

Declaration of Andrew Wolfe, Ph.D.
U.S. Patent No. 8,747,097

UNITED STATES PATENT AND TRADEMARK OFFICE

BEFORE THE PATENT TRIAL AND APPEAL BOARD

Shenzhen Tuozhu Technology Co., Ltd.

Petitioner,

v.

Stratasys, Inc.

Patent Owner.

U.S. Patent No. 8,747,097

**DECLARATION OF ANDREW WOLFE, PH.D.
ON BEHALF OF PETITIONER**

I, Andrew Wolfe, Ph.D., declare as follows:

1. I have been retained on behalf of Shenzhen Tuozhu Technology Co., Ltd. (“Petitioner” or “Tuozhu Tech”) to provide my independent opinions regarding U.S. Patent No. 8,747,097 (“the ’097 Patent”).
2. To the best of my knowledge, I have no financial interest in Shenzhen Tuozhu Technology Co., Ltd. or any related entity.
3. I am being compensated at my standard consulting rate of \$750 for my time. My compensation is in no way contingent on the results of this or any other proceedings relating to the ’097 Patent.
4. For ease of understanding, I have annotated figures and added emphasis in my discussions unless otherwise noted.

1. Background and Qualifications

5. My qualifications and professional experience are described in my curriculum vitae, a copy of which is provided as Appendix A to this declaration. The following briefly summarizes my relevant qualifications and professional experience.

6. I have more than 40 years of experience in consumer electronics and interactive graphics and interactive video computer systems, including as a computer architect, computer system designer, PC graphics designer, educator, and as an executive in the consumer electronics business.

7. In 1985, I earned the B.S.E.E. degree in Electrical Engineering and Computer Science from the Johns Hopkins University. In 1987, I received the M.S. degree in Electrical and Computer Engineering from Carnegie Mellon University and then in 1992, I received a Ph.D. in Computer Engineering from Carnegie Mellon University. My doctoral dissertation proposed a new approach for the architecture of a computer processor.

8. In 1983, I began designing Touch Sensing systems as a senior design engineer for Touch Technology, Inc. In some of these design projects, I designed interrupt-based I/O cards for PC-compatible computer systems including the IBM PC-AT to interface interactive touch-based computer terminals that I designed for use in public information systems. I later worked for the Carroll Touch division of AMP where I designed additional touchscreen technologies, developed system firmware, and designed the company's first custom integrated circuit. I designed the touch/pen input system for the Linus WriteTop, which many believe to be the

first commercial tablet computer. Between 1983 and 2003 I designed many different devices which detected touch and/or measured forces.

9. From 1986 through 1987, I designed and built a high-performance computer system at Carnegie Mellon University. From 1986 through 1988, I also developed the curriculum and supervised the teaching lab for the processor design courses.

10. In 1987-88, I worked as a senior design engineer for ESL-TRW Advanced Technology Division. I designed and built a bus interface and memory controller for a workstation-based computer system and worked on the design of a multiprocessor system.

11. At the end of 1989, along with some partners, I reacquired the technology I had developed at Touch Technology and at AMP and founded The Graphics Technology Company. As an officer and a consultant, I managed engineering development activities at that company and personally developed dozens of touch sensing devices over the next seven years. Many of these could distinguish between different levels of touch force.

12. I have consulted, formally and informally, for a number of consumer electronics design companies. In particular, I have served on the technical advisory

boards for two media processor design companies, BOPS, Inc., where I chaired the board, and Siroyan Ltd. I served in a similar role for three networking chip companies, Intellon, Inc., Comsilica, Inc., and Entridia, Inc. and one 3D game accelerator company, Ageia, Inc. I have also served as a technology advisor to Motorola and to several venture capital funds in the U.S. and Europe. Currently, I am a director of Turtle Beach Corporation, providing guidance in its development of premium audio peripheral devices for a variety of commercial electronic products. My consulting has included electromechanical and robotic systems for measuring touch pressure and stylus force including X-Y-Z positioning systems that move in the same way as common 3D printers.

13. From 1991 through 1997, I served on the Faculty of Princeton University as an Assistant Professor of Electrical Engineering. At Princeton, I taught undergraduate and graduate-level courses in Computer Architecture, Advanced Computer Architecture, Display Technology, and Microprocessor Systems courses as well as conducting sponsored research in the area of computer systems and related topics. My research included some of the first systems that displayed real-time video over a computer network in a web-based interface. My courses included teaching about electromechanical sensors and actuators. From 1999 through 2002, I also taught the Computer Architecture course to both

undergraduates and graduate students at Stanford University several times as a Consulting Professor. At Princeton, I received several teaching awards, both from students and from the School of Engineering. I have also taught advanced microprocessor architecture to industry professionals in IEEE and ACM sponsored seminars. I currently teach at Santa Clara University including courses on Embedded Systems, Real-Time Computing, Mechatronics, and Engineering Practice. Since 2014, these classes have included comprehensive instruction and experimentation with sensors and actuators for measuring distance, force, and other physical phenomena. I have also worked with two undergraduate teams to design and construct material extruders for 3D printing. Additionally, I teach all of these students to use 3D FDM printers and have used them myself for more than a decade.

14. From 1997 through 2002, I held a variety of executive positions at a publicly-held PC graphics company originally called S3, Inc. and later called Sonicblue Inc. These included Chief Technology Officer, Vice President of Systems Integration Products, Senior Vice President of Business Development, and Director of Technology. At the time I joined S3, it supplied graphics accelerators for more than 50% of the PCs sold in the United States.

15. In these roles, I managed teams of engineers developing complex graphics chips for use in personal computers. This included visualization of 3D objects and generating 2D representations of 3D objects. I also managed the video research lab. I was involved in every aspect of the relationship with PC manufacturers ranging from discussions of product requirements, testing and qualification procedures, and competitive analysis, to market segmentation and pricing discussions. I met with senior executives in major PC manufacturers on numerous occasions to discuss business opportunities and general market trends. I also developed numerous consumer audio and video products including the Rio MP3 players, the ReplayTV digital video recorders, certain Löewe televisions, and the GoVideo DVD and VCR products. I also developed user interfaces and remote control protocols. I further assisted in the launch of streaming services. During my time at SonicBlue we launched more than 30 new consumer electronics products.

16. I have published more than 50 peer-reviewed papers in computer architecture and computer systems design including papers related to video streaming. I have also chaired IEEE and ACM conferences in microarchitecture and integrated circuit design. I am a named inventor on at least fifty-seven U.S. patents and thirty-seven foreign patents, more than ten related to touch and/or force

sensing. I am an IEEE Fellow and an IEEE Computer Society Distinguished Contributor.

17. I have been the invited keynote speaker at the ACM/IEEE International Symposium on Microarchitecture and at the International Conference on Multimedia. I have also been an invited speaker on various aspects of technology or the PC industry at numerous industry events including the Intel Developer's Forum, Microsoft Windows Hardware Engineering Conference, Microprocessor Forum, Embedded Systems Conference, Comdex, and Consumer Electronics Show as well as at Harvard Business School and the University of Illinois Law School. I have been interviewed on subjects related to computer graphics and video technology and the electronics industry by publications such as the Wall Street Journal, New York Times, LA Times, Time, Newsweek, Forbes, and Fortune as well as CNN, NPR, and the BBC. I have also spoken at dozens of universities including MIT, Stanford, University of Texas, Carnegie Mellon, UCLA, University of Michigan, Rice, and Duke.

18. In summary, I have extensive familiarity with fields involving electromechanical devices, sensors, and material deposition. I am familiar with the state of this field at the time of the '097 Patent, which I have been asked by

Petitioner's counsel to assume as being August 18, 2010, for the purposes of this proceeding.

2. Relevant Legal Standards

19. I am not an attorney and offer no legal opinions, but in the course of my work, I have had experience studying and analyzing patents and patent claims from the perspective of a person skilled in the art.

20. In expressing my opinions and considering the subject matter of the claims of the '097 Patent, I am relying upon certain basic legal principles that have been explained to me.

21. I understand that "the time the claimed invention was made" is often referred to as the priority or critical date. I have been informed by Petitioner's counsel to assume that August 18, 2010 is the critical date, for the purposes of this proceeding.

22. I understand that, before considering the prior art, the claims are first construed to determine their scope. I understand that the claims are read from the perspective of POSITA at the time of the alleged invention. I understand that the words of a claim are generally given their ordinary and customary meaning as

understood by a POSITA in light of the entire patent specification in which they appear, as well as the prosecution history of the patent.

23. I understand, however, that the words of a claim may be given a meaning other than their plain and ordinary meaning if: (1) a patentee expressly and unambiguously defined a term in a way that is different from its plain meaning; or (2) a patentee “disclaims” the full scope of a claim term’s plain meaning, for instance, by making clear and unambiguous statements during prosecution that a claim term does or does not encompass certain features.

24. I understand that, after construing the claims, the teachings of the prior art are considered. I also understand that a POSITA is assumed to be aware of all relevant prior art in the field of endeavor covered by the patent-at-issue and all analogous prior art.

25. I understand that although the ultimate question of the obviousness of a claimed invention is a legal determination, obviousness is based on several factual inquiries, including: the scope and content of the prior art, the differences between the claimed subject matter and the prior art, the level of ordinary skill in the art at the time of the invention, and any “objective indicia” or “secondary considerations” of non-obviousness, which must all be considered.

26. I understand that, in determining the scope and content of the prior art, a reference is considered relevant prior art if it falls within the field of the inventor's endeavor, or if it is reasonably pertinent to the particular problem that the inventor was trying to solve. A reference is reasonably pertinent if it logically would have commended itself to an inventor's attention in considering his problem.

27. I understand that, to assess the differences between prior art and the claimed subject matter, the claimed invention must be considered as a whole.

28. I understand that there are several rationales for combining prior-art references. For instance, I understand that it is considered obvious to: combine prior-art elements according to known methods to yield predictable results; substitute one known element for another to obtain predictable results; use the prior-art elements in a predictable way according to their established functions; apply a known technique to a known device (method or product) ready for improvement to yield predictable results; choose from a finite number of identified, predictable solutions, with a reasonable expectation of success; or if there is some teaching, suggestion, or motivation in the prior art that would have led a POSITA to modify a prior-art reference or combine prior-art teachings to arrive at the claimed invention. I understand, however, that a POSITA does not

need to have the same motivations or reasons to combine the prior art as the inventors, and can arrive at the claimed invention for completely different reasons than the inventors.

29. I also understand that the prior art cannot be modified or combined using “hindsight.” I understand that hindsight refers to situations in which the patent-at-issue is used as a framework to pick and choose pieces from the prior art to arrive at the claims, or adopting rationales identified by the patent-at-issue that those in the art would not have recognized. Instead, I understand that the obviousness inquiry is evaluated from the perspective of a POSITA as of the critical date of the patent-at-issue, with all the prior art before them, to determine whether the POSITA would have independently arrived at the claimed invention without the benefit of the patent-at-issue for guidance.

30. I understand that “objective indicia” or “secondary considerations” of non-obviousness include whether: (1) there was a long-felt need for the claimed invention; (2) the claimed invention has achieved commercial success; (3) there was copying of the claimed invention by others; (4) there were failed attempts by others to make the alleged invention; (5) there was praise of the invention in the field; and (6) there was skepticism the claimed invention could be achieved, among a few others.

31. As of the time that I prepared this declaration, the Patent Owner had not identified any secondary considerations of non-obviousness. Therefore, I might address any secondary considerations if the Patent Owner later identifies any.

32. Finally, I understand that, in an inter partes review proceeding, the Petitioner bears the burden of proving obviousness of a challenged patent claim by “a preponderance of the evidence.” I understand that the preponderance of the evidence standard requires that a reasonable factfinder could find a material fact is more probable than the nonexistence of that fact. I have applied the “preponderance of the evidence” standard throughout my declaration.

3. Materials Considered

33. The opinions contained in this declaration are based on the documents I reviewed, my professional judgment, as well as my education, experience, and knowledge regarding electro-mechanical engineering.

34. In forming my opinions expressed in this declaration, I reviewed all the materials cited within this declaration, including:

- U.S. Patent No. 8,747,097 to Pettis et al. (“the ’097 Patent”; EX1001)

Declaration of Andrew Wolfe, Ph.D.
U.S. Patent No. 8,747,097

- Excerpts from the Prosecution History of the '097 Patent (“the Prosecution History”; EX1002)
- U.S. Patent No. 6,580,959 to Mazumder (“Mazumder”; EX1004)
- U.S. Patent No. 9,156,204 to Knighton (“Knighton”; EX1005)
- Luo et al., The Development of Internet Accessible Rapid Prototyping System, Proceedings of IECON '99: The 25th Annual Conference of the IEEE Industrial Electronics Society (1999). (EX1006)
- U.S. Patent Pub. No. 2004/0162798 to Mamoto et al. (“Mamoto”; EX1007)
- PCT Pub. No. WO2008/102266 to Biton et al. (“Biton”; EX1008)
- U.S. Patent No. 6,611,617 to Crampton (“Crampton”; EX1009)
- U.S. Patent Pub. No. 2006/0160250 to Bonassar et al. (“Bonassar”; EX1010)
- U.S. Patent Pub. No. 2002/0186245 to Chandhoke et al. (“Chandhoke”; EX1011)
- U.S. Patent Pub. No. 2004/0207662 to Anderson et al. (“Anderson”; EX1012)

- Tay et al., Distributed Rapid Prototyping – A Framework for Internet Prototyping and Manufacturing, Integrated Manufacturing Systems (November 2001) (“Tay”; EX1013)
- U.S. Patent Pub. No. 2010/0142759 to Ridley et al. (“Ridley”; EX1014)
- Bakhadyrov et al., Defect Detection in Indirect Layered Manufacturing, Proceedings of the 1998 IEEE International Conference on Systems, Man and Cybernetics (1998) (“Bakhadyrov”; EX1015)
- Exhibit H of Infringement Contentions from Stratasys, Inc., v. Shenzhen Tuozhu Technology Co., Ltd., et al., Case Nos. 2:24-cv-00644-JRG and 2:24-cv-00645-JRG (E.D. Tex. Nov. 14, 2024) (EX1016).

35. All of the opinions contained in this declaration are based on the documents I reviewed and my knowledge and professional judgment. My opinions have also been guided by my appreciation of how a person of ordinary skill in the art would have understood the claims and the specification of the '097 patent at the time of the alleged invention, which I have been asked to initially assume is August 18, 2010.

36. Based on my experience and expertise, it is my opinion that certain references disclose and/or suggest to a POSITA, alone or in combination, all the features recited in the Challenged Claims of the '097 patent, as I explain in detail below.

37. My opinions are based on my years of education, research, and experience, as well as my investigation and study of relevant materials. In forming my opinions, I have considered the materials I identify in this declaration and those listed in the Exhibit List above.

38. I may rely upon these materials and/or additional materials to respond to arguments raised by the Patent Owner. I may also consider additional documents and information in forming any necessary opinions — including documents that may not yet have been provided to me.

39. My analysis of the materials produced in this matter is ongoing and I will continue to review any new material as it is provided. This declaration represents only those opinions I have formed to date.

4. Level of Ordinary Skill in the Art

40. I understand that patents and prior art references are analyzed from the point of view of a person of ordinary skill in the art (“POSITA”) at the time of

the invention of, in this case, the '097 Patent, which, as I explained above, is assumed to be August 18, 2010. I have been informed that the level of ordinary skill of a POSITA at the time of the invention is based on consideration of factors such as the educational level of the inventor and persons working in the field, the types of problems encountered in the field, prior art solutions to those problems, rapidity with which innovations are made, and the sophistication of technology.

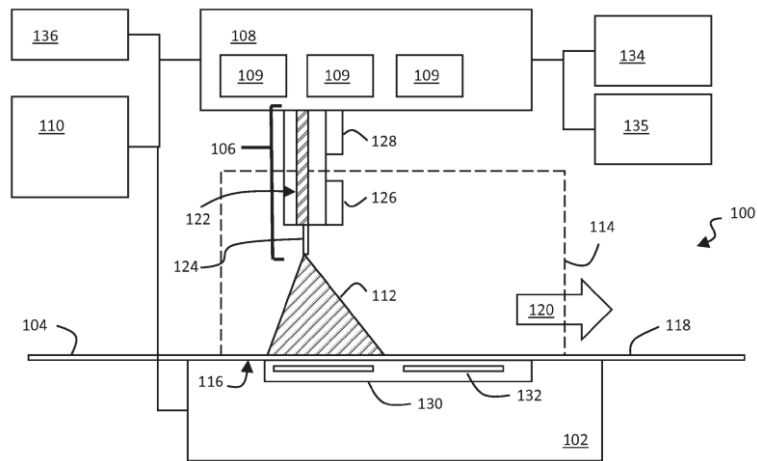
41. Based on my knowledge and experience in the field and my review of the '097 patent and its file history, I believe the range of qualifications for a POSITA would have included a bachelor's degree in Mechanical Engineering, Electrical Engineering, Computer Engineering, Materials Science, or a comparable field and two years of experience (e.g., research or industry experience) related to 3D printing including remote control of rapid fabrication systems. For example, pertinent to the '097 patent, the design and development of remote control and communication for a 3D printing system, including video camera monitoring, would have been well within the capabilities of a junior engineer. Such a person would have understood the purpose of such control and monitoring systems would have been able to apply basic product design principles. A POSITA could potentially have higher extent of education and a lower level of work experience or vice versa.

42. My analysis and conclusions expressed in this Declaration are based on the perspective of a POSITA having this level of knowledge and skill. My education, technical expertise and personal knowledge discussed above shows that I meet the qualifications of a POSITA. For example, I am a Ph.D. computer engineer, an expert on user interfaces and 3D visualization with many years of work and management experience in the field, an expert on user interfaces, and an experienced teacher and user of 3D modeling software and 3D FDM printers.

5. Overview of the '097 Patent

43. The '097 Patent describes that “[w]eb-based servers or the like can provide a single point of access for remote users to manage access to distributed content on one hand, and to manage use of distributed fabrication resources on the other.” EX1001, 1:33-39. Such fabrication resources include “networked three-dimensional printers.” *Id.*, 1:66-67. Such “three-dimensional printers 304 may be any computer-controlled devices for three-dimensional fabrication.” *Id.*, 8:28-30. For example, in a primary embodiment, the '097 Patent describes that the printer extrudes build material “at a controlled volumetric rate” to fabricate a three-dimensional object. *Id.*, 4:20-27. The system further includes a “controller 110” having “any combination of software and/or processing circuitry suitable for controlling the various components of the printer 100.” *Id.*, 5:21-23.

8:28-31.



EX1001, FIG. 1.

may “operate a web server or otherwise host remote users and/or activity through

the network interface 136.” *Id.*, 5:29-37. The local controller is described as “connected in a communicating relationship with, a network interface 136,” which may include “any combination of hardware and software suitable for coupling the controller 110 and other components of the printer 100 to a remote compute in a communicating relationship through a data network.” *Id.* 6:61-7:17; FIG. 1. The ’097 Patent further describes the network interface generically as a “network interface card” which includes any hardware with software “suitable for establishing and maintaining wired and/or wireless communications,” a physical “port,” or any variety of then-conventional structures. *Id.*, 8:32-48.

46. The ’097 Patent further describes that the printer 100 can include a “variety of additional sensors.” *Id.*, 5:38-39. The “positioning and mechanical/electrical interconnections” of the sensor 134 “will be readily understood and appreciated by one of ordinary skill in the art.” *Id.*, 5:40-44. The ’097 Patent further describes that the sensor 134 “may also include . . . a three-dimensional scanner using optical techniques” using any “suitable sensing and processing hardware.” *Id.*, 6:34-40. The ’097 Patent does not describe any meaningful or innovative details regarding the structure of the three-dimensional scanner.” *See id.*, 6:34-50. The claimed three-dimensional scanner was allegedly an element missing from the prior art, as is discussed further below.

6. Overview of the Prior Art

6.1. Mazumder (EX1004)

47. Mazumder describes a system for remotely controlling and monitoring a 3D printer via the Internet. Mazumder's system "utilizes advances in telecommunication and fast data transfer to control the fabrication of precisely dimensioned and intricately-detailed products through an automated feedback-controlled, laser-aided direct material deposition (DMD) process." EX1004, 1:62-66. Mazumder describes that users can design models for objects to be fabricated by a 3D printer using standard computer-aided design (CAD) software. *Id.*, 2:3-13. Computer-aided manufacturing (CAM) software is used to generate a deposition tool path for fabricating the object defined by the CAD model. *Id.* Mazumder describes that such CAD software can be used to generate tool paths for both material deposition based rapid fabrication and material removal based rapid fabrication. *Id.*

48. Mazumder describes that "[f]or remote control of the DMD process, a design team or an individual designer is located at the 'remote' site and operates, through a user interface, their 'remote' host computer. The remote computer stores the description of a product to be fabricated." EX1004, 2:14-23. The 3D printer at the local fabrication site includes a local computer 70 that coordinates and controls

all functions of the local fabrication site and communicates with the remote users computer 95. *Id.*, 3:26-39, 4:18-38. The local computer 70 at the location of the 3D printer “receives instructions from the remote computer 95 to control the deposition process and, if necessary, to alter the entire laser source path or parts of it.” *Id.*, 4:30-37. Mazumder also describes remotely controlling the deposition process via the remote computer 95 by providing the designer with the ability to “pause or abort the fabrication process by sending a command to the controller” of the system. *Id.*, 2:34-42, 6:44-67.

