transactions on Visualization and Computer Graphics* 2(4) Dec. 1996, pp. 313-322.
71. J.C. Hart. Sphere tracing: A geometric method for the antialiased ray tracing of implicit surfaces. *The Visual Computer* 12(10), Dec. 1996, pp. 527-545.
72. S. Worley, J.C. Hart. Hyper-rendering of hyper-textured surfaces. *Proc. of Implicit Surfaces '96*, Oct. 1996, pp. 99-104.
73. J.C. Hart, B. Baker. Implicit Modeling of Tree Surfaces. *Proc. of Implicit Surfaces '96*, Oct. 1996, pp. 143-152.
74. J.C. Hart. Fractal image compression and the inverse problem of recurrent iterated function systems. *IEEE Computer Graphics and Applications* 16(4) July 1996, pp. 25-33.
75. K. Albrecht, J. Hart, A. Shaw, and A.K. Dunker. Quaternion contact ribbons: A new tool for visualizing intra- and intermolecular interactions in proteins. *Pacific Symposium on Biocomputing* 1: 41-52, Jan. 1996.

76. D. Hepting, J.C. Hart. The escape buffer: Efficient computation of escape time for linear fractals. *Proc. of Graphics Interface '95*, May 1995. pp. 204-214.
77. J.C. Hart. Implicit formulations of rough surfaces. *Proc. Implicit Surfaces '95*, Apr. 1995, pp. 33-44.
78. B.T. Stander, J.C. Hart. A Lipschitz method for accelerated volume rendering. *Proc. of the 1994 Symposium on Volume Visualization*, Oct. 1994. pp. 107-114.
79. J.C. Hart. Distance to an Ellipsoid. Chapter in: *Graphics Gems IV*, P. Heckbert, Ed., Academic Press, 1994, pp. 113-119.
80. J.C. Hart, G.K. Francis, L.H. Kauffman. Visualizing quaternion rotation. *ACM Transactions on Graphics* 13(3) July 1994, pp. 256-276.
81. J.C. Hart. On recording virtual environments. *Proc. of IEEE Visualization '93 Symposium on Research Frontiers in Virtual Reality*, Nov. 1993, pp. 80-83.
82. J.C. Hart, G.W. Lescinsky, D.J. Sandin, T.A. DeFanti, L.H. Kauffman. Scientific and artistic investigation of multidimensional fractals on the AT&T Pixel Machine. *Visual Computer* 7(9) July 1993, pp. 346-355.
83. C. Cruz-Niera, D.J. Sandin, T.A. DeFanti, R.V. Kenyon, J.C. Hart. The CAVE audio visual experience automatic virtual environment. *Communications of the ACM* 35(6) June 1992, pp. 64-72.
84. J.C. Hart. The object instancing paradigm for linear fractal modeling. *Proc. of Graphics Interface '92*, Morgan Kauffman, May 1992, pp. 224-231.
85. J.C. Hart, T.A. DeFanti. Efficient antialiased rendering of 3-D linear fractals. *Computer Graphics* 25(3) (Proc. SIGGRAPH 91) Aug. 1991, pp. 91-100.
86. J.C. Hart, L.H. Kauffman, D.J. Sandin. Interactive visualization of quaternion Julia sets. *Proc. of Visualization '90*. IEEE Computer Society Press. Oct. 1990, pp. 209-218.
87. J.C. Hart, A. Norton. Use of curves in rendering fractures. *Proc. of SPIE/SPSE Symposium on Curves and Surfaces in Computer Vision and Graphics*. Feb. 1990.
88. J.C. Hart, D.J. Sandin, L.H. Kauffman. Ray tracing deterministic 3-D fractals. *Computer Graphics* 23(3) (Proc. SIGGRAPH 89) Aug. 1989, pp. 289-296.

Books, Invited Book Chapters and Edited Course Notes

89. J. Torrellas, S.V. Adve, V.S. Adve, D. Dig, M.N. Do, M.J. Garzaran, J.C. Hart, T.S. Huang, W.W. Hwu, S.T. King, D. Marinov, K. Nahrstedt, D.A. Padua, M. Parthasarathy, S.J. Patel, M. Snir. "Making Parallel Programming Easy: Research Contributions from Illinois," Sep. 2013.
90. M. Olano, W. Heidrich, J. Hart and M. McCool, *Real Time Shading*, AK Peters, July 2002.
91. J.C. Hart, "Procedural Geometry," Chapter in *Modeling and Texturing, a Procedural Approach*, 3rd Edition, D. Ebert, Editor, Morgan Kauffman, November 2002.
92. J.C. Hart, "Real-Time Procedural Solid Texturing," Chapter in *Modeling and Texturing, a Procedural Approach*, 3rd Edition, D. Ebert, Editor, Morgan Kauffman, November 2002.
93. D. Ebert and J. Hart, Editors, "Procedural Implicit Techniques for Modeling and Texturing," *ACM SIGGRAPH 1998 Course Notes*, July 1998.
94. D. Ebert and J. Hart, Editors, "New Frontiers in Modeling and Texturing," *ACM SIGGRAPH 1997 Course Notes*, August 1997.
95. J. Hart and D. Saupe, Editors, "Fractal Models for Image Synthesis, Compression and Analysis," *ACM SIGGRAPH 1996 Course Notes*, August 1996.
96. J. Hart, Editor, "New Directions for Fractal Modeling in Computer Graphics," *ACM SIGGRAPH 1994 Course Notes*, July, 1994.

97. J. Hart and K. Musgrave, Editors, "Fractal Modeling in 3-D Computer Graphics and Imaging," ACM SIGGRAPH 1991 Course Notes, July 1991.

Patents

98. H. Fang and J.C. Hart, Methods and Systems for Image Modification. #7,365,744. Filed: 26 July 2004, Granted: 29 April 2008.
99. S. Tibbitts, T. Coleman and J.C. Hart. Antialiased Procedural Solid Texturing Hardware. Provisional Patent #60,088,879. Evans & Sutherland, 1998.

Invited Papers, Articles, Tech Reports and Other Publications

100. S.V. Adve, V.S. Adve, G. Agha, M.I. Frank, M.J. Garzaran, J.C. Hart, W.W. Hwu, R.E. Johnson, L.V. Kale, R. Kumar, D. Marinov, K. Nahrstedt, D. Padua, M. Parthasarathy, S.J. Patel, G. Rosu, D. Roth, M. Snir, J. Torrellas, C. Zilles. Parallel Computing Research at Illinois: The UPCRC Agenda. Whitepaper, Nov. 2008.
101. S. Dong, P.-T. Bremer, M. Garland, V. Pascucci and J.C. Hart. Quadrangulating a Mesh using Laplacian Eigenvectors. Tech Rep. UIUCDCS-R-2005-2583, June 2005.
102. P. Lacz and J.C. Hart. Procedural Geometric Synthesis on the GPU. Poster (with accompanying manuscript) for SIGGRAPH 2004 and GP2: The ACM Workshop on General Purpose Computing on Graphics Processors, Aug. 2004.
103. J.D. Hall and J.C. Hart. GPU Acceleration of Iterative Clustering. Poster (with accompanying manuscript) for SIGGRAPH 2004 and GP2: The ACM Workshop on General Purpose Computing on Graphics Processors, Aug. 2004.
104. M. Mullan, R. Whitaker and J.C. Hart. Procedural Level Sets. Manuscript presented at NSF/DARPA CARGO Annual Meeting, May 2004.
105. J.D. Hall, N.A. Carr and J.C. Hart. Cache and Bandwidth Aware Matrix Multiplication on the GPU. Tech. Report UIUCDCS-R-2003-2328, May 2003.
106. M. Kameya, and J.C. Hart. Bresenham noise. SIGGRAPH 2000 Conference Abstracts and Applications, July 2000.
107. J.J. Kim and J.C. Hart. Contour-Based Polygonization of Regular Grid Terrain Data. Proc. Western Computer Graphics Symposium. Mar. 1999.
108. A. Aceves, K. Hammil and J.C. Hart. Proposal and Partially Implemented: The Studio: A Large High Resolution Immersive Projection System for Research and Education. Proc. Western Computer Graphics Symposium. Mar. 1999.
109. M. Kameya and J.C. Hart. Bit Width Necessary for Solid Texturing Hardware. Proc. Western Computer Graphics Symposium. Mar. 1999.
110. N. Carr and J.C. Hart. APST Antialiased Procedural Texturing Interface for OpenGL. Proc. Western Computer Graphics Symposium. Mar. 1999.
111. C. Kulratanayan and J.C. Hart. Restructuring the Scene Graph for Efficient Visibility of Natural Scenes. Proc. Western Computer Graphics Symposium. Mar. 1999.
112. J.C. Hart. Computational Topology for Shape Modeling. Invited Talk and Paper. Proc. Shape Modeling International '99, Univ. Aizu, Japan, Mar. 1999, pp. 36-45.
113. J.C. Hart. Morse Theory for Computer Graphics. WSU Technical Report EECS-97-002. Chapter in "New Frontiers in Modeling and Texturing," SIGGRAPH '97 course notes, J. Hart, D. Ebert eds., Aug. 1997.
114. I.M. Danciu, J.C. Hart. Fractal Color Image Compression in the $L^*a^*b^*$ Uniform Color Space. Poster. Abstract in: Proc. of Data Compression Conference '97. IEEE Computer Society Press, Apr. 1997, p. 434.