49. The local fabrication device includes a number of sensors for tracking the progress of a fabrication process being executed by the device, including “strain gages 40, acoustic sensors 50, optical sensors 60 and video or television camera 65.” *Id.*, 3:26-31. The “video or TV camera 65 records the laser-aided DMD process and transmits the images to the local computer 70, which then sends the images together with the associated temperature, strain and stress data to the remote computer 95 to be displayed preferably on a TV screen or shown on the remote computer monitor as streaming video.” *Id.*, 6:36-43. Specifically, Mazumder describes “using a video or television camera to record the fabrication of the product and sending the images to a display connected to the remote computer.” *Id.*, 8:51-54. Mazumder teaches that the remote computer 95 includes

a user interface “for image and video observation of the laser-aided direct material deposition process.” EX1004, 2:27-30, 6:36-55. The remote user can use the sensor data, including the video data, to identify defects or design flaws “for remote control of the process, or for modification of the product design, in its entirety or in part, and for replacement of the original CAM file with a new edited CAM file or CAM-file block to be transmitted back to the local computer 70” to improve the resulting design. *Id.*, 6:24-35.

50. Figure 1 shows the various components of Mazumder’s local site fabrication assembly and the network connection between the local computer 70 and the remote computer 95:

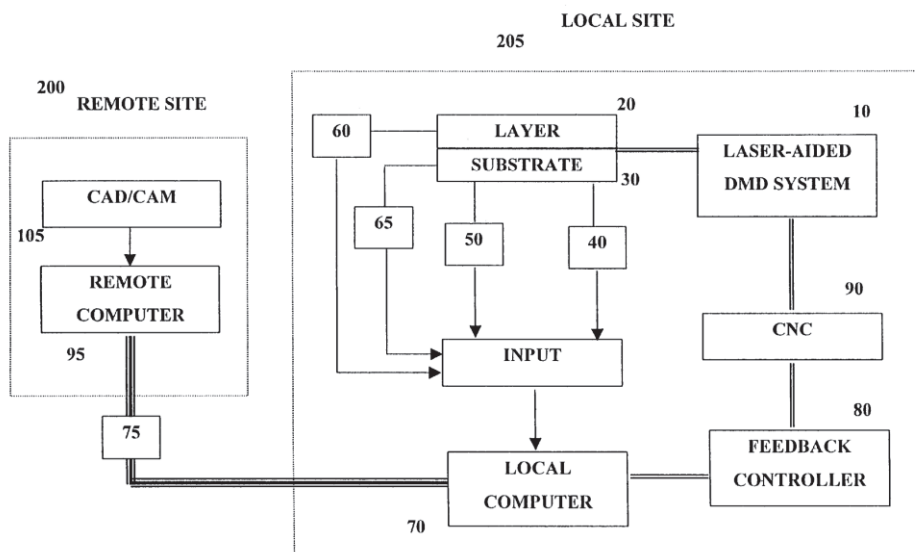


FIG - 1

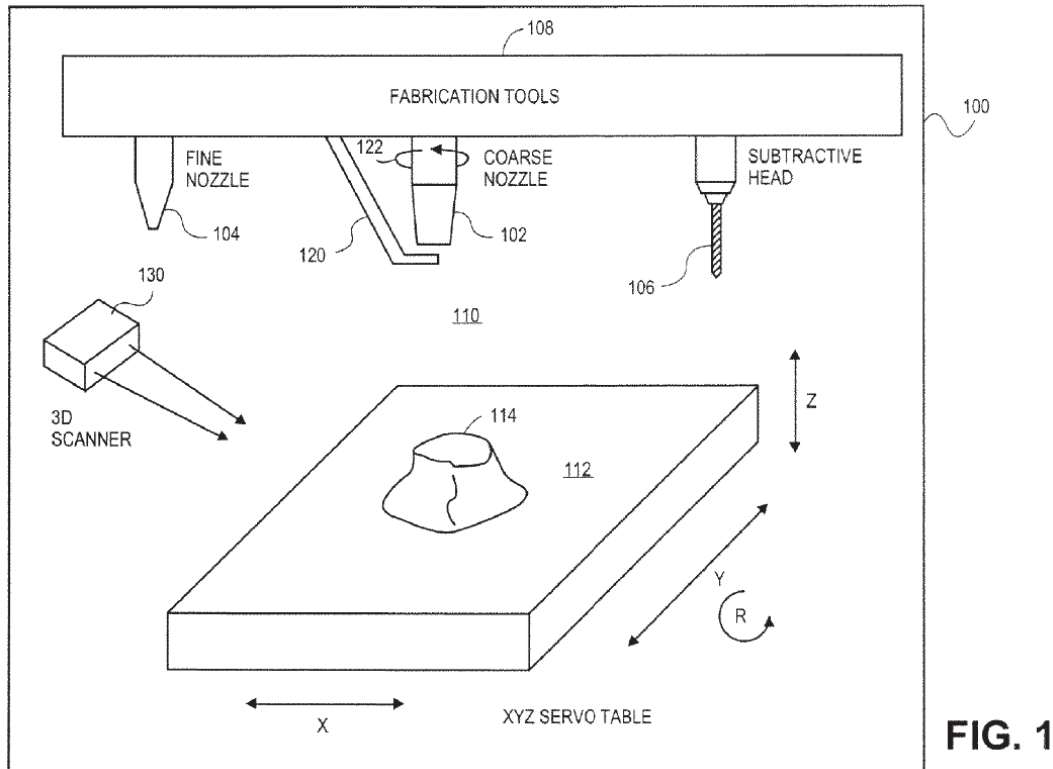
EX1004, FIG. 1, 3:26-63 (describing communication between the local computer 70 and the remote computer 95 “via the communications system 75”).

6.2. Knighton (EX1005)

51. Knighton describes a method and apparatus to fabricate three dimensional objects. EX1005, 1:5-9. Knighton’s apparatus includes a housing 100 which includes “a plurality of fabrication tools 108” which “may be disposed as a single head or individual independently movable heads.” *Id.*, 1:58-61. The apparatus includes a “work surface (also referred to as a build surface) 112 [which] provides a support for the fabrication of a three dimensional target object 114.” *Id.*, 1:65-2:1. The fabrication tools can be comprised of a “coarse print nozzle 102” “to deposit a fabrication material within a work space 110 at a granularity of greater than 0.030 square inches per deposition.” *Id.*, 1:61-64. The fabrication tools further include “a fine nozzle 104 to deposit smaller amounts of material than the coarse nozzle” which “permits detailing of an object created by the coarse nozzle 102 so that large features can be rapidly built with the coarse nozzle 102 and small features added with the fine nozzle 104.” *Id.*, 2:15-20. A “subtractive head 106” is also described which “can subtractively detail the object 114” and may be “a computer controlled milling bit.” *Id.*, 2:25-30.

52. The housing 100 also includes a “scanner 130” that “to scan the object 114 during fabrication.” This scanner is used to “perform interleaved scanning of the partial fabrication during fabrication.” *Id.*, Abstract. This allows “the fabrication process to be adjusted responsive to identification of variance in the fabricated object 114 from the intended object as reflected in the digital model sourcing the data for the fabrication.” *Id.*, 2:32-37. The scanner 130 uses “laser ranging to create the three dimensional model of the work in process 114.” *Id.*, 2:37-39. Knighton also contemplates using “[o]ther scanning methods.” *Id.*, 2:39-40

53. Figure 1 shows the various components of Knighton’s apparatus:



Id., FIG. 1.

54. As further described by Knighton, a “controller 200 interacts with a plurality of drivers 208, a three dimensional scan head 204, and monitoring software 202.” *Id.*, 2:62-65. The controller 200 instructs the drivers 208 using “a digital model of an object to be fabricated.” *Id.*, 2:65-67. During fabrication, the controller 200 “may periodically initiate a scan of the partial object using scan head 204. The resulting scan data may be provided to the monitoring software module 202, which may conduct an analysis.” *Id.*, 3:1-4. The monitoring software module 202 performs a “comparison of existing source model relative to what has

been built in the partial object.” *Id.*, 3:4-7. This comparison “may reflect a need to modify one or more aspects of the build, or do additional additive or subtractive detailing.” *Id.*, 3:7-9. Knighton discloses that a determination is made that a scan should be interleaved during the fabrication process “the object is scanned at block 308 and the three dimensional model of the partial object is created.” *Id.*, 3:37-41. “[T]he scan of the partial object is analyzed relative to, for example, the model on which the fabrication is based to evaluate if changes should be made to the fabrication process concurrently.” *Id.*, 3:42-45. “[V]ariations between the intended design reflected in the source model and what has actually been created may necessitate additional detailing or changes in the calibration of the system.” *Id.*, 3:46-49. The apparatus can also make determinations regarding whether “detailing can be deferred to the extent that such deferral will improve the efficiency of the fabrication process by, for example, reducing the number of the relative movement of the fabrication heads and the object.” *Id.*, 3:49-53.

6.3. Luo (EX1006)

55. Luo is a publication which discloses the “[a]utomated tele-control of Rapid Prototyping Machine via Internet for the application of tele-manufacturing system.” EX1006, Abstract. The local printer apparatus is comprised of a 3D printer described as “a thermal extrusion based layer-deposition rapid prototyping

machine.” *Id.* The “Rapid Prototyping machine uses ABS powder as object building material” which allows the system to “build up a physical object model through the deposition of filling materials extruded from the thermal barrel and processed layer by layer.” *Id.*, 1.

56. Luo’s system incorporates controllers that are each able to communicate with each other through a computer network. *Id.*, Abstract. The system allows users to use a “general-purpose computer” and web browser “for commanding the rapid prototyping machine in a remote location” through the Internet and a home page. *Id.*, Abstract; 1. This permits users to “directly control [the] rapid prototyping machine via the Internet and access [a] Home Page through a friendly user interface.” *Id.*, Abstract.

57. A remote user can also receive “real time images e.g. the completed rapid prototyping model parts captured by a CCD camera that is mounted on the rapid prototyping machine.” *Id.* The vision based hardware includes “an onboard image processor and a single camera” mounted to the rapid prototyping machine. *Id.*, 2.

58. Figure 1 of Luo provides the configuration of the hardware components for the system and illustrates that the local printer apparatus includes a

computing device electrically coupled to the printer equipment to provide a “PC-based control system”:

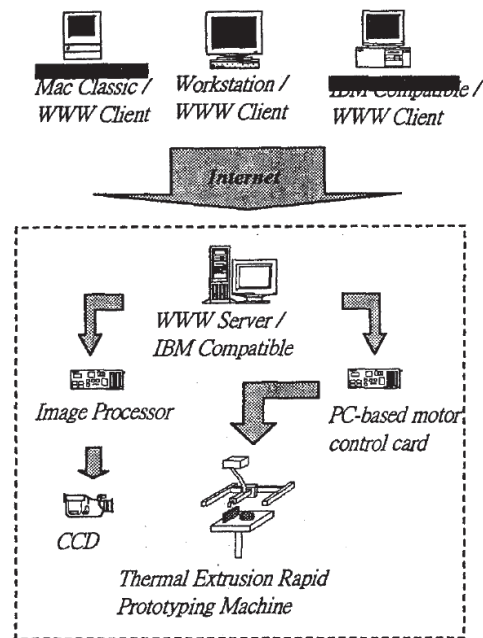


Figure 1. The Hardware Configuration of The Automated Tele-Manufacturing System.

Id., 1-2; FIG 1. The “WWW server” acts as the local controller in Luo’s system to provide communication through the Internet between the “remote user” and printer apparatus. *Id.* Luo expounds on the remote functionality by describing that a remote user can upload a STL file of a CAD model from a remote site to the Server/PC at the fabrication device. EX1006, 2. The STL file “is a standard format for transferring the CAD data to rapid prototyping machines us[ing] a faceted description of the computer model.” *Id.* “The WWW server is responsible for the

commands sent from remote user and call the CGI (Common Gateway Interface) programs correspond[ing] to the receiving command.” *Id.*, 3. Furthermore, during the “model building process and after the completion of the physical RP model” the server “can transmit the image data through [the] Internet to the remote Web browser.” *Id.*

59. Luo further discloses that a user interface is displayed at the remote user’s computer through a web browser when remote control is used. Figure 3 of Luo is an example of the user interface:

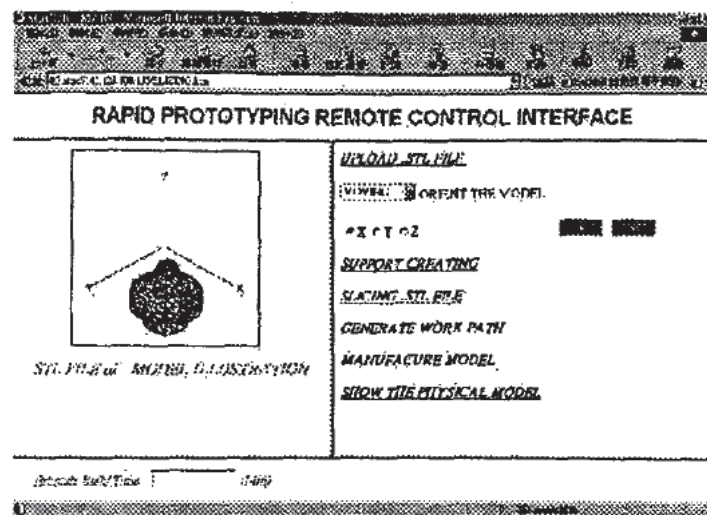


Figure 3. The User Interface for Remote Control of Rapid Prototyping System.

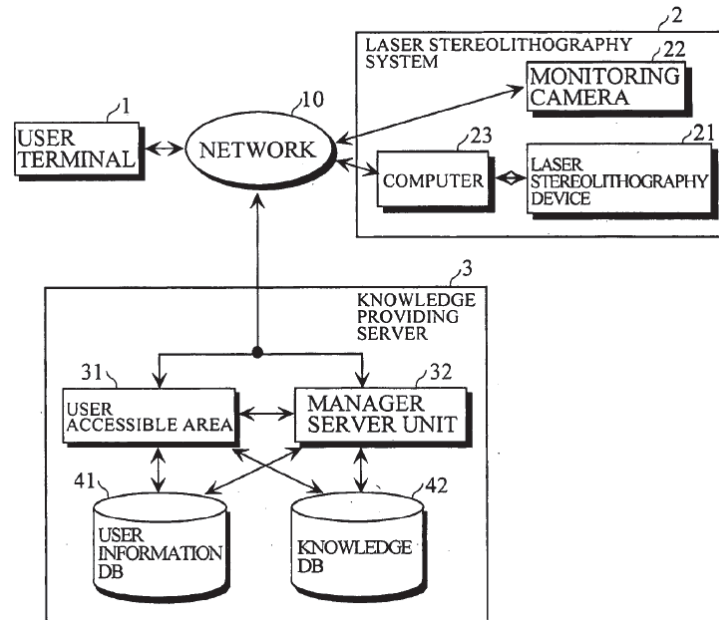
Id., 3; FIG 3.

60. The user clicks the hyperlink for uploading a STL file and saves the file to “the hard disk of the server.” *Id.*, 3. The STL file is then “illustrated in [the] left window of the interface: and the user “can orient the STL file with moving, rotation or scaling commands.” *Id.* The user interface further displays status information such as “Model STL file or Slicing Illustration, Process Control Window, and Estimate Building Time of Physical Model.” *Id.*, 1, 3. The user can also select “Show Image of the Physical Model” and the program will “show live images captured by the CCD in [the] rapid prototyping machine.” *Id.*, 4. This allows the user to “examine the physical model through the image display remotely.” *Id.* 4, 5.

6.4. Mamoto (EX1007)

61. Mamoto describes a “three-dimensional object generating system compris[ing] a user terminal 1 connected to a network 10 such as the Internet, a laser stereolithography system 2 connected to the network 10, and a user support server (a knowledge providing apparatus, a knowledge providing server) 3 connected to the network 10.)” EX1007, [0031]. Mamoto’s system further describes that the laser stereolithography system 2 “comprises a laser stereolithography device 21, a monitoring camera 22 for imaging the operating conditions of the laser stereolithography device 21, and a computer for controlling

a laser stereolithography device.” *Id.*, [0032]. Mamoto’s three-dimensional object generating system is depicted in Figure 1:



EX1007, FIG. 1.

6.5. Biton (EX1008)

62. Biton describes systems in the “art of rapid prototyping, including selective laser sintering (SLS), fused deposition modeling (FDM), stereolithography (SLA), laminated object manufacturing (LOM), electron beam melting (EBM), and 3D printing 93DP).” EX1008, [0015]. The described systems include using 3D printing for fabrication “using a printer head for dispensing conductive material and another printer head for dispensing insulative material.”

Id., [0016]. Specifically, Biton discloses “fabricating separate dielectric layers, forming conductive traces and vias upon each layer, and then fusing the layers together.” *Id.*, [00104]. Biton further describes that “individual layers fabricated are aligned and stacked.” *Id.*, [00109]. “The stack may then be fused or bonded together using, e.g., conventional annealing or bonding techniques.” *Id.*
“Alternatively, the layers may be attached together using a final polymerization and/or final curing step, thereby hardening the structure by fully-curing it.” *Id.*

63. Biton describes the “time savings” that may be achieved by changing the “equipment and materials used” and a process that is “fully automated and the single employee is merely responsible for replacing cartridges, load the system with fabrication data, simple system calibration etc.” *Id.*, [0026] Biton further describes the benefits of fabrication “using any rapid prototyping/SFF/direct writing technique using dielectric material, such as radiation-curable liquid composition, sintering dielectric powder, etc.” *Id.*, [0090]. Biton states that “primary advantage of additive fabrication is its ability to create rapidly almost any two or three-dimensional shape or geometric feature.” *Id.*, [0010]. Furthermore, “significant flexibility” and other advantages are described “such as simplifying other processes within the system.” *Id.*

64. Biton's system includes a "system manager (SM800)" comprised of a "process manager (PM 805)," "intra-machine communication interfaces 810" and "memory unit 815." *Id.*, [00111]. The process manager "is responsible for overall management and supervision of the fabrication process (e.g., as a transaction), including sub-processes synchronization and coordination, process control, e.g., motion axes control, temperature levels, ramp-up and ramp-down over time, etc." *Id.* The intra-machine communication interfaces "connect to some or all of the subcomponents of the system" and the memory unit "stores algorithms for process (serial and parallel coordination and others optimized for efficiency, etc.) and other related data." *Id.* The system further includes cameras for "image processing dedicated internally for the manufacturing process and for fabrication documentation."

65. As part of the supervision and management of the fabrication, the "system manager 800 may further include independent control and error recovery unit 825, responsible for external fabrication process supervision, error handling and recovery, etc." Specifically, the Biton system includes a "camera-aided alignment system . . . for responding to miss-positioning of the PCB in the tray caused by movement of the fabrication tray between stations." *Id.*, [0118]. This provides the advantage of making correction of miss-alignment easy and requiring

only “software-level adaptations for altering the coordinates of e.g., alignment marks.” *Id.* “Notably, when misalignment of the tray is detected, the tray does not need to be mechanically re-positioned. Rather, once the misalignment is measured, the system manager may shift the coordinates of the next layer by the proper amount to correct for the misalignment.” *Id.* The “system enables alignment for every layer (or even sub-layer) fabricates, thus errors accumulation is negligible, enabling fabricating boards with numerous layers and delicate features in a highly accurate manner.” *Id.*

6.6. Crampton (EX1009)

66. Crampton describes a “scanning apparatus and method for generating computer models of three-dimensional objects comprising means for scanning the object to capture data from a plurality of points on the surface of the object.”

EX1009, Abstract. To generate a computer model of the scanned object

Crampton’s system “captures data from two or more points simultaneously,”

“generates intermediate data structures,” combines the “intermediate data

structures to provide the model,” and includes “means for display and means for

manually operating the scanning apparatus.” *Id.*, 5:58-67. The scanning uses

“structured light to more quickly scan the surface of the object.” *Id.*, 6:8-9. This

also operates “to sense the colour of the surface of the object, resulting in a model

more like the real world object.” *Id.*, 6:9-11. As discussed in Crampton, the apparatus is “most efficient in the quest to reduce the time and cost of generating a computer model from a real world object by means of scanning with both time and cost reductions of an order of magnitude achieved over conventional techniques.”

Id., 6:1-5.

6.7. Bonassar (EX1010)

67. Bonassar describes “an article fabrication system” including “a plurality of material deposition tools containing one or more materials useful in fabricating the article.” EX1010, [0008]. The material deposition device includes “a tool interface for receiving the material deposition tools, the tool interface of the material deposition device being movable relative to a substrate to dispense material from the material deposition tool to the substrate.” *Id.* A “system controller” controls the operation of the material deposition device. *Id.*

68. The Bonassar system includes optimizations that “can also involve optimizing the shape and directionality of material deposition paths to achieve desired properties in the finished products.” *Id.*, [0097]. This includes “optimizing mechanical properties such as tensile strength along primary stress axes, or possibly even along 3-dimensional curves through an object being fabricated.” *Id.* The system can “compare the state (geometry and other automatically detectable

properties) of the simulation to the state of the real object being produced as measured by 3-D scanning (or other) sensors.” *Id.* As a result, “[d]iscrepancies can be remedied by generating modifications to the manufacturing plan which replace or circumvent the error.” *Id.* The manufacturing plan software can further include “special purpose data conversion capabilities to assist the designer in conveying design data to the system.” *Id.*, [0098].

69. Before “commencing to fabricate an article and/or after having made each deposit of material, the system can collect 3-dimneionsla geometry data of the current state of the substrate and any objects therein, the material deposited, and the article being fabricated.” *Id.*, [0010]. The system utilizes a “non-contact ranging sensor device” to “monitor the progress of a fabrication operation, identify and locate objects placed in the build environment, and to measure the geometry of the finished product.” *Id.*, [0104]. This scanner is “embed[d] within the material deposition tools near the point of material deposition (e.g. nozzle)” in order to “permit[] the acquisition of the geometry of deposited material with minimal interruption of the fabrication process (e.g. without pausing manufacturing in order to mount a separate sensing tool to perform the scanning)” and “improve[] the value off the resulting data for use in feedback control of the deposition tool.” *Id.* A “computerized scan” is generated where the “geometry to be dispensed can be

determined from any method capable of generating 2D and/or 3D data sets, including, without limitation, 2D laser scanning, confocal microscopy, multi-photon microscopy, computerized tomography, magnetic resonance imaging, ultrasound, and angiography.” *Id.*, [0145]. “other machine vision sensing technologies are also available, including microscopic video capture at the point of deposition.” *Id.*, [105].

6.8. Chandhoke (EX1011)

70. Chandhoke describes a “system and method for configuring a hardware device to execute a prototype.” EX1011, [0015]. The prototype “may comprise a software entity operable to perform or specify a plurality of executable operations, wherein the prototype is created by a user without requiring user programming.” *Id.* As part of this prototype execution, the prototyping environment may be “an image processing prototyping environment” where image processing is used “to refer to image processing, image analysis, and machine vision, among others.” *Id.*, [0081]. “[I]mage processing’ and ‘machine vision’ are used interchangeably to refer to the processing of images to extract useful information from the image or determine characteristics of the image (or to determine characteristics of one or more objects displayed in the image).” *Id.*, [0111]. Additionally, “one embodiment of a prototyping environment may provide a

library of operations including one or more image processing operations, one or more motion control operations, and one or more data acquisition (DAQ) operations.” *Id.*, [0087]. The prototyping environment is used “to create a prototype including image processing (machine vision) operations for acquiring and analyzing images of an object, motion control operations for moving the object, and DAW operations for acquiring measurement data of the object.” *Id.*

71. Chandhoke applies this image processing system can be applied for example “in a quality control system in an automated assembly plant.” *Id.*, [0174]. “[T]he image processing function may operate to analyze an image and detect, recognize, or characterize one or more features or characteristics of an object, such as position, orientation, color, or possible flaws or lack thereof, among others.” *Id.*, [0173], [0232], [0006]. “[I]n performing the image processing function on the acquired image, the image acquisition device may determine a characteristic of the image indicating that the imaged object is defective.” *Id.*, [0174]. “The image acquisition device may then send a signal, such as a pass/fail indication, to a motion control device which may remove the defective object from the assembly line.” *Id.*

6.9. Anderson (EX1012)

72. Anderson describes a user interface for providing status information for rapid fabrication processes executing on multiple, geometrically dispersed rapid fabrication systems. Such [t]hree-dimensional (3D) objects fabrication techniques” include “solid freeform fabrication (SFF) and layer manufacturing (LM)” to “allow a 3D object to be built layer-by-layer or point-by-point without using a pre-shaped tool (die or mold).” EX1012, [0001]. Such 3D printing is based on a model “representing the geometry or shape of an object to be fabricated.” *Id.*

73. In the primary example in Anderson, the system presents a user interface that visually depicts “three-dimensional object fabrication status in the form of a progressively filled-in wireframe model representation of the three-dimensional object.” EX1012, [0015]. An example of such a progressively filled-in wireframe model is shown in Figure 2A of Anderson:

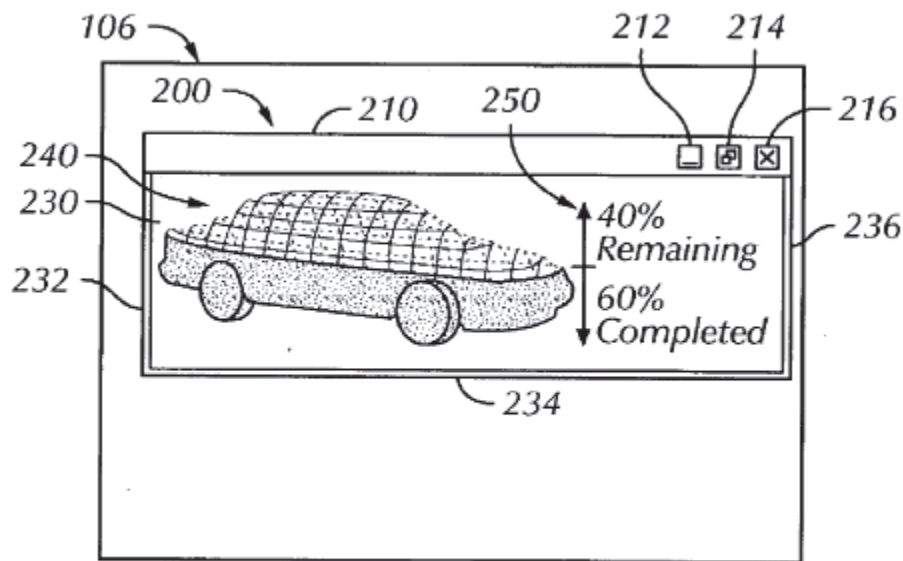


FIG. 2A

EX1012, FIG. 2A.

74. As shown in Figure 2A, in addition to the visual representation of the portion of the object completed, the user interface also provides a numerical value for the percentage of the object that is completed and the percentage of the object that remains to be fabricated. EX1012, [0021], [0025]. As shown in Figure 1, the user interface can provide status information for 3D objects being fabricated at various different 3D printers. “The graphical user interface 108 also has a main section 130 with ‘Job#’, ‘Owner’, ‘Status’ and ‘Progress’ (or similar) column headings under which information in the form of human-readable indicia and/or visual representations are provided for each 3D object fabrication.” *Id.* [0019].

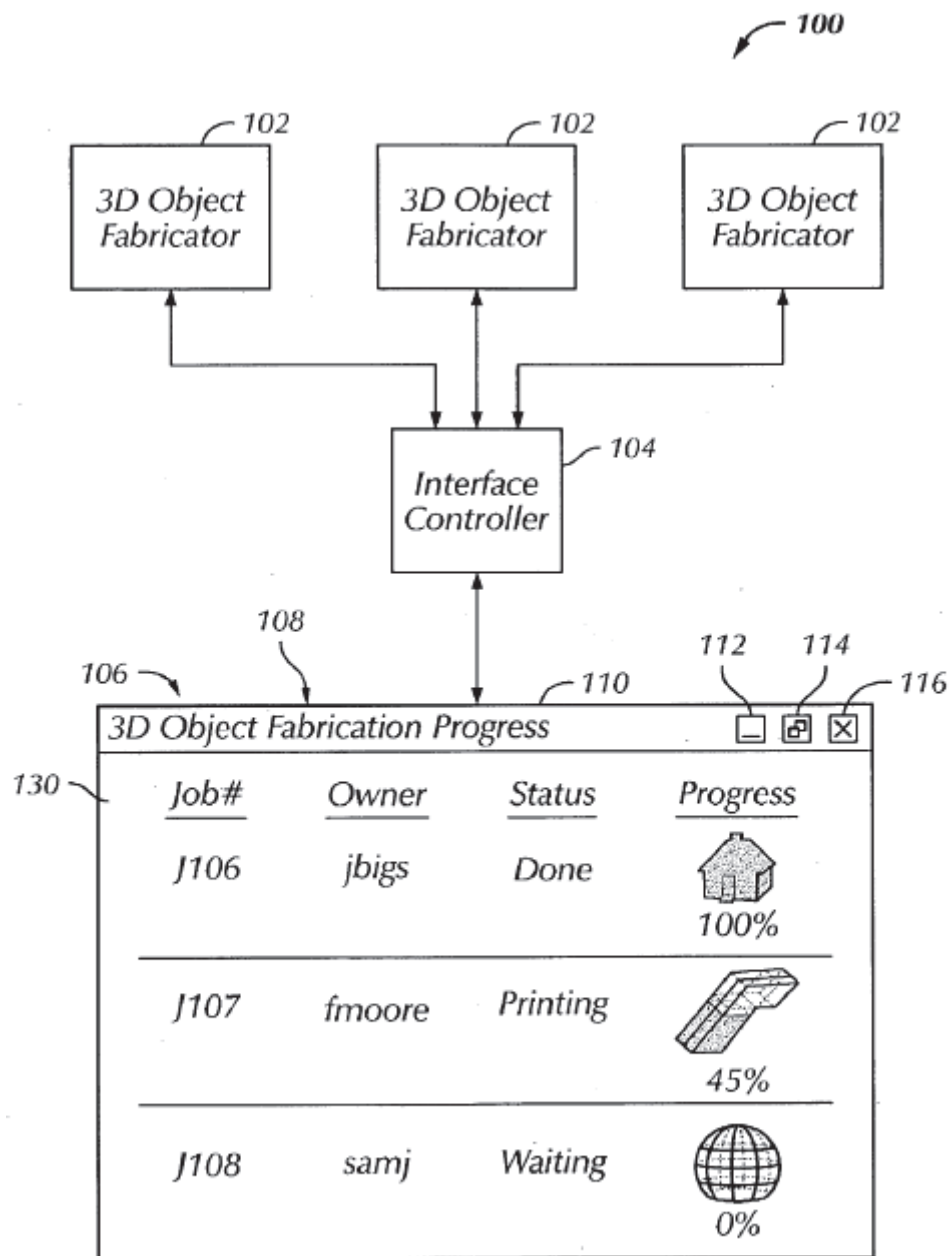


FIG. 1

EX1012, FIG. 1.

75. Anderson contemplates numerous other visualizations that can help the user to quickly assess the progress of a 3D print job:

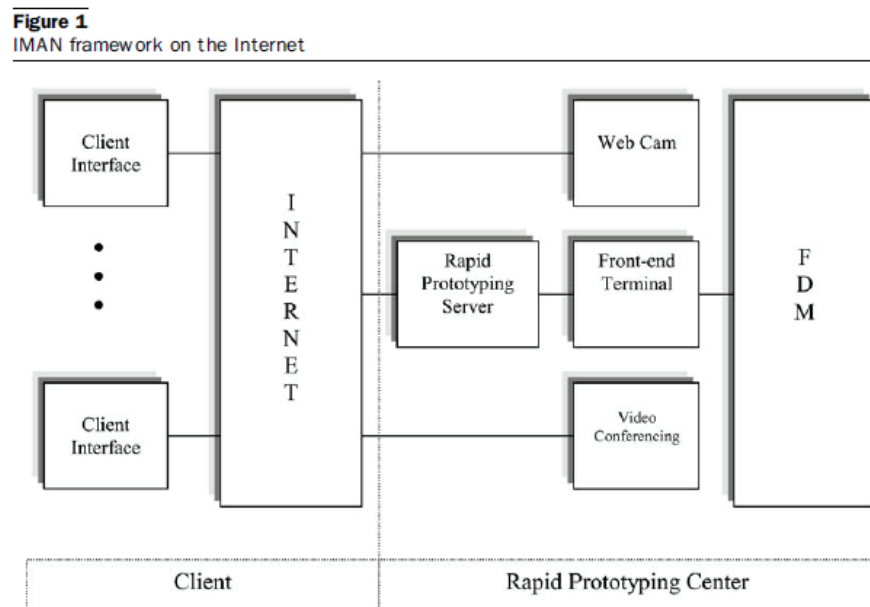
In one embodiment, the interface controller 104 is configured to control the graphical user interface 108 such that the filled-in portion(s) transition(s) from one color to another, for example, while the 3D object fabrications are in progress. In another embodiment, the interface controller 104 is configured to control the graphical user interface 108 such that the filled-in portion(s) pulsate(s). In another embodiment, the interface controller 104 is configured to control the graphical user interface 108 such that the filled-in portion(s) pulsate(s) at rates depending upon the progress of the 3D object(s) fabrication.

EX1012, [0021].

6.10. Tay (EX1013)

76. Tay describes that “[m]anufacturing and design technologies are gradually gravitating towards Internet integrated technology to cope with emerging challenges such as the need for shorter time to market, reduced lead time in the supply chain of new products, reduced cost and higher quality.” EX1013, 1. The system described by Tay allows “a wide audience using a disparate range of computer systems to access remotely located rapid prototyping facilities via the Internet for prototype fabrication.” *Id.* Tay leverages “client server

communications for the remote control of rapid prototyping hardware (called fused deposition modeling) via the Internet.” *Id.* Tay describes that “the server applications...have a direct link with the front-end terminals controlling the rapid prototyping hardware.” *Id.* Figure 1 of Tay shows the direct interface between the client device and the rapid prototyping center via the Internet:



EX1013, 3.

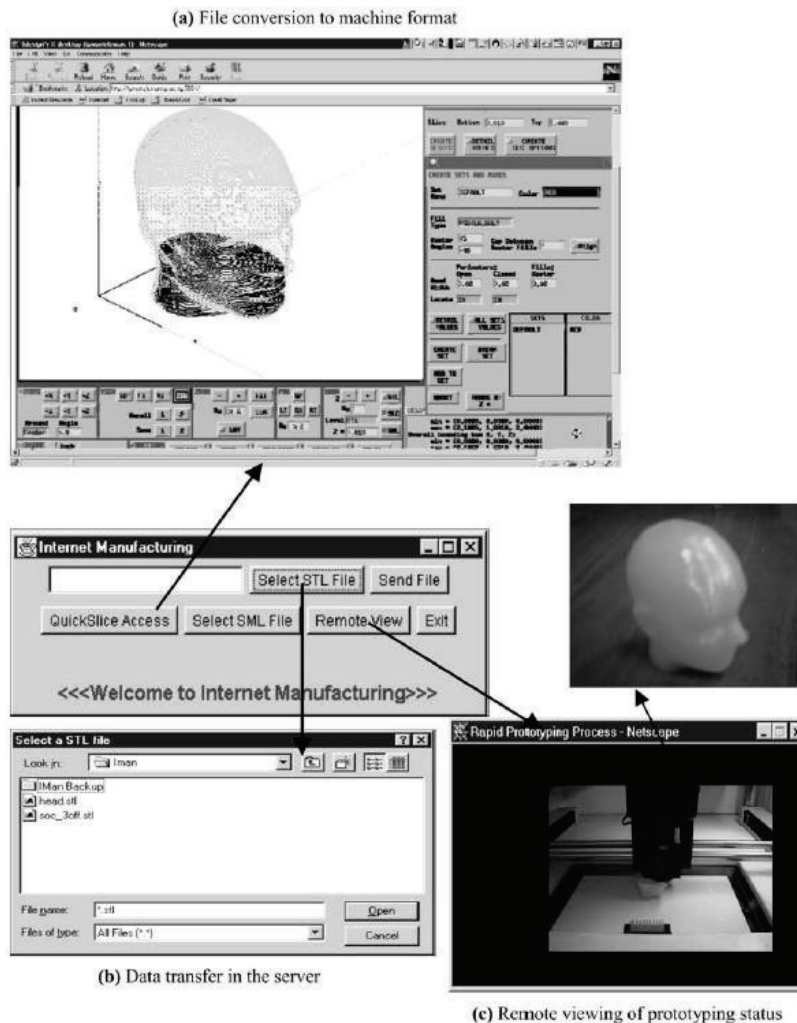
77. Tay’s remote control techniques are applicable to fused deposition modeling (FDM), selective laser sintering (SLS), stereo-lithography apparatus (SLA) and laminated object manufacturing (LOM) 3D printing technologies,

among others. EX1013, 2-3. To facilitate remote control of the 3D printer at the rapid prototyping center, Tay's client devices use "common Web tools such as Netscape Communicator browser" to present a "transparent and user friendly" interface that does not require "extra plug-ins to run the application." *Id.*, 3-4.

78. Tay utilizes "a platform neutral framework for the construction of the human computer interface (HCI)." EX1013., 2. "The client and server applications are linked to one another via the Internet." *Id.*, 3. The rapid prototyping center further includes a web cam and video conferencing software to provide images of the fabrication process in progress to the user at the client device. *Id.* Tay describes that the user interface at the client device includes functionality "for configuring and monitoring the remote prototyping system." *Id.* Figure 3 shows the user interface of Tay which includes displays of the model of the object to be fabricated and actual images of the build process captured by cameras located at the rapid prototyping center:

Figure 3

(a) File conversion to machine format (b) Data transfer in the server (c) Remote viewing of prototyping status



EX1013, 5.

79. As shown above, Tay's system provides "audio and visual feedback" from the fabrication system to the client device using a "Web cam and video conferencing." EX1013, 4. These web cams can allow "multiple clients...to watch the same fabrication process for discussion and analysis." *Id.* The user interface at

the client device displays status information for the object being fabricated, including showing a virtual rendering of the progress of the object in comparison to a wireframe of the entire object and actual images of the object being fabricated as captured by the Web cam. *Id.*, 5.

80. Tay describes that the described “platform independency was a critical factor to ensure that end users using different computer systems can interact with the rapid prototyping center effectively. EX1013, 5. Furthermore, “[t]he modular software architecture for the IMAN system is also highly scalable for further research and development.” *Id.*, 5-6. Utilization of the Internet as the means of communication also allows for cheap and reliable data communication. *Id.*, 6. As such Tay’s system can “considerably reduce the product development lead time.” *Id.*

6.11. Ridley (EX1014)

81. Ridley describes a system and method for detecting a damaged or missing machine part using image analysis and computer vision techniques. EX1014, [0001]. The system utilizes “an image capturing device for capturing image of the machine and a processor for processing the captured images.” *Id.*, Abstract. In Ridley, the “machine may be any type of machine and the machine part may be comprised of any type of part associated with the machine. *Id.*, [0011]-

[0012]. The system further includes “an image capturing device” “for capturing images of a machine against a background” and “a processor for processing the captured images to determine whether one or more machine parts is damaged or missing.” *Id.*, [0013]-[0015]. The Ridley system also includes a “sensible output for providing an indication of a damages or missing tooth. *Id.*, [0021]. “The sensible output may be comprised of a visual display, an audible alarm, or any other type of output which may be sensed by a person or apparatus. *Id.*

82. As an example, “the sensible output may be comprised of a signal which causes the mining shovel to stop operating when a damaged or missing tooth is detected. *Id.* The tooth line of the bucket “is analyzed on each upswing of the mining shovel and compared against a base-case scenario of a fully intact tooth line. *Id.* If a tooth is “partially or completely broken or missing, the system automatically alerts the shovel operator by a sensible output in the form of a visual alarm on a touch screen monitor.” The operator is “alerted to partial or complete tooth breakages as soon as the shovel comes into the viewing range of the camera.” *Id.*, [0083].

6.12. Bakhadyrov (EX1015)

83. Bakhadyrov describes a “Direct Layered Manufacturing (LM)” system which “is an additive manufacturing process where part is built layer by

layer based on its CAD file.” EX1015, Abstract. Bakhadyrov’s system also includes a “machine vision setup for surface voids detection which can be used for surface quality inspection of parts.” *Id.* This setup is used to perform “quick and precise quality inspection of each layer.” *Id.*, 2. Specifically, the machine vision is “designed for detection of surface defects (voids) in indirect and ‘zero-offset’ direct LM process.” *Id.*, 4. This system uses “double shading” to detect the voids wherein “voids appeared on the image as black spots, while the rest of surface appeared gray.” *Id.*, 3. Subsequently, “any voids on the surface can be characterized as defects, and voids detection, performed on each layer, would significantly increase the resulting quality.” *Id.*, 2. As described in Bakhadyrov, this void detection technique makes the inspection process “much faster and more affordable” by using “[c]omputation efficient algorithms. *Id.*, 4.

7. Application of the Prior Art to the Challenged Claims

7.1. Ground 1A: The Combination of Knighton with Luo and Anderson Renders Obvious Claims 1-2, 4-5, 9-10, 12, 15-16, and 18-19

84. A POSITA would have recognized that the teachings of Luo would have been readily applied to the 3D fabrication and monitoring system of Knighton such that in the resulting system, users can remotely control and monitor the fabrication process over the Internet, including by viewing status information

presented in a user interface to the remote user for multiple reasons to achieve predictable results. Such a modification would have also beneficially and predictably included implementing the Web Server functionality of the computer that controls Luo's 3D printer in Knighton's controller 200.

85. As a first reason a POSITA would have been prompted to implement Knighton's 3D printer system to provide remote monitoring and control (as suggested by Luo) so as to advantageously allow a user to upload a CAD file and monitor/control the process remotely without having to be in the same geographic location as the rapid fabrication apparatus. Such a predictable improvement would have provided "manufacturing facilities to geographically separated partners." EX1013, 2. A POSITA would have further understood that this disclosure is broad enough to suggest advantages to simply being able to be in a separate room or to leave the building.

86. As a second reason Luo expressly suggested that "rapid prototyping machine[s] [are] too expensive to offer many companies" and that providing "universal access" to a rapid fabrication apparatus "via Internet" was a "useful and effective" solution, and thus a POSITA would have recognized that providing such remote access to Knighton's rapid prototyping machine via the Internet would have beneficially provided opportunities for such companies "without the need for their

own investment for setting up costly prototyping facilities.” EX1006, 1; EX1013, 2.

87. As a third reason Luo expressly suggested such remote control was accomplished using merely “a general-purpose computer” having a “browser” at the remote client side. EX1006, Abstract, 6 (“no special software is required”). Accordingly, a POSITA would have recognized that that the predictable improvement to Knighton’s rapid prototyping machine (as suggested by Luo) would have beneficially enabled users to achieve the remote control/monitoring capabilities without imposing specialized equipment at the remote side.

88. As a fourth reason permitting such remote control of Knighton’s apparatus would “enhance the accessibility of available rapid prototyping services to a broader community of users.” EX1013, 2.

89. As a fifth reason remote monitoring of the fabrication process would allow remote users to visually observe progress of the fabrication process and identify defects or problems in the object, allowing users to manually stop defective fabrication processes and improve the design and/or process. While, Luo’s system uses cameras to monitor the fabrication process, a POSITA would have recognized that in the Knighton-Luo-Anderson combination, it would have

been beneficial to present a visual display of the “three dimensional model of the work in process” captured by Knighton’s scanner at the remote user computer because such a modification would have beneficially used the 3D scanner already present in Knighton’s apparatus and the “three dimensional model of the work in process” already generated by Knighton’s apparatus. EX1005, 2:37-40.