- 115.B.T. Stander, J.C. Hart. Topologically Guaranteed Blobby Surface Polygonization. Proceedings of Western Computer Graphics Symposium. Mar. 1996. pp. 1-9.
- 116.J.C. Hart. On the Hyperbolic Plane and Chinese Checkers. Proceedings of Western Computer Graphics Symposium. Mar. 1996. pp. 69-75
- 117.W.O. Cochran, J.C. Hart, P.J. Flynn. Similarity and Affinity Hashing. Proceedings of Western Computer Graphics Symposium. Mar. 1996. pp. 89-98.
- 118.B.T. Stander, J.C. Hart. Interactive re-polygonization of blobby implicit curves. Proceedings of Western Computer Graphics Symposium. Mar. 1995.
- 119.W.O. Cochran, J.C. Hart, P.J. Flynn. Principal component classification for fractal volume compression. Proceedings of Western Computer Graphics Symposium. Mar. 1995.
- 120.J.C. Hart. Sphere tracing: simple robust antialiased rendering of distance-based implicit surfaces. WSU Technical Report EECS-93-015. Chapter in ``Design, Visualization and Animation of Implicit Surfaces," SIGGRAPH '93 course notes, J. Bloomenthal, B. Wyvill, eds., Aug. 1993.
- 121.J.C. Hart. Ray Tracing Implicit Surfaces. WSU Technical Report EECS-93-014. Chapter in ``Design, Visualization, and Animation of Implicit Surfaces," SIGGRAPH '93 intermediate course notes, J. Bloomenthal and B. Wyvill, eds., Aug. 1993.
- 122.T.A. DeFanti, J.C. Hart, D.J. Sandin, L.H. Kauffman. Visualization of multidimensional fractals. Proceedings of the Argonne National Lab. Seventh International Conference on Advanced Science and Technology. Mar. 1991, pp. 289-298.
- 123.T.A. DeFanti, D.J. Sandin, G.W. Lescinsky, J.C. Hart, M.D. Brown, L.H. Kauffman. Simulacra/Stimulacra::Fractal. Art Futura, Jan. 1991.
- 124.J.C. Hart. Parallel algorithms for visualization of multidimensional fractal objects (extended abstract.) Electronic Imaging East '90. Nov. 1990, pp. 459-462.
- 125.D.J. Sandin, J.C. Hart, L.H. Kauffman. Interactive visualization of complex, stacked and quaternion Julia sets. Proceedings of Ausgraph '90, Sep. 1990. (Invited paper.)
- 126.T.A. DeFanti, D.J. Sandin, J.C. Hart, G.W. Lescinsky. One picture's worth a thousand gigaflops (One animation's worth a thousand teraflops). Pixel 1(3) July 1990, pp. 40-41.
- 127.J.C. Hart, A. Norton. Use of curves in rendering fractures. IBM Technical Report. Aug. 1989.