90. Additionally, displaying the three dimensional model of the work in process” captured by Knighton’s 3D scanner in place of or in addition to a video image of the object as it is being fabricated would have allowed the user to more readily visually identify contours or physical inconsistencies in the object that may be difficult to identify in an image due to the interplay of light and shadow with the object. Indeed, Luo’s user interface includes a control to “Show Image of the Physical Model in the Process Control Window” and a POSITA would have recognized that it would have been obvious and beneficial to display the “three dimensional model of the work in process” generated using Knighton’s 3D scanner as the image of the physical model in the process control window for the reasons described above. EX1006, 3. Not only does Luo disclose capability for displaying such three-dimensional models, a POSITA would have recognized that displaying such models of scanned three-dimensional data was well-known in prior art systems. *See e.g.*, EX1009, 6:43-60, 8:3-15.

91. As a sixth reason a POSITA would have recognized that presenting status information to the remote user in the user interface, including illustrations of the Model STL file, process control information, estimated building time, and images of the build process captured by Knighton's 3D scanner, would have improved the remote user's ability to understand and control the fabrication process by presenting helpful information regarding the fabrication process to the user. EX1006, 3.

92. Additionally, a POSITA would have beneficially applied Anderson's suggestions to the combination of Knighton with Luo such that the user interface presented at the remote user's computer includes additional status information, including indication of if a design is waiting, printing, or done, the percentage of the object completed, and a comparison of the portion fabricated against a wire frame in the user interface for multiple reasons. As a first reason, Knighton expressly discloses generating a "three dimensional model of the work in process" using its 3D scanner. EX1005, 2:31-40. Anderson provides complimentary disclosure of "receiving data pertaining to three-dimensional object(s) fabrication progress" (in this case, Knighton's "three dimensional model of the work in process") and "controlling a graphical user interface to provide a visual representation of the three-dimensional object(s) fabrication progress." EX1005,

2:31-40; EX1012, [0026]. This includes helpful information such as the three dimensional model of the work in process with respect to a wireframe of the model of the entire object a percentage that has been completed:

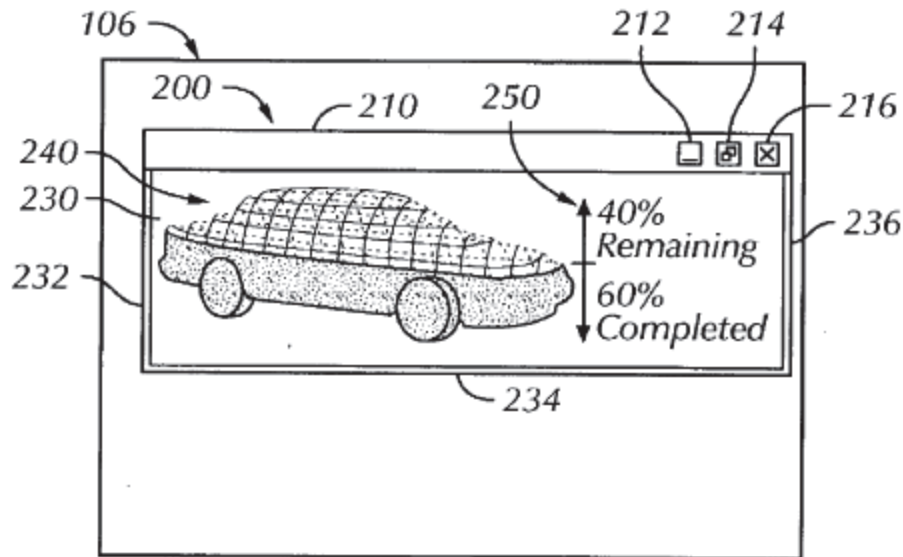


FIG. 2A

EX1012, FIG. 2A, [0018]-[0020], [0026]. Such additional context would have increased the user's knowledge and understanding of the overall fabrication process and help the user to visualize the completed portion of the object with respect to the full design. As a second reason, the additional information regarding progress of the object (including numerical indications of the percentage of completion) would help the user to readily assess the progress of the fabrication process and estimate the amount of time remaining. EX1012, FIG. 1-2A, [0018]-

[0020]. *As a third reason*, displaying this additional status information described by Anderson would have allowed users to easily identify where in a print queue the user's particular design is to help the user to better schedule other tasks with respect to the rapid fabrication process. For example, the user interface elements shown in Figure 1 of Anderson not only display progress of jobs in progress but also indicate the status of whether a print job is completed, in progress, or queued for future execution:

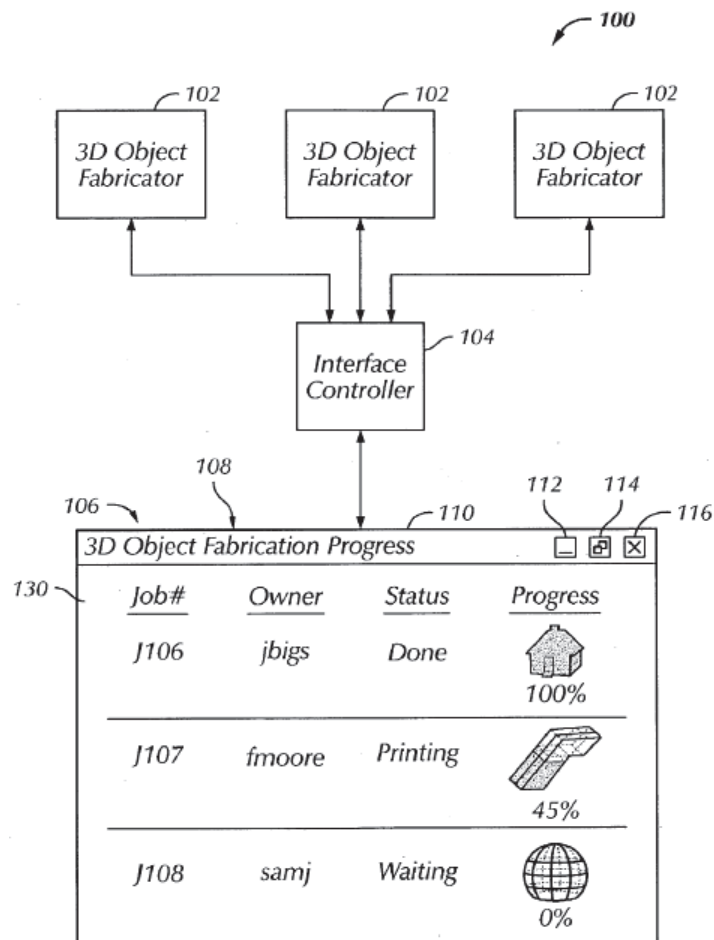


FIG. 1

EX1012, FIG. 1, [0019].

93. As a fourth reason, providing visual indicators of completion of the fabrication process for a given fabrication project in the user interface displayed to the remote user would have allowed users to conduct post fabrication actions (such as communicating with persons at the local fabrication site) in a timely manner.

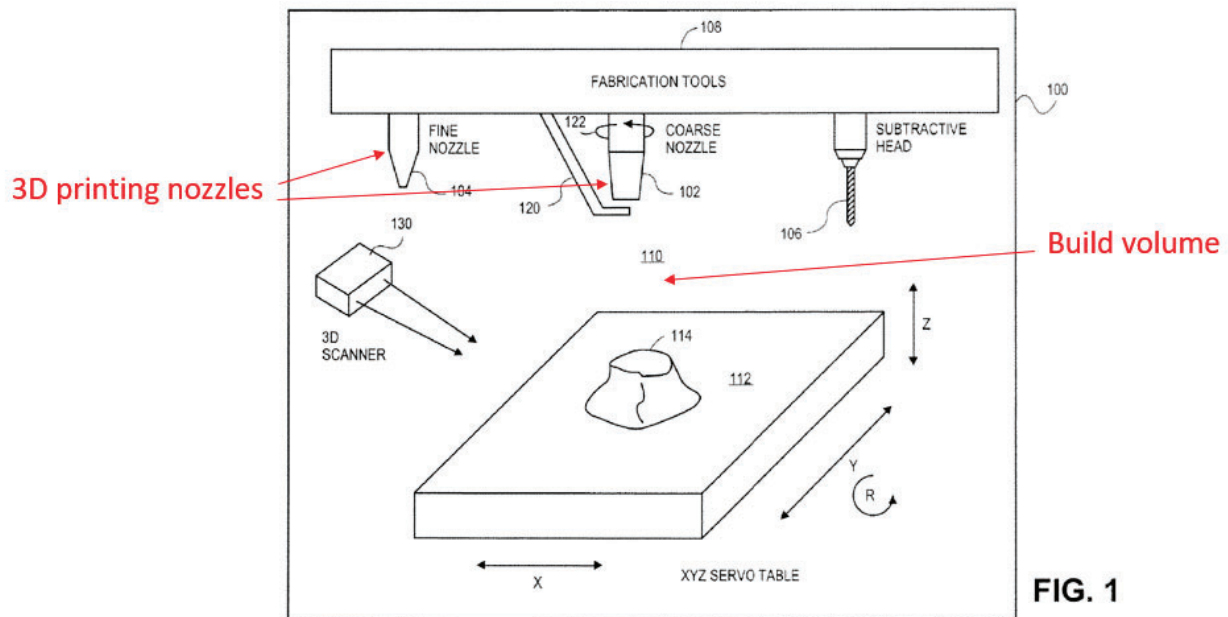
94. As a fifth reason, a POSITA would have been prompted to modify Knighton's rapid fabrication system to include the remote control functionality and web server functionality disclosed by Luo and the additional visual status information described by Anderson in the user interface displayed at the remote computer because doing so would be merely the application of a known technique to a known system (e.g., Knighton's 3D printer) ready for improvement to yield predictable results. Here, Luo provides straightforward teachings regarding remotely controlling a 3D printing process and Anderson provides straightforward evidence of a known technique for providing status information for a 3D printing process to a remote user and Knighton's teaching provides a known system that would have been improved by application of Luo's and Anderson's suggested techniques for at least the reasons described above. Based upon my knowledge and experience in this field and my review of Knighton, Luo, and Anderson, I am confident a POSITA would have recognized that this modification would have

yielded predictable results and required only routine adjustments to the system and as such a POSITA would have had a reasonable expectation of success in making such modifications. These modifications would not have significantly altered or hindered the functions performed by Knighton's system, and these modifications would have been within the predictable and ordinary level of skill of a POSITA (certainly by a time frame as late as 2010).

Element [1.pre]: A three-dimensional printer including a build volume, the three-dimensional printer comprising:

95. To the extent the preamble is considered limiting, Knighton discloses a three-dimensional printer which includes a build volume and, when predictably combined with Luo and Anderson, includes all of the features recited by claim 1. For example, Knighton describes "three dimensional printers . . . which can be used to fabricate a three dimensional object from a digital model." EX1005, 1:13-16. Specifically, Knighton embodiments of a "three dimensional printing apparatus" using "additive nozzles" to fabricate "three-dimensional object[s]" within a "structure defining a work area." *Id.*, 4:27-67. The Knighton apparatus includes "a coarse print nozzle 102 . . . to deposit a fabrication material within a work space 110 at a granularity of greater than 0.030 square inches per deposition." *Id.*, 1:61-2:14. The apparatus further includes a "fine nozzle 104 to deposit smaller amounts of material than the coarse nozzle." *Id.*, 2:15-2:30. As

shown in Figure 1, the deposition of materials occurs within the “work space 110” on a “work surface (also referred to as a build surface) 112” which “provides a support for the fabrication of a three dimensional target object 114.” *Id.*, 1:61-2:1.

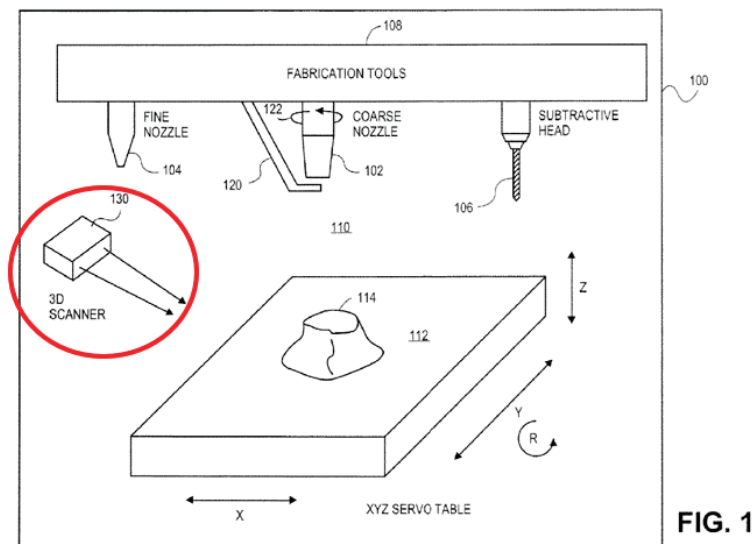


EX1005, FIG. 1.

Given that the fabrication of the three dimensional object occurs within this “work space 110” a POSITA would have understood that Knighton’s work space 110 is a build volume.

Element [1.a]: a three-dimensional scanner configured to capture three-dimensional information from an object being fabricated within the build volume during a print job executing on the three-dimensional printer;

96. Knighton discloses a three-dimensional scanner with all the functionality disclosed in this claim element. As shown in Figure 1 the embodiment of the Knighton apparatus includes “a three dimensional scanner within the housing 100 to scan the object 114 during fabrication.” EX1005, 2:31-40.



EX1005, FIG. 1. This scanner can be used to “perform interleaved scanning of the partial fabrication during the fabrication” with the fabrication process “adjusted based on the scan results.” *Id.*, Abstract. As disclosed in Knighton, the fabrication process is a “print job” wherein a “three dimensional printer” fabricates “a three dimensional object from a digital model” by depositing material. *Id.*, 1:13-17, 1:57-2:30, 2:62-67. During the fabrication process, the scanner “may use laser

ranging to create the three dimensional model of the work in process 114” which “permits the fabrication process to be adjusted responsive to identification of variance in the fabricated object 114 from the intended object as reflect in the digital model.” *Id.*, 2:31-40.

Element [1.b]: a machine vision system configured to capture and analyze image content from the three-dimensional scanner, thereby providing a status of the print job executing on the three-dimensional printer;

97. As I described above, Knighton discloses a “three dimensional scanner 130” within the “housing 100 to scan the object 114 during fabrication. EX1005, 2:31-34. The Knighton apparatus further describes a “control subsystem” which includes a “controller 200” which interacts with the “three dimensional scan head 204, and monitoring software 202. *Id.*, 2:62-67, FIG. 2. The “scan head 204” shown in Knighton Figure 2 is also physically depicted as part of the 3D scanner 130 in Figure 1, as shown above. *Id.*, FIG. 1, FIG 2.

98. During the fabrication process, the “controller 200 may periodically initiate a scan of the partial object using scan head 204.” *Id.*, 3:1-2. “The resulting scan data may be provided to the monitoring software module 202, which may conduct and analysis.” *Id.*, 3:1-4. This “monitoring software 202 may perform comparison of existing source model relative to what has been built in the partial object. *Id.*, 3:4-7. “The comparison may reflect a need to modify one or more

aspects of the build, or do additional additive or subtractive detailing.” *Id.*, 3:7-10.

This “scan of the partial object is analyzed relative to, for example, the model on which the fabrication is based to evaluate if changes should be made ot the fabrication process concurrently.” *Id.*, 3:36-45.

99. Furthermore, in some embodiments, “the intermediate scanned model may be analyzed to determine whether corrective measures may be deferred until later in the fabrication process where such deferral would improve the efficiency of the fabrication.” *Id.*, 2:41-52. An “evaluation” may be undertaken to “determine whether such additional detailing may be deferred.” *Id.*, 3:9-10. Knighton describes that the “deferral of the detailing should be undertaken . . . where such deferral makes the overall fabrication more efficient.” *Id.*, 3:11-27. “For example, where deferral of detailing reduces the number of movements the object must undergo in the process.” *Id.*

100. Similarly, and as described above, Anderson discloses a system wherein an “interface controller 104 is configured to control the graphical user interface 108 such that portions of the wireframe model representations of the three-dimensional object(s) ae filled in to provide a visual indication of the percentage of three-dimensional object(s) fabrication completed. EX1012, [0019], FIGs. 1-2A. Anderson further discloses “[v]arious other graphical representations

of three-dimensional object fabrication progress (e.g., providing an eye-catching visual representation.”) *Id.*, [0021]. For example, a “model representation” may indicate when a fabrication is “is 60% completed.”

101. As I addressed above in the predictable Knighton-Luo-Anderson combination, Knighton’s disclosure of comparing the “existing source model relative to what has been built in the partial object” would have included determining the completion percentage of the three-dimensional object based on disclosure in Anderson. EX1005, 3:4-7; EX1012, [0019], [0021], [0025], FIGs. 1-2A. A POSITA would have understood that Knighton’s “controller 200” and monitoring software module 202” would work in conjunction with the 3D scanner to “conduct an analysis” of the scanned model versus the source model (i.e. a STL file). This predictable understanding of Knighton in light of Anderson would provide a machine vision system. EX1005, 3:1-10, 3:39-57, 4:63-67.

Element [1.c]: a network interface configured to couple the three-dimensional printer in a communicating relationship with a data network; and

102. Knighton, in a predictable combination with Luo and Anderson, discloses this element. As illustrated in Figure 1 of Luo, Luo’s system provides a solution wherein a “remote user” can utilize “a general-purpose computer and a World Wide Web browser” to communicate with a “WWW server” at the location

of “thermal extrusion rapid prototyping machine” (i.e. the 3D printing apparatus) to control the apparatus. EX1006, 1-3, FIG. 1.

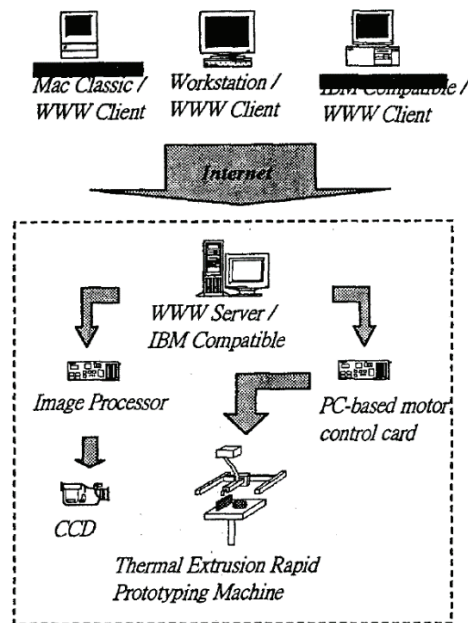


Figure 1. The Hardware Configuration of The Automated Tele-Manufacturing System.

EX1006, FIG. 1. As illustrated in Figure 1, Luo further suggests the use of multiple processors, including an “image processor” and “PC-based motor control card” on a “general-purpose computer [which] is used as a server which receives [a] client’s request” over the internet. *Id.*, 1-2, FIG. 1. The “WWW server is responsible for the commands sent from [a] remote user” and “can transmit the image data through [the] Internet to the remote Web browser.” *Id.*, 3. In this way, Luo specifically discloses bi-directional network communication between the WWW

server/controller, local to the 3D printing apparatus, and the remote computer via the Internet. *Id.*, 1-4.

103. As with Knighton's control system, described above, Luo's WWW server is to "control the rapid prototyping machine." *Id.* As I described above regarding the Knighton-Luo-Anderson combination, a POSITA would have been motivated to apply Luo (and Anderson's) suggested improvements to the Knighton system to implement WWW server capabilities. In fact, by the time frame leading up to 2010, conventional controllers were even more sophisticated and powerful such that web server functionality in a local controller subsystem would have been predictable in light of Luo's suggestion.

104. Furthermore, as I addressed above, Luo expressly suggests bi-directional network communication. The predictable combination with Knighton would include a conventional network connection at the improved Knighton controller so that Knighton's controller accomplished internet connectivity. Even if Luo did not specifically address a conventional network interface, it would have been predictable to implement Knighton's controller (with Luo's WWW server functionality) with an ordinary network interface to achieve the advantage of Internet communication via the server/controller. In fact, Luo specifically illustrates the use of the Internet as part of controlling the 3D printing apparatus.

EX1006, FIG. 1. As a POSITA would have been aware, and as evidenced by Luo's suggestion of using a "general-purpose computer" as a "server" to further connect to the "Internet" in 1999, a network interface for a computing device was widely available off-the-shelf by the relatively late timeframe leading up to 2010. Thus, it would have been straightforward to integrate the Knighton controller for the 3D printing apparatus, modified in light of Luo, with a network interface.

Element [1.d]: a web server configured to transmit the status of the print job for display at a remote client through the network interface.

105. As I described above, Luo expressly describes a bi-directional network communication between the WWW server/controller and the remote computer through the "Internet. EX1006, 1-3. This functionality, when predictably applied to Knighton's 3D printer, discloses this element, especially when the additional teachings of Anderson are further applied to the combination. Luo's system is specifically designed to achieve the advantageous feature of allowing a local "WWW server" using a "general-purpose computer" to "control" the 3D printing apparatus and provide "Internet" communications with remote users. *Id.*, 1-3, FIG. 1.

106. As shown in Figure 3, Luo shows that an aspect of the communication between the “WWW server” and the remote user is the inclusion of a “user interface.” EX1006, 3, FIG. 3.

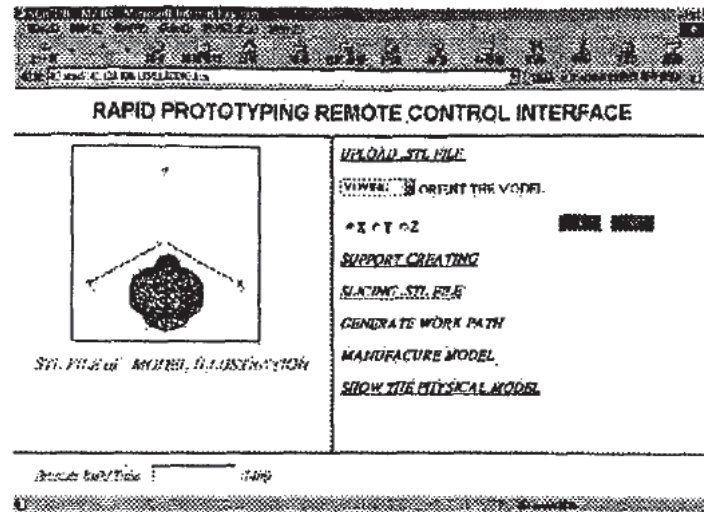


Figure 3. The User Interface for Remote Control of Rapid Prototyping System.