Film and Animation Credits

- 128.Executive Producer (with C. Machover). "The Story of Computer Graphics." A SIGGRAPH Production of a feature-length documentary on the human struggle to bring computer graphics from the inspired revelation that computers can be used to draw pictures to the present, where low-cost graphics and the Internet combine to provide virtual environments for people to communicate. Premiered at a special event in the Shrine Auditorium, LA, as part of the SIGGRAPH 99 Computer Animation Festival.
- 129.Contributor. "Air on the Dirac Strings." Produced by L.H. Kauffman, G.K. Francis, D.J. Sandin. SIGGRAPH '93 Electronic Theater. SIGGRAPH Video Review 93, Aug. 1993.
- 130.Producer. "SIGGRAPH 93 Technical Session Sampler." SIGGRAPH '93 Electronic Theater. Video compilation, narrated by J. Blinn. SIGGRAPH Video Review 91, Aug. 1993
- 131.Producer. "Highlights from the SIGGRAPH '92 Technical Session." SIGGRAPH '92 Electronic Theater. Video compilation, narrated by J. Blinn.
- 132.Producer/Director/Animator. "Fun with Octrees: Graph Topologies on the Recurrent Cube." SIGGRAPH '92 Animation Screening Room. SIGGRAPH Video Review 87, Aug. 1992. Appears in: ``The Fractal Universe: Animation," Media Magic, 1993.

- 133.Producer/Director/Animator. "unNatural Phenomena." SIGGRAPH '91 Electronic Theater. SIGGRAPH Video Review 71, Aug. 1991. Appears in: ``The Fractal Universe: Animation," Media Magic, 1993. Excerpts appear in: ``Beyond The Minds Eye," Mirimar, and ``Prime Time Live," ABC.
- 134.Producer/Director/Animator (with S. Das.). "Sierpinski Blows His Gasket." SIGGRAPH '90 Animation Screening Room. SIGGRAPH Video Review 61, 1990. First Runner-Up, Truevision Videographics Competition, 1990. Appears in: ``The Fractal Universe: Animation," Media Magic, 1993.
- 135.Producer/Director/Animator. "Dynamics in the Quaternions." SIGGRAPH Video Review 42, 1989. Appears in: ``The Fractal Universe: Animation," Media Magic, 1993.

∞ Educational Activities ∞

Postdoctoral Associates

- Moussa Mansour, 2015-6. Visiting from Univ. Sao Paolo.
- Matei Stroila, 2005-6. Research Scientist, Navteq, Nokia, Here.
- Peer-Timo Bremer, 2004-6. Research Scientist, Lawrence Livermore National Labs.
- Nate Carr, 2004-5. Senior Research Scientist, Adobe.

Ph.D. Students

- Apollo Ellis. Apple Internship 2016.
- Mingcheng Chen (2016). Currently at Google.
- Victor Lu (2013). Currently at Nokia.
- Mahsa Kameya (2012). Currently at Microsoft. MSR Internship 2010.
- Yuntao Jia (2010). Currently at Facebook.
- Jared Hoberock (2008). Research Scientist, Nvidia. NVidia Fellowship 2005,2007. NVidia Internship 2005.
- Xinli Ni (2007). Currently at Google, Microsoft Internship 2005.
- Hui Fang (2006). Currently at Google. Adobe Internship 2005.
- Nate Carr (2004). Senior Research Scientist, Adobe. NVidia Fellowship 2002 and 2003. Intel Internship 1999. NVidia Internship 2002.
- Wayne Cochran (1998). Assistant Professor, School of Engineering and Computer Science, Washington State University, Vancouver.
- Bart Stander (1997), Full Professor, Computer and Information Technology, Dixie State College of Utah.

M.S. Students

- 2017: Yiwen Xu.
- 2015: Jared Saul.
- 2013: JohnMark Lau.
- 2011: Rajesh Bhasin.

- 2009: Apeksha Godiyal. Microsoft Visio.
- 2005: Jerry Talton (Ph.D. Stanford, 2012), Tony Kaap (Alias), Matei Stroila (NAVTEQ).
- 2004: Jesse Hall (NVidia, Microsoft Research Internship 2002. NVidia Fellowship 2003 and 2004), Patrick Lacz (RadTIME), Wen Su (NVidia).
- 2002: Hui Fang (continued), Ed Bachta (visualization programmer at IUPUI)
- 2000: Nate Carr (continued), Jay Kim.
- 1999: Chanikarn Kulratanayan.
- 1998: Jeyprakash Michaelraj (Alias).
- 1997: Paul Sherman (Periphery Consulting).
- 1996: Ioana Danciu. (Adobe), Brandon Burch (WSU Instructor), Yingjun Yu (Nokia), Wenbiao Jiang (CFD Research), Kurt Albrecht.
- 1994: Anand Ramagopalrao (Microsoft), Wayne Cochran (continued).
- 1992: Yongqi Yang (Adobe).

Courses Taught

UIUC Courses

- CS 498 Data Visualization (via the Coursera platform for the MCS-DS program)
- ENG 198 Grand Challenges (Fall 2012)
- CS 418 Interactive Graphics
- CS 419 Production Graphics
- CS 519 Scientific Visualization
- CS 497 JCH Advanced Shape Modeling (Fall 2000)
- CS 498 Procedural Modeling and Shading in Computer Graphics (Fall 2002)
- CS 498 Particle System Programming (Spring 2004, voluntary addition to course load)
- CS 498 Shape Modeling (Fall 2004)
- CS 598 JCH Surface Reconstruction (2008)
- CS 491 EH Computational Topology Seminar (co-organized with J. Erickson)
- CS 491 GHY Graphics Seminar (co-organized with M. Garland, Y. Yu)

WSU Courses

- CptS 330 Numerical Computing
- CptS 442 Computer Graphics
- CptS 443 Computer-Human Interaction
- CptS 548 Advanced Computer Graphics

Coursera Courses

- Data Visualization, July-Aug. 2015. Enrollment: 88,399 from 198 different countries, including 1,197 with signature track credit toward the Data Mining certificate.

SIGGRAPH Reviewed One-Day Courses

- 2005: “Modern Techniques for Implicit Modeling” (Terry Yoo, James O’Brien), and “GPU Shading and Rendering” (Marc Olano)
- 2004: “Real Time Shading” (Marc Olano)
- 2003: “Beyond Blobs: Recent Advances in Implicit Surfaces” (Terry Yoo, Greg Turk) and “Real Time Shading” (Marc Olano)
- 2002: “Beyond Blobs: Recent Advances in Implicit Surfaces” (Terry Yoo and Greg Turk, org.) and “Real Time Shading” (Marc Olano).
- 2001: “Real Time Shading” (Marc Olano)
- 2000: “Approaches for Procedural Shading on Graphics Hardware” (Marc Olano)
- 1998: “Procedural Implicit Techniques for Modeling and Texturing” (Co-organizer with D. Ebert)
- 1997: “New Frontiers in Modeling and Texturing” (Co-organizer with D. Ebert.)
- 1996: “Fractal Models for Image Synthesis, Compression and Analysis” (Co-organizer with D. Saupe), “Procedural Modeling, Texturing, and Animation Techniques” (D. Ebert) and “Implicit Surfaces for Geometric Modelling and Computer Graphics (Jai Menon and Brian Wyvill)
- 1995: “Procedural Modeling, Texturing, and Animation Techniques” (D. Ebert).
- 1994: “New Directions for Fractal Modeling in Computer Graphics” (Course organizer).
- 1993: “Design, Visualization and Animation of Implicit Surfaces” (J. Bloomenthal, B. Wyvill).
- 1992: “Fractals: from Folk Art to Hyperreality” (P. Prusinkiewicz).
- 1991: “Fractal Modeling in 3-D Computer Graphics and Imaging” (Co-organizer with K. Musgrave).

Other

- Adler Planerarium, Scientific Visualization by Supercomputer. Chicago, Sept.-Nov. 1988.

Invited Colloquia and Presentations

Note: colloquia presented for the purpose of interviewing have been omitted.

- **Symposium on the Future of Data Analytics of the American & Canadian Societies of Animal Science**, invited talk on “Data Visualization,” July 2018.
- **Workshop High Throughput Phenotyping and Data Analytics**, invited talk on “Data Visualization,” Univ. Maryland, Nov. 2017.
- **31st Discovery Conference on Big Data Dairy Management**, invited talk on “Data Visualization,” Nov. 2016.
- **University of Lorraine**, June 2014.
- **University of Notre Dame**, Center for Research Computing, “High Performance Computer Vision, An Oxymoron?,” May 2012.