EX1006, FIG. 3. The Luo user interface shown to the user through their “Web Browser” includes status information such as “Estimate Building Time of Physical Model” and an “Image of the Physical Model in the Process Control Window.” *Id.* As I discussed above in the predictable Knighton-Luo-Anderson combination, it would have been a predictable to combine Knighton’s controller with a web server to achieve the interaction with remote users. Furthermore, in this predictable combination, the “Image of the Physical Model” would have included a visual representation of “the three dimensional model of the work in process 114” using

the information obtained from Knighton's "three dimensional scanner 130 . . . scan[ning] the object 114 during fabrication." EX1005, 2:31-40. This would provide a predictable solution to the problem described in Knighton where "anomalies or inconsistencies within the build process cannot be identified, while the processing is occurring." EX1005, 1:29-36.

107. This predictable combination, and the advantages provided by such combination, is further supported by Anderson's express suggestions. Anderson specifically describes an "interface controller 104" which provides "a visual representation of progress of the three-dimensional object(s) fabrication in the form of one or more progressively filled-in wireframe model representations of the three-dimensional object(s)." EX1012, [0017], [0020], [0026]. As discussed in Anderson, the status information provided by this visual representation can include a numeric percentage "pertain[ing] to the progress of the three-dimensional object(s) fabrication." *Id.*, [0019]. For example, such visual representations take the forms "(such as 05, 25%, 50%, 75% and 100% completion)" or a model showing fabrication "which is 60% completed." *Id.*, [0021], [0025], FIG. 2A.

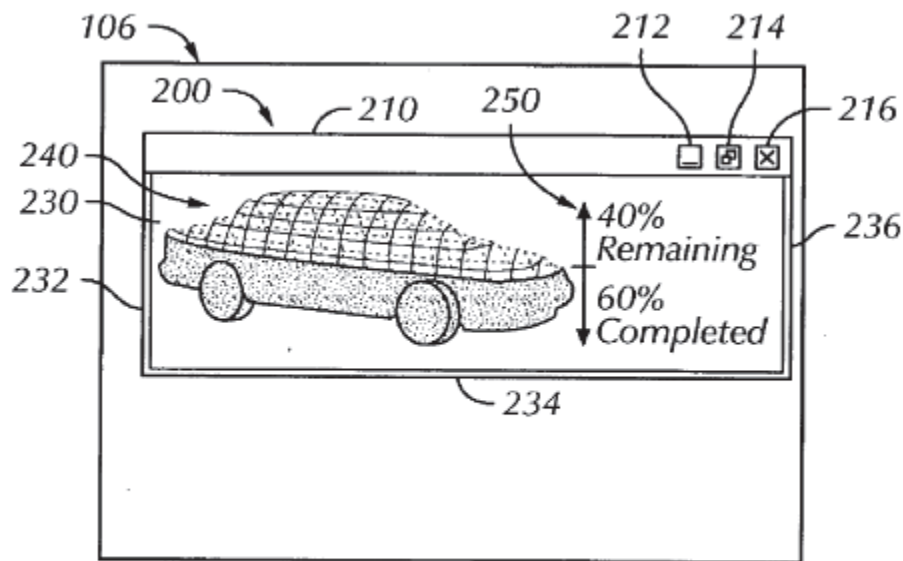


FIG. 2A

EX1012, FIG. 2A. Based on Patent's Owners contentions, displaying a numerical percentage of a print job's completion and visual representation of this progress both fall within the scope of this claim element. EX1016, 18.

108. In combination with the wireframe model and numeric percentage of completion disclosed in Anderson, Knighton's controller would have displayed the wireframe and progress information as part of its "three dimensional model of the work in process 114." EX1005, 2:31-40. Furthermore, Luo's teachings evidence that a user of a remote computer could view the user interface with a generic "Web Browser" and would not require "special software." EX1006, 1, 3, 6. Thus, a POSITA would understand that the status information presented by Knighton's

controller, in predictable combination with Luo, would be generated and transmitted by the controller/web server. This would allow the status information to be displayed to the user without requiring any “special software” on the user’s end of the system. EX1006, 1, 3, 6.

Claim [2]: The system of claim 1 wherein the three-dimensional printer is a fused deposition modeling printer.

109. Knighton describes a fused deposition modeling printer. Furthermore, even if Knighton did not disclose fused deposition modeling, this would have been a predictable implementation in light of the Knighton-Luo-Anderson combination. Knighton specifically describes “fabrication tools” to deposit a fabrication material” and fabricate a “three-dimensional object.” EX1005, 1:57-2:24, 4:27-39. Knighton’s description would be understood by a POSITA as fused deposition modeling. Additionally, and in the alternative, Anderson specifically discloses “fused deposition modeling (FDM)” as a type of 3D fabrication technique. EX1012, [0016].

110. Knighton specifically contemplates “various modifications and changes” that could be made “without departing from the broader spirit and scope of the invention.” EX1005, 4:18-25. Furthermore, as evidenced by the specific mention of “fused deposition modeling (FDM)” in Anderson, FDM was a well-

known deposition technique prior to 2010. EX1012, [0016]. As such, even to the extent that Knighton does not specifically mention FDM by name, a POSITA implementing the Knighton-Luo-Anderson combination would have included FDM capability. This would have increased the applicability of the improvements described in Knighton, Luo, and Anderson to encompass a wider range of rapid fabrication systems. Implementing FDM in Knighton's system would have been implementing a known technique with known advantages without the need for undue experimentation.

Claim [4]: The system of claim 1 wherein the web server is configured to host a remote user of the three-dimensional printer through the network interface.

111. Luo specifically describes a web server configured to host a remote user through a network interface and, thus, the predictable Knighton-Luo-Anderson combination describes this element. As illustrated in Luo, a "remote user" uses "a general-purpose computer" which "is used as a server which receives [the] client's request from remote world wide network." EX1006, 1, FIG. 1.

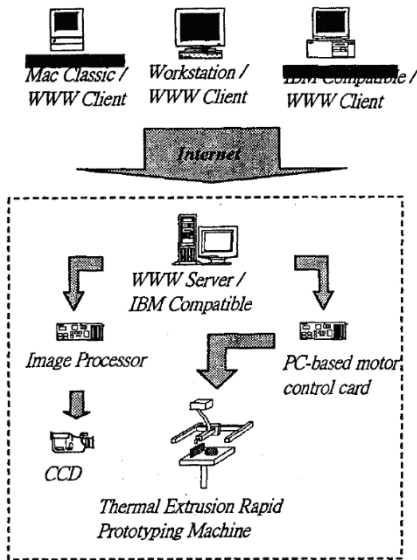
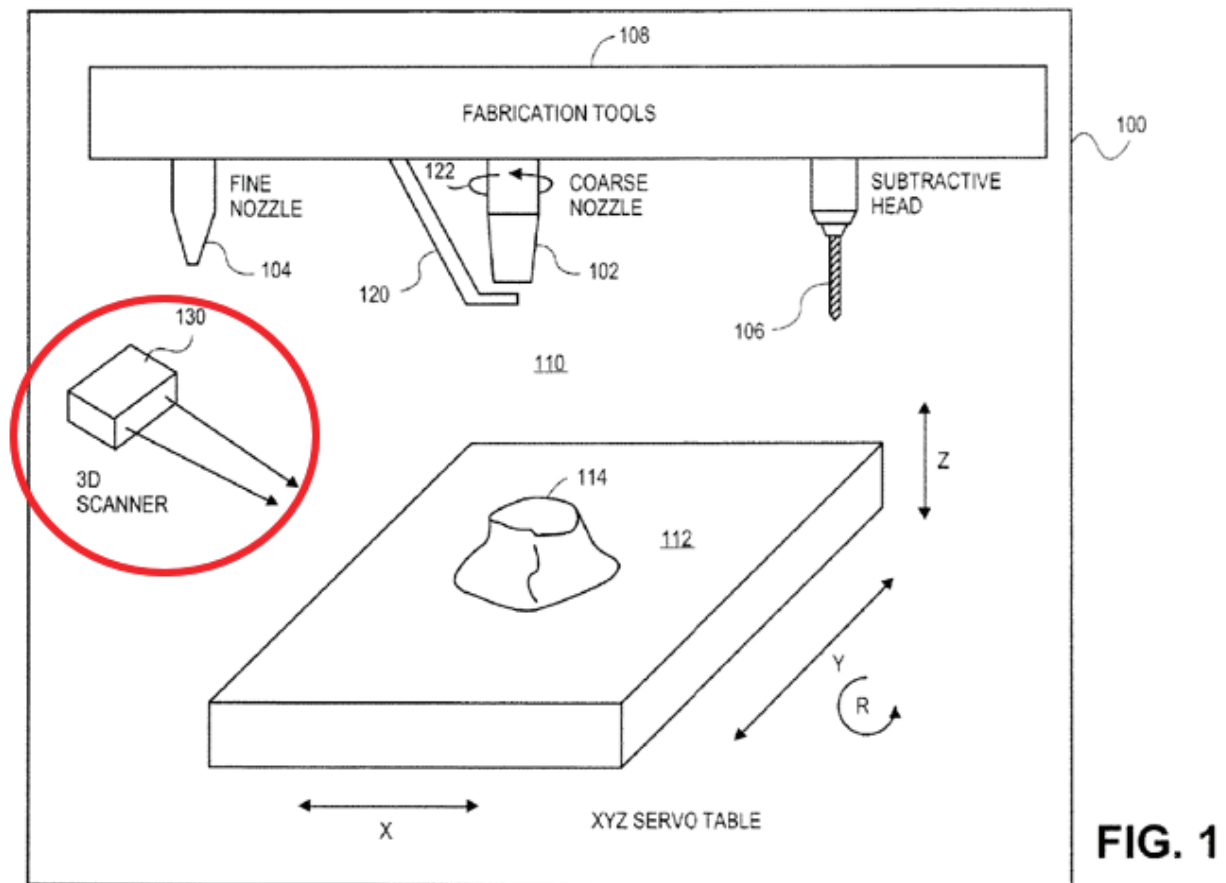


Figure 1. The Hardware Configuration of The Automated Tele-Manufacturing System.

EX1006, FIG. 1. This system “allows users to directly control our rapid prototyping machine via the Internet.” EX1006 3, 6. Thus, the Knighton-Luo-Anderson combination would specifically include a web server designed to host a remote user and control the prototyping apparatus as specifically disclosed in Luo and to implement the advantages of network communication.

Claim [5]: The system of claim 1 wherein the web server displays status information from one or more sensors of the three-dimensional printer

112. The predictable Knighton-Luo-Anderson combination describes this element. As illustrated in Figure 1 of Knighton, as part of the 3D printer apparatus, Knighton includes “a three dimensional scanner 130 . . . within the housing 100 to scan the object 114 during fabrication.” EX1005, 2:31-40, FIG. 1.



EX1005, FIG. 1. The 3D scanner is illustrated as part of the 3D printing apparatus and collects information “to create the three dimensional model of the work in process 114.” *Id.*, 2:31-40. As such a POSITA would have understood the Knighton’s 3D scanner 130 is a sensor of the three-dimensional printer.

113. Additionally, as I discussed above, Luo includes an “Image or the Physical Model in the Process Control Window” as part of its “user interface.”

EX1006, 3. In predictable combination with Knighton, the information provided at

the user interface would be in the form of the “three dimensional model of the work in process” created using information from Knighton’s 3D scanner. EX1005, 2:31-40.

114. Furthermore, Anderson discloses displaying a numerical and/or wireframe representation of the percentage of fabrication completion. EX1012, [0019], [0021], [0025]. This interface is further illustrated in Figure 2A of Anderson:

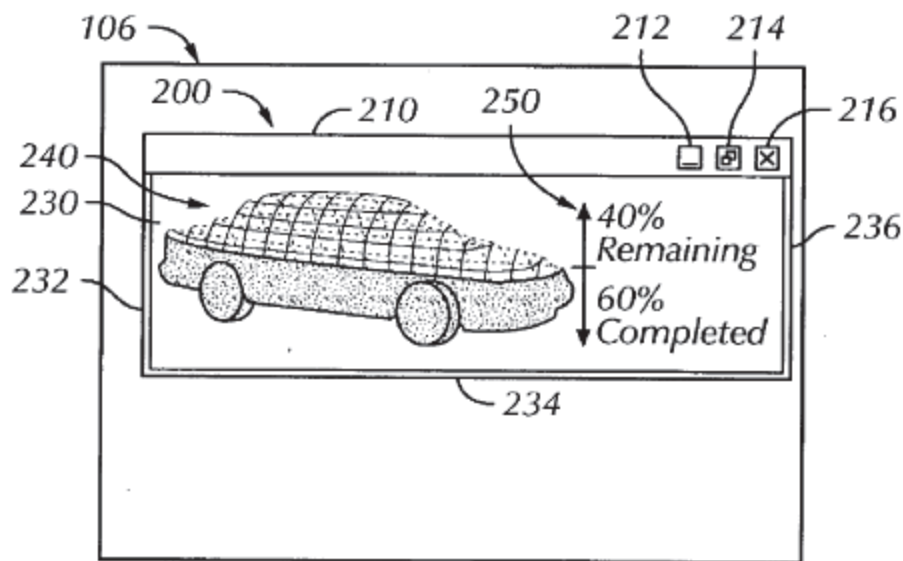


FIG. 2A

EX1012, FIG. 2A. Thus, the predictable Knighton-Luo-Anderson combination would include the information obtained by Knighton’s 3D scanner (a sensor of the

3D printer) to display percentage completion (i.e. printer status) suggested by Anderson in a user interface as described by Luo.

Claim [9]: The system of claim 1 wherein the machine vision system provides automatic inspection of the object being fabricated within the build volume.

115. This claim is specifically described in Knighton. Knighton's "[d]uring fabrication" the Knighton "controller 200 my periodically initiate a scan of the partial object using scan head 204." EX1005, 3:1-7. The Knighton system then performs a "comparison of existing source model relative to what has been built in the partial object." *Id.*, 3:4-7. This comparison is used to identify "variance in the fabricated object 114 from the intended object" identify if there is "a need to modify one or more aspects of the build, or do additional additive or subtractive detailing," and if "such additional detailing may be deferred." *Id.*, 3:4-13, 2:31-37.

Claim [10]: The system of claim 1 wherein the machine vision system provides a robotic guidance function for the three-dimensional printer.

116. The machine vision system described in Knighton describes this claim. In Knighton, "a scan of the partial object using scan head 204" is used to identify "variance in the fabricated object 114 from the intended object" determine whether there is "a need to modify one or more aspects of the build, or do additional additive or subtractive detailing" or to implement "corrective measures." EX1005, 2:31-43; 3:4-13. In addition to necessitating "additional detailing"

“variations between the intended design reflected in the source model and what has actually been created” may necessitate “changes in the calibration of the system.” *Id.*, 3:46-53. As described in Knighton, the corrective measures can encompass “additional additive . . . detailing” including additional deposition using the “fine nozzle 104.” *Id.*, 2:41-52. This additional detailing would involve determining the “movements” for the robotic systems which includes controlling “servo drives to drive notions 210, 212, 214, and 216 to drive the relative motion between the work surface...and the fabrication tools” in the x, y, and z axes. *Id.*, 3:7-27. For example, “motor 210 controls x motor, motor 212 controls y motor, motor 214 controls z motor and motor 216 controls rotation.” *Id.* Based on Patent Owner’s infringement contentions, descriptions of controlling the robotic guidance of the fabrication device in order to make corrective depositions based on variance/errors “to guide the printer when there is an error” satisfies this claim. EX1016, 38-42.

Claim [12]: The system of claim 1 wherein the machine vision system provides error detection for the object being fabricated within the build volume.

117. The machine vision system described in Knighton provides error detection of the object being fabricated. Scan information comparing the source model relative to what has been built in the partial object” is used to identify “variance in the fabricated object 114 from the intended object.” EX1005, 2:31-43, 3:4-13. This allows the system to detect “variations between the intended design

reflected in the source model and what has actually been created.” *Id.*, 3:46-53.

The system then determines if there is “a need to modify one or more aspects of the build, or do additional additive or subtractive detailing” or to take other “corrective measures.” *Id.*, 2:31-43, 3:4-13. A POSITA would understand that identifying variances between the intended object and the object being fabricated provides, or at least renders obvious, error detection. This is particularly clear given the Knighton describes taking “corrective measures” in response to these variations.

Claim [15]: The system of claim 1 wherein the machine vision system tracks actual progress of the print job against a predicted progress of the print job.

118. Knighton, in light of the predictable combination with Anderson, provides tracking the actual progress of the print job against a predicted progress. Knighton uses scan information to identify “variance in the fabricated object 114 from the intended object as reflected in the digital model sourcing the data for the fabrication.” EX1005, 2:31-40. Knighton further describes performing a “comparison of existing source model relative to what has been built in the partial object.” Similarly, Anderson describes tracking the actual progress of the print job against the predicted progress. EX1012, FIG. 2A, [0017], [0019]-[0021], [0025]-[0026]. This information is then displayed in the user interface as illustrated in Figure 2A:

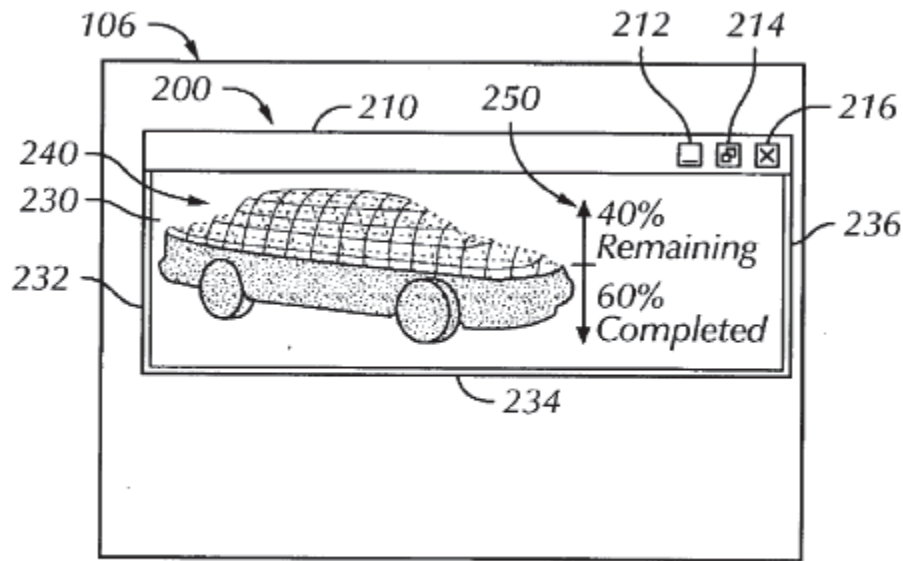


FIG. 2A

EX1012, FIG. 2A. The predictable combination of Knighton's vision system, with the actual and real progress information described in Anderson would provide for the predictable advantage of using the sensor described in Knighton to provide the actual progress of the print job in comparison to the predicted progress remaining.

Claim [16]: The system of claim 1 wherein the machine vision system compares an actual three-dimensional result in the build volume with an expected three-dimensional result based upon a source model.

119. Knighton directly provides for this claim. Scan information in Knighton's machine vision system is used to identify "variance in the fabricated object 114 from the intended object as reflected in the digital model sourcing the data for the fabrication." EX1005, 2:31-40. The Knighton system subsequently

performs a “comparison of existing source model relative to what has been built in the partial object.”

Claim [18]: The system of claim 16 wherein the machine vision system is configured to detect a misalignment of layers.

120. As I have described above, Knighton’s machine vision system detects errors in the form of “variance in the fabricated object 114 from the intended object.” EX1005, 2:31-40. The system compares the existing source model relative to what has been built and determines whether “corrective measures” need to be taken. EX1005, 2:31-43; 3:4-13, 3:46-53.

121. Additionally, Knighton specifically mentions taking actions such as “performing subtractive detailing before addition of a subsequent layer.” Luo also describes processing the deposition “layer by layer” and Anderson addresses “layer additive technique[s].” EX1006, 1; EX1012, [0001]-[0004]. Given the reliance on layers throughout the 3D fabrication process, a POSITA would understand that Knighton’s error detection would include the detection of misalignment of layers. Thus, the predictable Knighton-Luo-Anderson combination would be directly configured to detect the misalignment of layers.

Claim [19]: The system of claim 16 wherein the machine vision system is configured to detect an unexpected surface hole.

122. As I described above relating to Knighton's machine vision system, Knighton specifically discloses variations between the object being fabricated and the expected result. Knighton's system detects errors in the form of "variance in the fabricated object 114 from the intended object" and system compares the existing source model relative to what has been built to determine whether "corrective measures" need to be taken. EX1005, 2:31-43; 3:4-13, 3:46-53. A POSITA would have understood that detecting "variance in the fabricated object 114 from the intended object" would have provided, or at least rendered obvious, detection of "unexpected surface holes" (i.e. holes on the surface of the fabricated object that were not in the source model). As a result, the predictable Knighton-Luo-Anderson system would be configured to detect an unexpected surface hole as a result of the error detection system described by Knighton.