- **Graphics Interface Conference**, Keynote: Assistive Technology for the Aesthetically Impaired,” May 2011.
- **University of Iowa Computing Conference**, organized and invited by U. Iowa students, “Assistive Technology for the Aesthetically Impaired,” Feb. 2010.
- **AMS MathViz09**, U. Illinois, “It’s Nice to See This Stuff Actually Used for Something,” Mar. 2009. Host: George Francis.
- **INRIA**, Grenoble, France, “Assistive Technology for the Aesthetically Impaired,” Sep. 2009. Host: Elmar Eisemann.
- **Texas A&M University**. Distinguished Lecture: “Assistive Technology for the Aesthetically Impaired,” Feb. 2008. Host: Scott Schaeffer.
- **NAVTEQ**. “Industry Collaborations,” Nov. 2007, Chicago, IL. Host: Matei Stroila.
- **Adobe-MIT Research Retreat**. “Textureshop Redux,” Oct. 2007, Cambridge, MA. Host: David Salesin and Fredo Durand.
- **University of Konstanz Summerschool**. “Computational Topology of Implicit Surfaces” and “Computational Topology of Meshes,” Sep. 2006, Gaschurn, Austria. Host: Dietmar Saupe.
- **Wolfram Research**. “Mathematical Visualization,” May 2006, Champaign, IL. Host: Roger Germundsson.
- **Carnegie-Mellon University**. “Surface Constrained Particle Systems” and “Global Illumination on the GPU,” Feb. 2005. Host: Doug James.
- **Imagina**. “Global Illumination on the GPU,” Monaco, Feb. 2005.
- **3D Festival**. “Global Illumination on the GPU,” Copenhagen, Denmark, May 2004.
- **INRIA**, Grenoble, France, “Global Illumination on the GPU,” Mar. 2004, Host: Samuel Hornus.
- **University of Utah**. “Global Illumination on the GPU,” Oct. 2003, Host: Chuck Hansen.
- **NVidia U**. Keynote speaker. July 2003, Host: Herbert Hu.
- **Army High Performance Computing Research Center (AHPCRC) Workshop on Graphics Modeling, Simulation and Visualization**. “Harnessing the Supercomputer in your PC’s Graphics Card,” June 2003. Host: Boquan Chen.
- **University of Illinois at Chicago (Math Dept.)**. “Computational Topology for Computer Graphics.” Apr. 2002. Host: Anatoly Libgover.
- **Colorado Springs SIGGRAPH Chapter**. “The Quest for Real-Time Procedural Solid Texturing.” Mar. 2001. Host: Dino Schweitzer.
- **Northwestern University**. “The Quest for Real-Time Procedural Solid Texturing.” Oct. 2000. Host: Benjamin Watson.
- **Shape Modeling International**. Invited Speaker, Aizu, Japan, March 1999.
- **Universität Freiburg**. “Recurrent Modeling.” Sep. 1997. Host: Dietmar Saupe.
- **University of Utah**. “The Topology of Implicit Surfaces.” Feb. 1997. Host: Chuck Hansen.
- **University of Illinois at Chicago (EECS Dept.)**. “The Topology of Implicit Surfaces.” Feb. 1997. Host: Tom DeFanti.
- **Interval Research**. “Recurrent Modeling.” July 1996. Host: Sally Rosenthal.
- **University of Washington**. “Recurrent Modeling.” Dept. of Computer Science and Engineering. Jan. 1996. Host: Linda Shapiro.

- **Boeing Information & Support Services.** "Why Fractal Image Compression Isn't Fractal." Computer Graphics & Multimedia Group. Jan. 1996. Host: David Kerlick.
- **University of Idaho.** "Why Fractal Image Compression Isn't Fractal." Computer Science Dept. Nov. 1995. Host: Deborah Frincke.
- **NATO Advanced Study Institute** on Fractal Image Compression and Image Analysis. "Similarity Hashing: A model-based vision solution to the inverse problem of recurrent iterated function systems." July 1995.
- **Simon Fraser University.** "Recurrent Modeling." School of Computing Science. July 1995. Host: F. David Fracchia.
- **University of Calgary.** "Procedural Geometric Instancing." Dept. of Computer Science. Jan. 1994. Host: Przemyslaw Prusinkiewicz.
- **Purdue University.** "Linear Fractals in Computer Graphics." Computer Science Dept. June 1992. Host: Chandrajit Bajaj.

∞ Professional Activities ∞

Editorships and Papers Chairships

- Area Editor (Visual Computing) and Editorial Board Member, ACM Books 2014-.
- Papers Co-Chair (with Scott Schaefer), Shape Modeling International, 2012.
- Editor-in-Chief, ACM Transactions on Graphics, 2002-2008. Past EiC, 2008-2011.
- Associate Editor, ACM Transactions on Graphics, 2000-2002, 2011-.
- Guest Editor, Communications of the ACM 35(6) June 1992.
- Guest Editor, SIGGRAPH Video Review 96, "Video Supplement to the Conference Proceedings," Aug. 1993.
- Guest Editor (with E.E. Catmull), SIGGRAPH Video Review 86, "Video Supplement to the Conference Proceedings," July 1992.