7.2. Ground 1B: The Combination of Knighton-Luo-Anderson with Mamoto Renders Obvious Claim 3

123. A POSITA would have recognized the teachings of Mamoto could be readily applied to the Knighton-Luo-Anderson combination to achieve predictable results. Mamoto specifically addresses a "three-dimensional object generating system" which, similar to Luo, "is connected to a network 10 such as the Internet." EX1007, [0031]. The Mamoto system specifically describes using a "laser stereolithography device 21" and "a monitoring camera 22 for imaging the

operating conditions of the laser stereolithography device.” *Id.*, [0032]. Mamoto also describes using “3D data (STL (Stereo Lithography) data) representing the three-dimensional object.” *Id.*, [0043].

124. A POSITA would have known to implement the Knighton-Luo-Anderson combination with the teachings of Mamoto such that Knighton’s 3D printing apparatus included a stereolithography printer to take advantage of the scanning and analysis techniques described by Knighton, the remote control and user interface described by Luo, and the status information disclosed by Anderson. This combination would allow for the advantages of the combination to be applied with a wider variety of fabrication devices. Furthermore, like Mamoto, Luo specifically describes users uploading “STL (stereolithography Interface) files of models they have designed.” EX1006, 1. Knighton also contemplates “various modifications and changes” that could be made “without departing from the broader spirit and scope of the invention.” EX1005, 4:18-25. Thus, it would have been obvious to a POSITA to expand the techniques described in the Knighton-Luo-Anderson combination to stereolithography printers.

125. A stereolithography printer (as suggested by Mamoto) also has a benefit in printing more complex geometries because the laser-curing of the liquid resin would achieve higher resolution and smoother surface finishes, particularly

along curved surfaces. A POSITA would have been aware that stereolithography fabrication has a much better surface quality than Fused Deposition Modeling and is therefore employed as an advantageous form of rapid fabrication when the goal of the fabricated item is to produce a visually pleasing item or a casting in which a smooth surface is desirable. As such, implementing this type of printer would be beneficial for parts that are intended as visual props, decorative items, or for casting, such as jewelry. Thus, a POSITA would be motivated to implement the local printing apparatus of the predictable combination as a stereolithography printer to achieve this conventional benefit. A POSITA would recognize this implementation as the predictable application of known techniques, to a known system ready for improvement, to yield predictable results.

Claim [3]: The system of claim 1 wherein the three-dimensional printer is a stereolithography printer.

126. As I described above, Mamoto specifically provides using a “laser stereolithography device 21” as its “three-dimensional object generating system.” EX1007, [0031]-[0032]. A POSITA would have understood applying the stereolithography printer suggested to the Knighton-Luo-Anderson combination. Thus, the predictable combination, in light of Mamoto provides for the three-dimensional printer including a stereolithography printer.

7.3. Ground 1C: The Combination of Knighton-Luo-Anderson with Crampton Renders Obvious Claim 8

127. Multiple reasons would have motivated a POSITA to modify the system of Knighton-Luo-Anderson to implement or augment the scanning functionality in the predictable combination with the functionality of structured light described by Crampton. Similar to Knighton, Crampton describes implementing “a scanning apparatus for scanning an object to provide a computer model thereof.” EX1009, 5:58-67. Campton directly discloses using “structured light to more quickly scan the surface of the object.” *Id.*, 6:8-9. This structured light technique carries a further benefit of “sens[ing] the colour of the surface of the object, resulting in a model more like the real world object.” *Id.*, 6:1-11.

128. The Knighton system describes using “laser ranging to create the three dimensional model of the work in process 114.” EX1005, 2:37-39. Knighton also addresses that additional scanning techniques could be implemented in its system, stating, “[o]ther scanning methods are also within the scope and contemplation of the invention. EX1005, 2:37-40. A POSITA would have understood to either implement Knighton’s 3D scanner using a structured light technique as suggested by Crampton or alternatively to implement an additional scanner using this technique. This would have resulted in a POSITA applying a known technique

with understood advantages to a known system to yield the predictable results of increasing the information obtained from scanning the fabricated object.

Claim [8]: The system of claim 1 wherein the three-dimensional scanner obtains three-dimensional data using structured light techniques

129. As I discussed above, Crampton directly provides for using a three-dimensional scanner to obtain three-dimensional data using a structured light technique. EX1009, Abstract, 5:58-67, 6:1-11. A POSITA would have been motivated to implement the structured light technique into the predictable Knighton-Luo-Anderson combination. Thus, the improved combination would directly provide for this claim.

7.4. Ground 1D: The Combination of Knighton-Luo-Anderson with Chandhoke Renders Obvious Claim 11

130. A POSITA would be motivated to modify the Knighton-Luo-Anderson combination to implement a pass/fail evaluation as suggested by Chandhoke to achieve the known benefits and avoid wasting time or material on a failed object fabrication. Knighton describes using a 3D scanner to identify defects in the fabricated object by detecting “variance in the fabricated object 114 from the intended object.” EX1005, 2:31-43. The Knighton system then determines whether there is “a need to modify one or more aspects of the build, or do additional additive or subtractive detailing” or to implement other “corrective measures.” *Id.*,

2:31-43, 3:4-13. However, this technique assumes that any defects or errors in the fabricated object can be corrected.

131. A POSITA would have understood that in some situations, defects in a fabricated object would be sufficiently severe such that the defects could not be corrected through additive or subtractive detailing. In such a situation, making additional depositions or removing material would be insufficient to correct the fabricated project and any attempts would simply amount to a waste of time and resources. Having the machine vision system provide an automatic pass/fail evaluation (as suggested by Chandhoke) would allow for the fabrication process to be stopped either by the system or by a remote user once an unrecoverable defect is detected. This would provide a known advantage of avoiding the waste of time, deposition material, and power consumption on an unsalvageable project. This would also provide the additional benefits of avoiding unnecessary wear on the Knighton fabrication apparatus and tools. Additionally, a POSITA would understand that some defects may not be readily detectable with the naked eye and human quality inspection may not identify the defect. A pass/fail evaluation would allow the system to identify such minute, yet unrecoverable defects, and minimize the potential for defective products to be put into circulation or used for other purposes.

Claim [11]: The system of claim 1 wherein the machine vision system provide a pass/fail evaluation of the object being fabricated within the build volume.

132. Implementing the techniques of Chandhoke, in combination with the Knighton-Luo-Anderson system, provides this claim. Chandhoke describes “a system and method for configuring a hardware device to execute a prototype.” EX1011, [0015]. The methods disclosed in Chandhoke include “image processing (machine vision) operations for acquiring and analyzing images of an object” using “an image acquisition device.” *Id.*, [0087]. The Chandhoke prototyping environment includes “machine vision, pattern matching, shape matching, or other applications.” *Id.*, [0081]. Once the image of a manufactured object is analyzed, the Chandhoke system can “perform an operation based on this result, such as rejecting a part from an assembly line.” *Id.*, [0125]-[0127]. As an example, Chandhoke describes using the image processing function of the “image acquisition device” to “analyze an image and detect, recognize, or characterize one or more features or characteristics of an object such as . . . possible flaws or lack thereof.” *Id.*, [0173]. Based on this information the “image acquisition device may generate a pass/fail indication after executing to perform the image processing function on the image.” *Id.* Upon determining that the “imaged object is defective” the device may “send a signal, such as a pass/fail indication, to a motion control device which may remove the defective object from the assembly line.” *Id.*,

[0174]. Furthermore, Chandhoke describes that objects may be “inspected for defects” and sorted “according to their defect levels.” *Id.*, [0318].

133. The techniques disclosed in Chandhoke directly provide a pass/fail evaluation of an object being fabricated. Implementing the techniques disclosed in Chandhoke with the 3D printing apparatus of the Knighton would lead to the predictable resulting of using Knighton’s scanner and defect detection to determine when a defect is too severe to salvage using corrective measures. As such, the Knighton-Luo-Anderson system, in combination with Chandhoke, provides this claim.

7.5. Ground 1E: The Combination of Knighton-Luo-Anderson with Ridley Renders Obvious Claims 13-14

134. Multiple reasons would have motivated a POSITA to modify the system of Knighton-Luo-Anderson to modify Knighton’s machine vision error detection system to include an audible and/or visual alert when an error is detected based on the suggestions of Ridley.

135. As a first reason, providing an audible and/or visual alert in conjunction with Knighton’s machine vision error detection system would helpfully alert the user that the printing apparatus is taking additional actions that were not part of the original fabrication process. As discussed in Ground 1A,

above, Knighton discloses that in the Knighton-Luo-Anderson combination, the machine vision system detects errors in the form of “variance in the fabricated object 114 from the intended object” which may require “corrective measures.” EX1005, 2:31-43; 3:4-13, 3:46-53. Providing an alert to the user would inform the user that the machine may be performing “additional additive or subtractive detailing” that may not have been part of the original process in order to correct the error.

136. As a second reason, alerting the user that an error has been detected allows for user to visually inspect the object being fabricated. This would provide the opportunity for additional quality control either by direct visual inspection by the user or by visual inspection by someone onsite and the fabrication location. This not only permits a human determination regarding whether the error is severe or minor, but would also draw attention to the fact that there was an error in the fabrication of this particular object. Thus, additional steps can be taken to ensure the final quality of the fabricated object.

137. As a third reason, an audible and/or visual alert would inform the user that the fabrication process may take longer than originally anticipated. By informing the user an error has been detected, and thus the additional steps will need to be performed, the user is also informed that the fabrication process will

likely take longer than planned. This permits the user to reschedule other tasks that may be dependent on the completion of the fabrication and to mitigate the impact of the resultant delays.

138. *As a fourth reason*, alerting the user that an error has been detected allows the user to make a decision regarding whether the fabrication process should be aborted. A user could determine whether the resulting delays or potential for lower quality in the final product is such that the fabrication process should be aborted entirely or restarted from scratch. This would allow a user to make real-time risk assessment regarding the fabrication process based on the occurrence of defects.

Claim [13]: The system of claim 12 wherein the machine vision system creates an audible alert when an error is detected.

139. Ridley demonstrates that in the resulting Knighton-Luo-Anderson-Ridley combination, the machine vision error detection system of Knighton's printer apparatus creates an audible alert when an error is detected. This is demonstrated, for example, by Ridley's system which outputs "a sensible output for providing an indication of a damaged or missing [part]." EX1014, [0021]. This output includes "an audible alarm, or any other type of output which may be sensed by a person or apparatus." *Id.* In another similar example, Ridley

demonstrates that in the Knighton-Luo-Anderson-Ridley combination whenever a portion of the object being fabricated is “is partially or completely broken or missing, the system automatically alerts the [user] by a sensible output.” EX1014, [0082]. Thus, the system operator is quickly alerted to a detected defect, error, or break. *Id.*, [0083]. A POSITA would have recognized that the audible alarm described by Ridley, in combination with the Knighton error detection system, satisfies claim 13.

Claim [14]: The system of claim 12 wherein the machine vision system creates a visual alert when an error is detected.

140. Ridley demonstrates that in the resulting Knighton-Luo-Anderson-Ridley combination, the machine vision error detection system of Knighton’s printer apparatus creates a visual alert when an error is detected. As I described above in relation to claim 13, Ridley’s system outputs “a sensible output for providing an indication of a damaged or missing [part].” EX1014, [0021]. This output may include “a visual display.” *Id.* As one example, when a broken or damaged part is detected “the system automatically alerts the [user] by a sensible output in the form of a visual alarm on a touch screen monitor.” *Id.*, [0082]-[0083]. A POSITA would have recognized that the visual alarm described by Ridley, in combination with the Knighton error detection system, satisfies claim 14.

7.6. Ground 1F: The Combination of Knighton-Luo-Anderson with Mazumder Renders Obvious Claim 17

141. Multiple reasons would have motivated a POSITA to modify the system of Knighton-Luo-Anderson to include the termination of the fabrication process when an unrecoverable error is detected based on the suggestions of Mazumder.

142. As a first reason, the termination of the fabrication would expand upon the corrective actions available to the Knighton machine vision error detection system. As discussed in Grounds 1A and 1D above, Knighton expressly describes comparing the scan data of the object being fabricated compared with the desired object and taking “corrective measures” in response to the detection of errors in the fabricated objection. EX1005, 2:31-43; 3:4-13, 3:46-53. Mazumder describes that one of the corrective actions that could be taken includes the “termination of the deposition process” if necessary. EX1004, 6:24-35. Thus, the Knighton system would have the additional option of terminating the fabrication if additional additive or subtractive measures would not be sufficient to correct the detected error. EX1005, 2:31-43; 3:4-13, 3:46-53.

143. As a second reason, Mazumder discloses that some of the sensors implemented to detect a “failure criteria” are “optical sensors 50” EX1004, 5:37-

39, 6:10-12. The sensor disclosed in Knighton is a 3D scanner with is simply an optical sensor. EX1005, 2:31-43; 3:4-13, 3:46-53. Thus, the hardware implemented by Mazumder is already included in the Knighton printer apparatus. Using the techniques suggested by Mazumder would merely require that the 3D scanner be given a “failure criteria” based on the information that is already being gathered.

144. As a third reason, similar to the benefits I discussed in Ground 1D above, automatic termination of the fabrication process would assist the user in saving time and resources that would otherwise be wasted on an unsalvageable fabrication project. Certain errors may not be remedied by additional additive or subtractive corrective measures. In this event, it would be beneficial to avoid using deposition materials, production time, and power consumption on a fabrication object that will not meet the required standards. Additionally, this would cause unnecessary wear on Knighton’s fabrication tools. Automatic termination of the fabrication process would help the user mitigate any wasted resources.

Claim [17]: The system of claim 16 wherein the machine vision system is configured to abort a fabrication process of the three-dimensional printer upon detection of an unrecoverable error in the fabrication process.

145. Mazumder demonstrates that in the resulting Knighton-Luo-Anderson-Mazumder combination, the Knighton machine vision system is configured to abort a fabrication process upon detection of an unrecoverable error

in the fabrication process. In Mazumder, sensor data is gathered during the fabrication process and compared “with pre-determined failure criteria.” EX1004, 6:10-13. Depending on the results of the failure analysis, “the local computer. . . sends an electronic signal to the remote computer for online control, or sends appropriate commands to a feedback controller 80.” *Id.*, 6:18-23. In response, the system “initiates corrective action, such as termination of the deposition process.” *Id.*, 6:24-35. A POSITA would have recognized that this termination of the deposition process in response to identified failure criteria satisfies claim 17.

7.7. Ground 1G: The Combination of Knighton-Luo-Anderson with Biton Renders Obvious Claim 18

146. Multiple reasons would have motivated a POSITA to modify the system of Knighton-Luo-Anderson to include the specific detection of misalignment of the fabrication layers based on the suggestions of Biton.

147. As a first reason, Knighton’s machine vision system already detects errors based on the “variance in the fabricated object 114 from the intended object” and takes “corrective measures” to correct such variance. EX1005, 2:31-43; 3:4-13, 3:46-53. To the extent that the error detection in Knighton does not use the specific term “misalignment of layers,” it would have been obvious to a POSITA to consider the misalignment of layers as one of the “variances” that the Knighton

system should detect based on Biton's suggestion. As described by Biton, "once the misalignment is measured, the system manager may shift the coordinates of the next layer by the proper amount to correct of the misalignment." EX1008, [00118]. [00119]. Implementing the detection of misalignment would merely require including misalignment as a variance that the Knighton system is set to detect during the fabrication process.

148. As a second reason, a POSITA would have been motivated to implement the suggestion of Biton with Knighton's system to add to the "corrective measures" that could be taken to minimize any issues with "variance" in the fabrication process. Biton's suggestion allows for correction based on misalignment to ensure that any error accumulation is "negligible" and enable fabrication of "numerous layers and delicate features in a highly accurate manner." EX1008, [0118]. Implementing Biton's suggestion in the Knighton system would lead to the advantage of providing additional corrective measures that Knighton could utilize to minimize any damages or problems based on detected errors.

149. As demonstrated below, the predictable combination of the Knighton-Luo-Anderson combination and Biton renders obvious claim 18.

Claim [18]: The system of claim 16 wherein the machine vision system is configured to detect a misalignment of layers.

150. Biton demonstrates that in the resulting Knighton-Luo-Anderson-Biton combination, the Knighton machine vision system is configured to detect a misalignment of layers. Biton specifically describes a system for detecting, measuring, and correcting for “misalignment.” EX1008, [00118], [00119]. The system may then “shift the coordinates of the next layer by the proper amount to correct for the misalignment” and the system “enables alignment for every layer (or even sub-layer) fabricated, [and] thus errors accumulation is negligible.” *Id.* A POSITA would have recognized that this detection of layer misalignment satisfies claim 18.

7.8. Ground 1H: The Combination of Knighton-Luo-Anderson with Bakhadyrov Renders Obvious Claim 19

151. Multiple reasons would have motivated a POSITA to modify the system of Knighton-Luo-Anderson to include the void detection technique in order to detect unexpected surface holes based on the suggestions of Bakhadyrov.

152. As a first reason, Knighton’s machine vision system already compares scan data to detect errors based on “variance in the fabricated object 114 from the intended object.” EX1005, 2:31-43; 3:4-13, 3:46-53. To the extent that Knighton does not use the specific term “unexpected surface hole,” as one of the errors that the system detects, a POSITA would understand that it would be obvious and

beneficial to include detecting unexpected surface holes or “voids” based on Bakhadyrov’s suggestion. EX1015, 1-6. The Knighton system is meant to detect the variations in order to identify “corrective measures” such as “additional additive or subtractive detailing” that can be implemented to correct the errors. EX1005 3:4-13. By implementing Bakhadyrov’s image processing techniques for void detection, this would add to the “variance” that the Knighton system could detect and subsequently correct. In the event that the surface holes constitute an unrecoverable error, the Knighton system would also be able to reject the fabricated object and conserve materials if necessary.

153. *As a second reason*, implementing Bakhadyrov’s suggestion in the Knighton machine vision system would increase the efficiency of the inspection process described by Knighton. Bakhadyrov’s techniques make the “inspection process much faster and more affordable.” EX1015, 1, 4. This is accomplished by using “[c]omputation efficient algorithm” to achieve a “quick and precise quality inspection.” *Id.*, 1, 2, 4. Thus, using Bakhadyrov’s techniques with the Knighton machine vision system would result in predictable results of increased efficiency in the fabrication process.

154. *As a third reason*, implementation of Bkhadrov’s void detection techniques to the Knighton-Luo-Anderson combination would have resulted in a

process that “significantly increase[d] the resulting quality” of the objects being fabricated, including “better smoothness” of the surfaces of such objects. EX1015, 4, 1.

155. As demonstrated below, the predictable combination of Bakhadyrov with the Knighton-Luo-Anderson combination renders obvious claim 19.

Claim [19]: The system of claim 16 wherein the machine vision system is configured to detect an unexpected surface hole.

156. Bakhadyrov demonstrates that in the Knighton-Luo-Anderson-Bakhadyrov combination, the machine vision system of Knighton is configured to detect an unexpected surface hole. In particular, Bakhadyrov describes a “machine vision setup” for a “Direct Layered Manufacturing (LM)” system for conducting a “surface quality inspection” of manufactured objects/parts. EX1015, Abstract, 2. This includes the detection of “surface voids” which “on the surface can be characterized as defects.” *Id.*, 2. Bakhadyrov directly describes the “Machine Vision setup has been designed for detection of surface defects (voids) in indirect and ‘zero-offset’ direct LM process.” *Id.*, 4. As a result, the Knighton-Luo-Anderson in predictable combination with Bakhadyrov, directly discloses that the system is configured to detect an unexpected surface hole.

7.9. Ground 2A: The Combination of Mazumder with Bonassar renders obvious claims 1-5, 9-19

157. A POSITA would have recognized that the teachings of Bonassar would have been readily applied to the system of Mazumder for multiple reasons to achieve predictable results. Specifically, a POSITA would have recognized multiple benefits that would have predictably been provided by modifying Mazumder's system based on Bonassar's teachings to include error detection capabilities to Mazumder's optical sensors. A POSITA would have further recognized that by 2010 (over a decade after the original priority date of Mazumder), advances in the conventional technologies of three-dimensional rapid fabrication systems and the detection and correction of errors during the fabrication process had become even more sophisticated and therefore routine to implement.

158. As a first reason, implementing the suggestions of Bonassar would provide improvements to the Mazumder system's ability to correct errors in the fabricated object during fabrication. As described by Mazumder, the system utilizes sensors, such as "optical sensors" to identify "crack initiation, defect formation, and phase transformation, during the fabrication of the product fabrication through laser-aided material deposition." EX1004, 5:37-38, 5:51-63. These sensors send information via a communications system "to determine the need for corrective measures." *Id.*, 2:43-50, 3:26-39. This is accomplished by

comparing the data to “pre-determined failure criteria” *Id.*, 6:10-30. Similarly, Bonassar describes additional details regarding various “machine vision sensing technologies” such as “3D laser scanning.” EX1010, [0104]-[0105], [0110], [0145] This system “compare[s] the state (geometry and other automatically detectable properties) of the simulation” to the model of the object intended to be fabricated “to the state of the real object being produced as measured by 3-D scanning (or other) sensors.” *Id.*, [0097]. The Bonassar system specifically allows for “[d]iscrepancies [to] be remedied by generating modifications to the manufacturing plan which replace or circumvent the error.” *Id.* Implementing the discrepancy detection and remedies suggested by Bonassar in the Mazumder’s system and existing optical sensors would lead to a predictable and advantageous result of allowing the Mazumder system to address additional defects and corrective measures.

159. As a second reason, Bonassar describes detecting “the geometry of the finished product” using a sensor that “is compact enough to embed within material deposition tools near the point of material deposition (e.g. nozzle), and of low enough cost to use in each cartridge, even in multiples.” EX1010, [0104]. A POSITA would recognize the benefit of using low cost sensors to maintain the quality of the finished product while reducing overall costs of fabrication.

160. *As a third reason*, implementing compact sensors which can be embedded “within the material deposition tools” as suggested by would provide the obvious benefit of allowing the sensors to get closer to the object being fabricated, and thus obtain more accurate information, without interfering with the deposition process. As described by Bonassar this “permits the acquisition of the geometry of deposited material with minimal interruption of the fabrication process. . . very near the point of deposition. EX1010, [0104].