Professional Organization Leadership

- SIGGRAPH Small Conferences Committee, 2010-
- Chair, SIGGRAPH Service Award, 2005-8.
- ACM SIGGRAPH Advisory Board, 2005.
- Director for Communications, SIGGRAPH Executive Committee, 1996-9.
- Director at Large, SIGGRAPH Executive Committee, 1994-6.

External Research Center Review Panels

- King Abdullah University of Science and Technology, Mar. 2012.
- Science Foundation Ireland, Oct. 2006.

- INRIA Systemes Cognitifs D, May 2006.

Conferences Chaired

- Co-Chair (with A. Marshall-Colon, S.P. Long and E.H. DeLucia), Plants-in-Silico, NCSA, UIUC, 2016.
- Co-Chair (with S. Gao, J. Jorge, K. Polthier and W. Wang), Shape Modeling International, Hong Kong, Oct. 2014.
- Co-Chair (with Marie-Paule Cani), Shape Modeling International, MIT, June 2005.
- Co-Chair (with K. van Overveld), Implicit Surfaces, Eindhoven, Netherlands, 1996.
- Chair. Western Computer Graphics Symposium, Panorama, BC, 1996.

Program Committees

- SIGGRAPH Papers Committee: 2001, 2006, 2007, 2010
- SIGGRAPH Asia Papers Committee, 2008.
- SIGGRAPH Sketches Jury: 1998, 1999.
- Symposium on Geometry Processing, all since 2006.
- Interactive 3D Graphics and Games, all since 2005.
- Pacific Graphics, all since 2002.
- Shape Modeling International, all since 1997.
- Implicit Surfaces (all).
- Eurographics 2004.
- Graphics Hardware, all since 2004.
- Web3D 2003.
- IEEE Virtual Reality 2000, 2001, 2002.
- Virtual Reality Annual International Symposium 1998.
- Visualization and Mathematics 1997.
- Supercomputing 1991-3, 1995.

Memberships

- Association for Computing Machinery
- ACM Special Interest Group on Computer Graphics and Interactive Techniques (SIGGRAPH)
- IEEE Computer Society

University of Illinois Committees

University of Illinois System

- Steering Committee, Start MyResearch Portal for university system-wide research management software, 2014-2016.
- University Technology Management Team, 2012-2013.

Urbana-Champaign Campus

- Ex-Officio (Graduate College Representative), Senate Educational Policy Committee, 2014-.
- Chair, Senate Subcommittee on IT, 2013-6, Member, 2008-2010.
- University Senate Executive Committee, 2013-6.
- IT Governance Executive Committee, 2012-5.
- Chair, IT Governance Research Subcommittee, 2012-5.
- Chair, Stewarding Excellence IT Project Team, 2010.
- Human Factors Transition Committee, 2008-9.
- Senate, 2007-14,

College of Engineering

- Chair, Promotion & Tenure Committee, 2013, Member 2012-2013.
- Vice-Chair, Executive Committee, 2013. Secretary, 2012-2013. Member, 2011-2013.
- Chair, Engineering IT Steering Committee, 2010-11.

Dept. of Computer Science

- Area Chair, Graphics and Human-Computer Interaction, 2004-2011.
- Department Head Search Committee, 2007-9.
- Advisory Committee (peer elected), 2005-2006.
- Industry Relations Committee, 2005-2007.
- Technology, Facilities and Services Committee (CS), 2005-2012.
- Engineering Open House CS Representative (CS), 2001-2006.
- Recruiting Committee, 2004, 2005.
- Curriculum Committee, 2002-3.
- Chair, Distinguished Lecture Series 2001-2002, Member 2000-2002.
- Computer Systems (CS), 2000-2001.
- Fellowships, Assistantships and Admissions, 2000-2001.

WSU

- School of EECS Computer Science Area Chair, 1998-2000.
- School of EECS Computer Science Accreditation Coordinator, 1999-2000.

- School of EECS Curriculum Committee 1998- (Chair, 1999-2000).
- School of EECS Graduate Studies Committee 1993-8.
- School of EECS Laboratory Committee 1994-6.
- WSU Center for Visualization, Analysis and Design in the Molecular Sciences (VADMS) Advisory Board 1994-2000.