161. *As a fourth reason*, the scanning technique described in Bonassar “improves the value of the resulting data for use in feedback control of the deposition tool—geometric flaws in deposited material can be detected quickly, minimally allowing the manufacturing planning software to design compensating material deposits which can be executed in a timely fashion, without compromising the properties of materials which are sensitive to the time since deposition.” EX1010, [0104] This modification would is useful “for online feedback control of the deposition tool—allowing the control law for the tool to adjust tool actuator commands in order to achieve the desired deposit geometry.” *Id.* A POSITA would recognize the benefit of implementing a system that can detect and react to potential errors in the fabricated object quickly. This would not only minimize the any delays caused by additional steps needed to correct errors in

the fabrication but would also minimize that number of errors that may be unsalvageable if they are compounded for too long during the deposition process.

162. As a fifth reason, modifying Mazumder based on the teachings of Bonassar would have “improv[ed] the achievable final quality of the object being fabricated, because it allows the manufacturing planning software to compensate for variability in the properties of the materials being employed, or other deposition errors by automatically generating modified manufacturing plans which compensate for the errors, for instance by depositing material into undesired gaps, or by modifying subsequent deposition paths so that they do not collide with excess material that was accidentally deposited.” EX1010, [0104]. Modifying Mazumder this way would not only increase the overall quality of fabricated objects but also increase the number of errors that could be effectively addressed by the system. This would decrease the number of errors that may result in the entire product being unsalvageable and thus a waste of resources.

163. As a sixth reason, the scanning information described in Bonassar would “provide superior distance resolution, and reduced sensitivity to the reflectivity of the material.” EX1010, [0105]. Implementing this technique in the Mazumder system would result in a predictable increase to the quality of the resulting products.

164. As a seventh reason, a POSITA would have been prompted to modify Mazumder's rapid fabrication system to include the additional scanning and error identification functionality described by Bonassar because doing so would be merely the application of a known technique (as suggested by Bonassar) to a known system (e.g., Mazumder's remotely controlled rapid fabrication system) ready for improvement to yield predictable results. Here, Bonassar provides straightforward evidence of a known technique for obtaining information on the three-dimensional geometry of an object being fabricated in a 3D printer and comparing that scanned information to model data for the object to detect errors, and Mazumder's teaching provides a known system that would have been improved by application of Bonassar's suggested technique for at least the reasons described above. Based upon my knowledge and experience in this field and my review of Mazumder and Bonassar, I am confident a POSITA would have recognized that this modification would have yielded predictable results and required only routine adjustments to the user interface and software to provide the virtual images disclosed by Bonassar and as such a POSITA would have had a reasonable expectation of success in making such modifications. This modification would not have significantly altered or hindered the functions performed by Mazumder's system, and these modifications would have been

within the predictable and ordinary level of skill of a POSITA (certainly by a time frame as late as 2010). Both systems are directed to 3D printers, and Mazumder contemplates the additional “optical sensors” that Bonassar expounds upon.

EX1004, 5:37-38, 5:51-63. Thus, this combination would be based on predictable mechanical components and software and the state of the art at the time.

Element [1.pre]: A three-dimensional printer including a build volume, the three-dimensional printer comprising:

165. To the extent the preamble is considered limiting, Mazumder-Bonassar system discloses the claimed three-dimensional printer including a build volume. Mazumder describes that “[t]he local site includes a laser-aided, computer-controlled direct material deposition system 10, which is used to fabricate, repair or modify three-dimensional products by applying sequentially layers of material 20 on a substrate 30.” EX1004, 3:11-25. In another example, Mazumder describes remote control of “an automated, feedback-controlled, laser-aided direct material deposition (DMD) process, as described in co-owned and co-pending U.S. patent application Ser. No. 09/107,912, filed Apr. 10, 1997, and in U.S. patent application Ser. No. 09/522,671, filed Mar. 10, 2000.” EX1004, 1:62-2:2, 7:39-51.

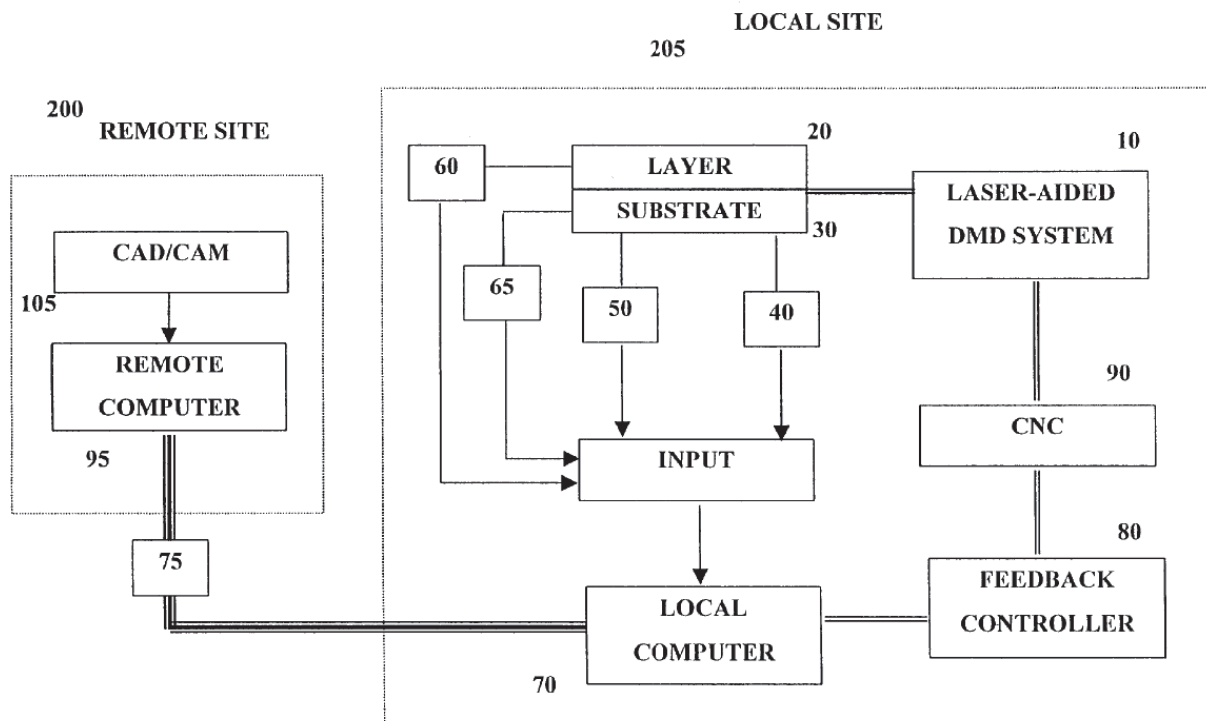


FIG - 1

EX1004, FIG. 1.

166. As shown in Figure 1, a POSITA would have recognized that the substrate and the work space defined by and immediately above the substrate is a build volume. EX1004, 4:7-10.

167. Mazumder's local site 205 further includes "[o]ne or more cameras" that enable "dimensions to be remotely determined from the remote location. Contact and non-contact metrological instruments may also be used to perform accurate measurements to monitor the fabrication process." *Id.* Mazumder

describes this system as a “computer-aided manufacturing system” having a number of “important sub-systems.’ *Id.* 2:3-13, 2:61-62. In another example, Mazumder refers to the local site as “a local manufacturing system for fabricating the product in accordance with the design description using a laser-aided direct material deposition (DMD) process.” 7:5-12, 7:39-51 (“A remote control manufacturing system...”). Mazumder discloses that all functions of the computer-aided manufacturing system at the local site 205 system are “coordinated by the local computer 70” and as such a POSITA would have recognized that the local computer 70 controls the other “sub-systems” to coordinate the 3D manufacturing process. EX1004, 4:32-38. A POSITA would have recognized that the various sub-systems that make up the local site system collectively constitute a device under the control of the local computer 70. *Id.* However, to the extent that this claim element is read narrowly and/or that Mazumder does not expressly describe its “local manufacturing system” as a device that is included within a single housing, a POSITA would have recognized that it would have been obvious and beneficial to integrate the various components (sub-systems) of the manufacturing system at the local site 205 into a device and that such a configuration would have been straight forward and routine. The fact that the various sub-systems of the local site are all collectively dedicated to the three-

dimensional fabrication of a “product” using direct material deposition (rather than conducting disparate, unrelated tasks) would have suggested to a POSITA that the various sub-systems would have beneficially implemented together as a device. EX1004, FIG. 1, 3:25-39, 4:7-10, 7:5-12, 7:39-51. This is especially true given developments in 3D printing and computing technology that occurred in the decade between the priority date of Mazumder and the relatively late time frame leading up to 2010. As such, a POSITA would have readily recognized that such a predictable configuration of Mazumder’s local sub-systems depicted in FIG. 1 would have allowed for easier transportation and installation of the local site portion of Mazumder’s system thereby increasing the ease of use of such a device.

Element [1.a]: a three-dimensional scanner configured to capture three-dimensional information from an object being fabricated within the build volume during a print job executing on the three-dimensional printer;

168. As I discussed above, Mazumder describes implementing “[o]ptical sensors at the manufacturing site [to] continuously monitor the composition, temperature, ***and dimensions*** of the product.” EX1004, 2:43-45, 5:37-39, Abstract. These “optical sensors 50 include a variety of devices” and are used to detect “defect formation . . . of the product fabrication.” *Id.*, 5:51-63.

169. Similarly, Bonassar describes optical sensors with the additional detail of including a 3D scanner as a “a non-contact ranging sensor device which can be

scanned by the positioning system across the build surface” similar 3D printers to that described in Mazumder. EX1010, [0104]. This scanner is used to “automatically monitor the progress of a fabrication operation,” “measure the geometry of the finished product,” and acquire “the geometry of deposited material with minimal interruption of the fabrication process (e.g. without pausing manufacturing in order to mount a separate sensing tool to perform the scanning).” *Id.*, [0104], [0105]. For example, Bonassar teaches that various “Machine vision sensing technologies are also available” and compatible for use in 3D printers. *Id.*, [0150]. Specifically, Bonassar describes an objects geometry “can be determined from any method capable of generating 2D and/or 3D data sets, including, without limitation, 3D laser scanning, confocal microscopy, multi-photon microscopy, computerized tomography, magnetic resonance imaging, ultrasound, and angiography.” *Id.*, [0145]. This information is then “used for online feedback control of the deposition tool—allowing the control law for the tool to adjust tool actuator commands in order to achieve the desired deposit geometry.” *Id.*, [0104]. Furthermore, Bonassar specifically identifies determining “the state of the real object being produced as measure by 3-D scanning.” *Id.*, [0097]. “[T]he system can collect 3-dimensional geometry data of the current state of the product being fabricated” as well as the geometry data “of the current state of the substrate and

any objects therein, the material deposited, and the article being fabricated.” *Id.*, [0110]

170. A POSITA would have recognized that the Mazumder-Bonassar system would be configured to include a scanner and to capture three-dimensional information from an object being fabricated within the build volume during a print job. A POSITA would understand that Bonassar specifically discloses using a scanner which collects three-dimensional information. *Id.*, [0097], [0104], [0105]. Furthermore, Bonassar specifically discloses that this information is collected during the print job to determine the “current state of the product being fabricated.” *Id.*, [0110].

Element [1.b]: a machine vision system configured to capture and analyze image content from the three-dimensional scanner, thereby providing a status of the print job executing on the three-dimensional printer;

171. Mazumder describes its implementation of optical sensors that, when predictably combined with Bonassar’s description of its 3D scanner, provides the functionality described by this claim element. The optical sensors in Mazumder are used to detect “dimensions of the product” including “defect formation . . . of the product fabrication.” EX1004, 2:43-45, 5:51-63, Abstract. Bonassar goes on to describe that, in a Mazumder-Bonassar combination, the local 3D printer uses “machine vision sensing technology.” EX1010, [0105]. This technology includes

implementing “machine vision software” in conjunction with a “machine vision sensor” to analyze the image content from the 3D scanner and provide the status of the print job including “the current state of the substate and any objects therein, the material deposited, and the article being fabricated.” *Id.*, [0105], [0085], [0110].

172. The 3D scanner implemented in Bonassar, “permits the acquisition of the geometry of deposited material” and then implements this “data for use in feedback control of the deposition tool” to detect “geometric flaws in deposited material...allowing the manufacturing planning software to design compensating material deposits.” EX1010, [0104]. By comparing the “state (geometry and other automatically detectable properties) of the simulation” based on the model of the desired object “to the state of the real object being produced as measured by 3-D scanning (or other) sensors” the system can detect errors in the fabrication and perform “error recovery/correction during a manufacturing process.” *Id.*, [0097]. Thus, the system can remedy discrepancies by “generating modifications to the manufacturing plan which replace or circumvent the error.” *Id.*

173. Furthermore, the data is also used to “online feedback control of the deposition tool—allowing the control law for the tool to adjust tool actuator commands in order to achieve the desired deposit geometry.” *Id.* Bonassar uses the data from 3D scanning “to compensate for variability in the properties of the

materials being employed, or other deposition errors by automatically generating modified manufacturing plans which compensate for the errors.” *Id.* The system can also implement the “error volume” with the “manufacturing planning software” to “modify the manufacturing plan in order to attempt to remove the error by making additional material deposits, or may cancel the entire manufacturing operation.” *Id.*, [0110]. Thus, in a predictable combination with Mazumder, the optical sensors disclosed in Mazumder would implement the machine vision system described in Bonassar to provide the capture and analyze the scanner information and provide a status for the print job.

Element [1.c]: a network interface configured to couple the three-dimensional printer in a communicating relationship with a data network; and

174. As I discussed above, Mazumder discloses that all functions of the computer-aided manufacturing system at the local site 205 system are “coordinated by the local computer 70” and as such a POSITA would have recognized that the local computer 70 controls the other “sub-systems” to coordinate the 3D manufacturing process. EX1004, 4:32-38. Figure 1 shows that the local computer 70 communicates with the remote computer 95 “via a communications system 75, preferably including the Internet.” EX1004, 3:4-10.

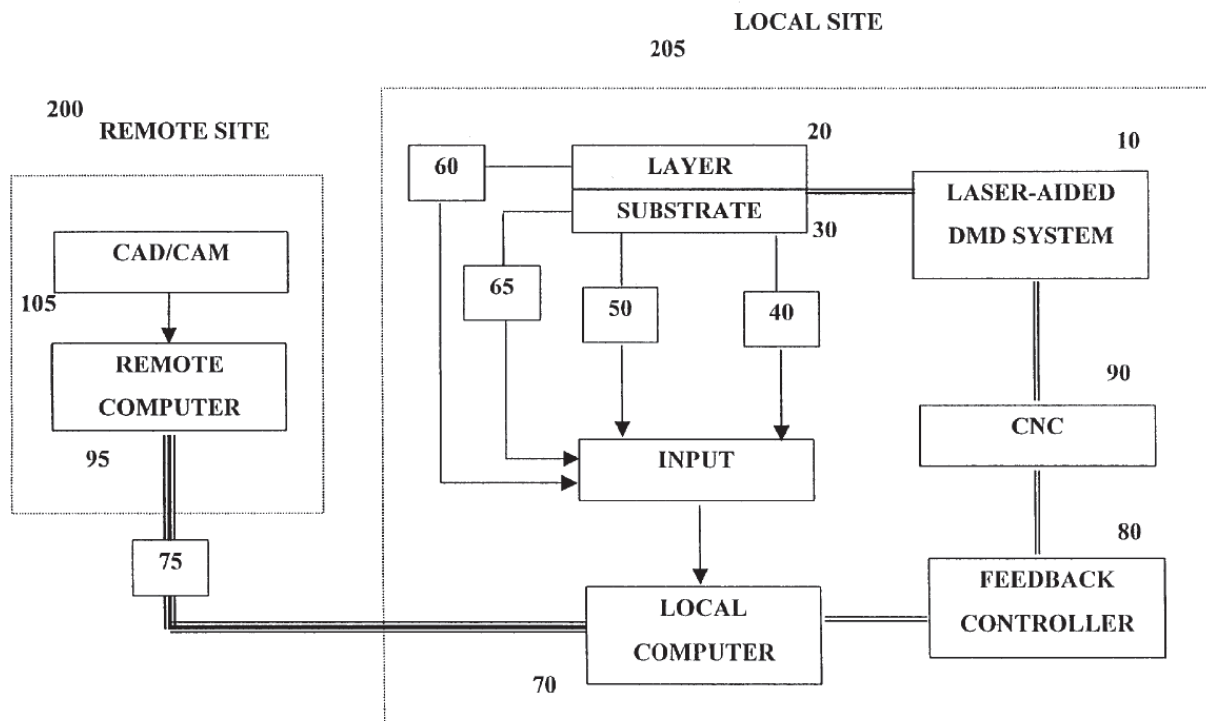


FIG - 1

EX1004, FIG. 1. For example, Mazumder describes that “[t]he local computer 70 communicates with a remote computer 95 via the communication system 75 and receives the necessary computer files defining the deposition tool path for the numerical controller (CNC) 90.” EX1004, 3:26-56. Mazumder describes transmitting data over the communication system 75, including control files for controlling the fabrication process. *Id.* (“For remote-control DMD manufacturing, the deposition tool-path files generated by the CAM software reside in the remote

computer 95 and are sent via the communications system 75 to the local computer 75 which interfaces with the feedback controller 80.”).

175. Mazumder’s system “utilizes advances in telecommunications” (col. 1:62-2:2), which Mazumder earlier described as “including the Internet, as well as advances in data acquisition and manipulation, allow the transfer of large volumes of data between distant sites” using “high-speed links in asynchronous transfer mode (ATM) or using Ethernet and Fast-Ethernet in a Local Access Network (LAN) or Wide Access Network (WAN) environment.” EX1004, 1:24-35. A POSITA would have known that the Internet is a data network and the point at which the local computer 70 interfaces with the communication system 75 (the Internet) is a network interface. Thus, based on Mazumder’s teaching for the bi-directional network communication between the local manufacturing system and the remote computer (over a communications system 75 such as “the Internet”), Mazumder discloses or plainly suggests that the local computer 70 of the manufacturing system included a conventional network interface to achieve such connectivity via the Internet. EX1004, 3:5-7, 3:36-39.

176. Alternatively, even though a POSITA would have recognized that the connection between Mazumder’s local computer 70 is a network interface, to the extent that Mazumder does not expressly use the term “network interface,” it

would have been obvious to a POSITA to implement Mazumder's local computer 70 to include an ordinary and conventional network interface at the time so as to advantageously achieve Mazumder's suggestions for "fast data transfer," "fast transmission, e.g., over the Internet," and "fast communication connections."

EX1004, 1:62-2:2, 2:23-26, 4:38-48, 6:36-55, 7:59-61. For example, Mazumder describes that "temperature, strain and stress data, visual images or metrological information collected at the local manufacturing site 205 are ***all processed through the local computer 70, which communicates with the remote computer 95.***" *Id.*, 6:36-55. A POSITA would have been readily aware that such a conventional network interface for a computing device such as Mazumder's local computer 70 was widely available as an off-the-shelf component by the relatively late timeframe leading up to 2010 and would have been straightforward to integrate into Mazumder's local computer to facilitate such communications with the remote computer 95.

Element [1.d]: a web server configured to transmit the status of the print job for display at a remote client through the network interface.

177. As I described above, Mazumder discloses that all functions of the computer-aided manufacturing system at the local site 205 system are "coordinated by the local computer 70." EX1004, 4:32-38. A POSITA would have recognized that Mazumder disclosure of this local computer provides, or at least renders

obvious, the claimed web server. As background to its system, Mazumder describes the use of “web browsers” which “enable user to view not only text, but also video, graphics and audio files.” *Id.*, 1:14-29. Mazumder describes that “[c]onnections between sites may be effected by high-speed links in asynchronous transfer mode (ATM) or using Ethernet and Fast-Ethernet in a Local Access Network (LAN) or Wide Access Network (WAN) environment.” *Id.*, 1:30-35. Furthermore, Mazumder describes a “communications link [which] facilitate[es] the electronic transfer of design, manufacturing and control information between the remote computer system and the local manufacturing system.” *Id.*, 7:12-17. Mazumder expressly ties this “communication link” to the use of a web browser by describing implementations where “a user interfaces to the communications link through an Internet browser” and “wherein the communications system connecting the local and remote computers includes an Internet browser.” *Id.*, 7:36-38, 8:18-20. As a result of these express disclosures, a POSITA would have recognized that the local computer is acting as a web server which produces the user interface for display in the “Internet browser” of the remote computer. *Id.*

178. Furthermore, the functionality of the Mazumder-Bonassar combination system further supports that the combination provides this claim element and transmits the status of the print job to the remote client computer 95

based on the information gathered by the various sensors. As I discussed above, in Mazumders the “[o]ptical sensors at the manufacturing site continuously monitor the composition, temperature, and dimensions of the product.” EX1004. The “data from the sensor systems 40, 50, 60 are processed by the local computer to produce real-time temperature, strain and stress data for the fabrication process.” *Id.*, 6:24-30. In the predictable Mazumder-Bonassar combination, the sensors described by Mazumder would include Bonassar’s 3D scanner and sensor data regarding the “the state of the real object being produced as measured by 3-D scanning (or other) sensors.” EX1010, [0097], [0104]-[0105], [0110]. Specifically, Bonassar in the predictable combination implements the 3D scanner data to “permit[] the acquisition of the geometry of deposited material with minimal interruption of the fabrication process,” “measure the geometry of the finished product,” and “compensate for variability in the properties of the material being employed, or other deposition errors.” *Id.*, [0097], [0104], [0110].

179. Additionally, “[s]ome or all of the information from the sensors is sent via a communications system to the remote computer at the designer site to determine the need for corrective measures.” EX1004, 2:47-50. As described in Mazumder “the data from the sensor system 40, 50, 60 are processed by the local computer to produce real-time temperature, strain and stress data during the

fabrication process.” *Id.*, 6:27-30. This data “are transmitted through the communications system 75 to the remote computer 95 for remote control of the process, or for modification of the product design . . . and for replacement of the original CAM file with a new edited CAM file or CAM-file block to be transmitted back to the local computer 70.” *Id.*, 6:30-35. The “local computer 70 . . . sends the images together with the associated temperature, strain and stress data to the remote computer 95 to be displayed preferably on a TV screen or shown on the remote computer monitor.” *Id.*, 6:36-43. In the predictable combination with Bonassar, the information transmitted to the remote computer 95 would include the 3D scanning data and information regarding the comparison of the 3D scanning data with the model and any discrepancies/errors. EX1010, [0097], [0104], [0110]. Complimentary to this implementation, Bonassar discloses that “a shaded surface representation of the part was displayed to the user” based on data regarding “the geometry of each part.” EX1010, [0209].

180. In the alternative, it would have been obvious to a POSITA and beneficial to display the 3D scanning data, comparison data, and data regarding discrepancies or errors from Bonassar’s machine vision system to Mazumder’s user interface at the remote computer. This implementation would provide the user with more information that the user could use to make “[m]odification[s] of CAD

and CAM files.” EX1004, 6:44-55. Mazumder describes this implementation of displaying sensor data including “temperature, strain and stress data” to the “designer” to allow the “designer interfacing with the remote computer to monitor, control and modify the fabrication of the product in real time on line.” *Id.*, Abstract. This includes allowing the designer to identify “a defect, an abnormality or other undesirable characteristic affecting the final quality of the product” based on sensor data so that the designer can “improve the design.” *Id.*, 2:34-59.

Bonassar’s 3D scanner sensor data would provide further information and improve the designer’s ability to determine the appropriate change to make in order to address “a defect [or] abnormality.” *Id.*, 2:34-59; EX1010, [0097], [0104], [0110].

Claim [2]: The system of claim 1 wherein the three-dimensional printer is a fused deposition modeling printer.

181. Mazumder directly describes that its 3D printer utilizes a “direct material deposition” fabrication process. EX1004, 1:62-2:13; 3:11-25. Standing alone, a POSITA would have understood that Mazumder discloses utilizing a fused deposition modeling printer. Furthermore, Bonassar similarly describes rapid fabrication systems with “a plurality of material deposition tools” and that its teachings are consistent with “a variety of material deposition tools” including “fusible-material extrusion tools for depositing thermally liquefied plastics.” EX1010, [0008], [0057], [0062], [0084].

182. Additionally, fused deposition modeling (FDM) was a well-known deposition based rapid fabrication technique by 2010. *See, e.g.*, EX1012, [0016]; EX1008, [0015]; EX1013, 2. It would have been obvious to a POSITA to implement the Mazumder-Bonassar combination using FDM. This would have increased the applicability of the improvements described in Mazumder and Bonassar to encompass a wider range of rapid fabrication systems. Implementing FDM in the Mazumder-Bonassar combination would have been implementing a known technique with known advantages without the need for undue experimentation.

Claim [3]: The system of claim 1 wherein the three-dimensional printer is a stereolithography printer.

183. As I discussed above, Bonassar describes using “a variety of material deposition tools” and specifically discloses using “stereolithography.” EX1010, [0057], [0151], [0159], [0037], [0084], [0008]. As a result, it would have been obvious to a POSITA to implement the Mazumder-Bonassar combination using stereolithography, based on the Bonassar suggestion, to encompass a wider range of rapid fabrication systems. Implementing stereolithography in the Mazumder-Bonassar combination would have been implementing a known technique with known advantages without the need for undue experimentation. Indeed, a POSITA would have been aware that stereolithography was a common rapid fabrication

technique that would have equally benefited from the remote control and monitoring functionality described in Mazumder. *See e.g.*, EX1007, [0031]-[0032], FIG. 1; EX1008, [0015]; EX1013, 2. A stereolithography printer (as suggested by Bonassar) also has a benefit in printing more complex geometries because the laser-curing of the liquid resin would achieve higher resolution and smoother surface finishes, particularly along curved surfaces. A POSITA would have been aware that stereolithography fabrication has a much better surface quality than Fused Deposition Modeling and is therefore employed as an advantageous form of rapid fabrication when the goal of the fabricated item is to produce a visually pleasing item or a casting in which a smooth surface is desirable. A such, implementing this type of printer would be beneficial for parts that are intended as visual props, decorative items, or for casting, such as jewelry. Thus, a POSITA would be motivated to implement the 3D printer of the predictable combination as a stereolithography printer to achieve this conventional benefit.

Claim [4]: The system of claim 1 wherein the web server is configured to host a remote user of the three-dimensional printer through the network interface.

184. As a I discussed above in relation to claim elements [1.c]-[1.d], Mazumder permits a “a designer interfacing with the remote computer to monitor, control, and modify the fabrication of the product in real time on line” through communication with the local computer. EX1004, Abstract. Mazumder specifically

addresses “advances in telecommunication and fast data transfer to control the fabrication of . . . products through an automated, feedback-controlled, laser-aided direct material deposition (DMD) process.” *Id.*, 1:62-66. Mazumder addresses “remote control of the DMD process,” “real-time, on-line control of the deposition process from the remote site,” and transmitting sensor data “through the communications system 75 to the remote computer 95.” 2:14-23, 4:38-49; 6:36-67. This process is further illustrated in Figure 1 of Mazumder:

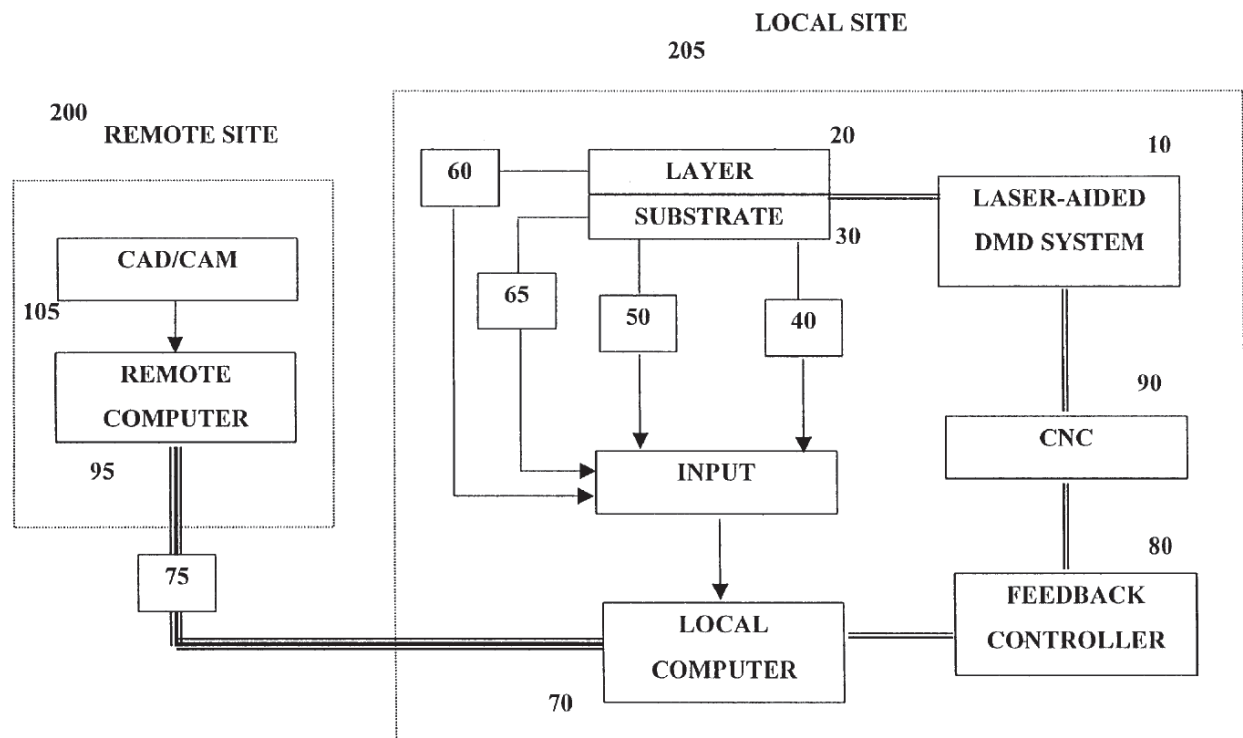


FIG - 1

EX1004, FIG. 1. As I discussed above, Mazumder's a POSITA would have understood that Mazumder's local computer 70 provides, or renders obvious, a web server and that communication between the local computer 70 and remote computer 95 occurs through the network interface.

Claim [5]: The system of claim 1 wherein the web server displays status information from one or more sensors of the three-dimensional printer

185. Mazumder discloses that it captures status information for the three-dimensional printer using various sensors and includes information captured by those sensors in the user interface provided by the local computer 70 for display at the remote computer 95. Mazumder describes that the various sensors located at the rapid fabrication device include "strain gages 40, acoustic sensors 50, optical sensors 60 and video or television camera 65." EX1004, 3:26-31. As I discussed above, in Mazumders the "[o]ptical sensors at the manufacturing site continuously monitor the composition, temperature, and dimensions of the product." EX1004. The "data from the sensor systems 40, 50, 60 are processed by the local computer to produce real-time temperature, strain and stress data for the fabrication process." *Id.*, 6:24-30. In the predictable Mazumder-Bonassar combination, the sensors described by Mazumder would include Bonassar's 3D scanner and sensor data regarding the "the state of the real object being produced as measured by 3-D scanning (or other) sensors." EX1010, [0097], [0104]-[0105], [0110]. "Some or all

of the information from the sensors is sent via a communications system to the remote computer at the designer site to determine the need for corrective measures.” EX1004, 2:47-50. As described in Mazumder “the data from the sensor system 40, 50, 60 are processed by the local computer to produce real-time temperature, strain and stress data during the fabrication process.” *Id.*, 6:27-30. This data is “transmitted through the communications system 75 to the remote computer 95 for remote control of the process, or for modification of the product design . . . and for replacement of the original CAM file with a new edited CAM file or CAM-file block to be transmitted back to the local computer 70.” *Id.*, 6:30-35. The “local computer 70 . . . sends the images together with the associated temperature, strain and stress data to the remote computer 95 to be displayed preferably on a TV screen or shown on the remote computer monitor.” *Id.*, 6:36-43.

186. As I addressed above in relation to claim element [1.d], the predictable combination of Mazumder and Bonassar would include sending Bonassar’s scanning data to be displayed at the computer along with the information on the comparison of the 3D scanning data with the model and any errors or discrepancies that were identified. EX1010, [0097], [0104], [0110].

Claim [9]: The system of claim 1 wherein the machine vision system provides automatic inspection of the object being fabricated within the build volume.

187. In the predictable combination of Mazumder and Bonassar, Bonassar expressly discloses a machine vision system that provides automatic inspection of the object being fabricated. As stated in Bonassar, “[i]n order for the manufacturing planning and control system to be able to automatically monitor the progress of a fabrication operation, to identify and locate objects placed in the build environment, and to measure the geometry of the finished product, the system may include a non-contact ranging sensor device which can be scanned by the positioning system across the build surface.” EX1010, [0104]. This system allows for the “acquisition of the geometry of deposited material with minimal interruption of the fabrication process (e.g. without pausing manufacturing in order mount a separate sensing tool to perform the scanning).” *Id.* The “manufacturing planning software” conducts the 3D scanning, compares the scans to the model of the object to identify “deposition errors” and “automatically generat[es] modified manufacturing plans which compensate for errors.” *Id.*

188. As a further example, Bonassar describes that its machine vision system includes “automatic sensor[s] mounted on the material deposition tool.” EX1010, [0085], [0104]. Bonassar specifies that the system can “at any step in the manufacturing process, [] compare the state (geometry and other automatically

detectable properties) of the simulation to the state of the real object being produced as measured by 3-D scanning (or other sensors).” *Id.*, [0097]. The system further allows for the “automatic conversion of point cloud data resulting from non-contact scanning directly into manufacturing plan geometry data.” and automatically scanning to “collect 3-dimensional geometry data of the current state of the product being fabricated.” *Id.*, [0098], [0110].

Claim [10]: The system of claim 1 wherein the machine vision system provides a robotic guidance function for the three-dimensional printer.

189. As I discussed above, the 3D scanner of Bonassar automatically obtains the “geometry of deposited material” of the object being fabricated in order to collect “data for use in feedback control of the deposition tool” EX1010, [0104]. As a result, “geometric flaws in deposited material can be detected quickly, minimally allowing the manufacturing planning software to design compensating material deposits which can be executed in a timely fashion.” *Id.* “[S]uch sensing could be used for online feedback control of the deposition tool—allowing the control law for the tool actuator commands in order to achieve the desired deposit geometry.” *Id.* This further allows for “automatically generating modified manufacturing plans which compensate for the errors.” *Id.*, [0097], [0110], [0104]. Based on Patent Owner’s infringement contentions, descriptions of controlling the robotic guidance of the fabrication device in order to make corrective depositions

based on variance/errors “to guide the printer when there is an error” satisfies this claim. EX1016, 38-42.

Claim [11]: The system of claim 1 wherein the machine vision system provide a pass/fail evaluation of the object being fabricated within the build volume.

190. Bonassar’s specifically discloses that its machine vision system detects “discrepancies” and “errors in the manufacturing process” such “undesired gaps,” and “excess material that was accidentally deposited.” EX1010, [0097], [0104], [0110]. While Bonassar’s system can automatically generate “modified manufacturing plans which compensate for the errors” a POSITA would understand that, in some instances, errors in the fabrication would be unrecoverable and could not be remediated through such modifications. *Id.* This is reflected in Bonassar’s description that while the “manufacturing software” may modify the “manufacturing plan to attempt to remove [an] error” it may also “cancel the entire manufacturing operation.” *Id.*, [0110]. A POSITA would have recognized that such a disclosure of identifying an error that requires canceling the manufacturing operation provides, or at least renders obvious, a pass/fail evaluation of the object being fabricated within the build volume being conducted by the machine vision system.

191. Similarly, Mazumder provides additional disclosure of aborting a fabrication process automatically based on a pass/fail evaluation revealing an unrecoverable error. The Mazumder system compares sensor data for the fabrication process, which includes Bonassa's 3D scanner data in the predictable combination, "with predetermined failure criteria." EX1004, 6:10-13, 5:37-67. "Based on the results of the failure analysis, the local computer...sends an electronic signal to the remote computer for online control, or sends appropriate commands to a feedback controller 80." *Id.*, 6:10-23. Based on this failure analysis, the "controller initiates corrective action, such as termination of the deposition process." *Id.*, 6:24-35.

192. A POSITA would have understood that "termination of the deposition process" or "cancel[ing] the manufacturing operation" based on errors provides, or at least renders obvious a "fail determination." Conversely, a POSITA would also have understood that a determination that the "failure criteria" are not met, would constitute a "pass" determination. Thus, the Mazumder-Bonassar combination provides for, or at least renders obvious a pass/fail evaluation of the object being fabricated.

Claim [12]: The system of claim 1 wherein the machine vision system provides error detection for the object being fabricated within the build volume.

193. As I have discussed above, Bonassar's machine vision system expressly provides for "error recovery/correction during a manufacturing process" to "detect and recover from errors during the manufacturing process." EX1010, [0097]. The system detects "[d]iscrepancies" between "the simulation" performed based on the "model" and "the state of the real object being produced as measured by 3-D scanning" so that such "[d]iscrepancies can be remedied." *Id.* This further includes identifying "variability in the properties of the materials being employed, or other deposition errors" and "[a]ny substantial unexpected deviation of the deposit geometry from that predicted by the manufacturing simulation for the current manufacturing step will be captured as an error volume." *Id.*, [0104], [0110]. In further examples, Bonassar's system can automatically generate "modified manufacturing plans which compensate for the errors." *Id.* Bonassar additionally describes that while the "manufacturing software" may modify the "manufacturing plan to attempt to remove [an] error" it may also "cancel the entire manufacturing operation." *Id.*, [0110]. As such, the machine vision system the Mazumder-Bonassar combination provides error detection for the object being fabricated.

Claim [13]: The system of claim 12 wherein the machine vision system creates an audible alert when an error is detected.

194. As I described above, Mazumder discloses comparing sensor data, such as optical sensor data to “pre-determined failure criteria.” EX1004, 6:10-12. Mazumder uses this data and the failure criteria to conduct a “failure analysis” of the object being manufactured. *Id.*, 6:10-23, 5:37-56. Furthermore, in the predictable combination of Mazumder and Bonassar, the sensor data used in the failure analysis includes Bonassar’s 3D scanner data and any errors/deficiencies detected by Bonassar’s machine vision system. EX1010, [0097]-[0098], [0104]-[0105], [0110]. Mazumder also expressly discloses that “[b]ased on the results of the failure analysis, the local computer issues a warning/alarm signal for a human operator at the local site, or sends an electronic signal to the remote compute for online control.” EX1004, 6:18-24. A POSITA would have understood that a “warning/alarm signal” at the “local site” would predictably take the form of an audible alert to notify the user that an error or failure has been detected for the object being fabricated.

Claim [14]: The system of claim 12 wherein the machine vision system creates a visual alert when an error is detected.

195. For similar reasons as I described above in relation to claim 13, the predictable Mazumder-Bonassar combination provides a visual alert when an error is detected. Mazumder conducts a “failure analysis” of the object being manufactured and “[b]ased on the results of the failure analysis, the local computer

issues a warning/alarm signal for a human operator at the local site, or sends an electronic signal to the remote compute for online control.” EX1004, 6:10-23, 5:37-56, 6:18-24. A POSITA would have understood that the “electronic signal [sent] to the remote computer” would predictably take the form of a visual alert to notify the user that an error or failure has been detected for the object being fabricated.

Claim [15]: The system of claim 1 wherein the machine vision system tracks actual progress of the print job against a predicted progress of the print job.

196. Bonassar in the predictable Mazumder-Bonassar directly provides a machine vision system that tracks the actual progress of the print job against the predicted progress. The Bonassar machine vision system “compare[s] the state (geometry and other automatically detectable properties) of the simulation to the state of the real object being produced as measured by 3-D scanning.” EX1010, [0097]. This “simulation of the manufacturing process” is based on a “model” of the object being fabricated. *Id.* As described in Bonassar, “[t]he simulation may make use of models of material evolution over time and in response to environmental conditions which are stored in the materials/tools/substrates databased, models of system operation and performance, and may perform physical simulations of a candidate manufacturing process for a given design (including finite element models, or other physics-based modeling).” *Id.* As a

further example, in the Bonassar machine vision system “[a]fter having made a deposit of material, the system can collect 3-dimensional geometry data of the current state of the product being fabricated. Any substantial unexpected deviation of the deposit geometry from that predicted by the manufacturing simulation for the current manufacturing step will be captured as an error volume (polytope).” *Id.*, [0110], [0104]. A POSITA would have understood that Bonassar’s disclosures regarding the “simulation of the manufacturing process” based on a “model” of the desired object provides for, or at least renders obvious, tracking an actual progress of the print job against a predicted progress.

Claim [16]: The system of claim 1 wherein the machine vision system compares an actual three-dimensional result in the build volume with an expected three-dimensional result based upon a source model.

197. For similar reasons as those I discussed above in relation to claim 15, Bonassar in the predictable Mazumder-Bonassar provides, or at least renders obvious, this claim. The Bonassar machine vision system provides a “simulation of the manufacturing process” which is based on a “model” of the object being fabricated. EX1010, [0097]. “After having made a deposit of material, the system can collect 3-dimensional geometry data of the current state of the product being fabricated. Any substantial unexpected deviation of the deposit geometry from that predicted by the manufacturing simulation for the current manufacturing step will

be captured as an error volume (polytope).” *Id.*, [0110], [0104]. A POSITA would have understood that Bonassar’s disclosures regarding the “simulation of the manufacturing process” based on a “model” of the desired object provides for, or at least renders obvious, comparing an actual three-dimensional result in the build volume with an expected three-dimensional result based upon a source model.

Claim [17]: The system of claim 16 wherein the machine vision system is configured to abort a fabrication process of the three-dimensional printer upon detection of an unrecoverable error in the fabrication process.

198. As I discussed above in relation to claim 11, the Bonassar machine vision system detects “discrepancies” and “errors in the manufacturing process” such “undesired gaps,” and “excess material that was accidentally deposited.” EX1010, [0097], [0104], [0110]. A POSITA would understand that, in some instances, errors in the fabrication would be unrecoverable and could not be remediated through modifications to the manufacturing process. Bonassar reflects this by describing that while the “manufacturing software” may modify the “manufacturing plan to attempt to remove [an] error” it may also “cancel the entire manufacturing operation.” *Id.*, [0110].

199. Mazumder also describes aborting a fabrication process automatically based on the detection of an unrecoverable error. The Mazumder system compares sensor data for the fabrication process, which includes Bonassa’s 3D scanner data

in the predictable combination, “with predetermined failure criteria.” EX1004, 6:10-13, 5:37-67. “Based on the results of the failure analysis, the local computer...sends an electronic signal to the remote computer for online control, or sends appropriate commands to a feedback controller 80.” *Id.*, 6:10-23. Based on this failure analysis, the “controller initiates corrective action, such as termination of the deposition process.” *Id.*, 6:24-35.

200. A POSITA would have understood that Bonassar’s disclosure of cancelling the manufacturing operation in response to an error and Mazumder’s disclosure of corrective action including termination of the deposition process provides for, or at least renders obvious, a machine vision system that is configured to abort a fabrication process of the three-dimensional printer upon detection of an unrecoverable error.

Claim [18]: The system of claim 16 wherein the machine vision system is configured to detect a misalignment of layers.

201. As I have described above, the Bonassar machine vision system discloses the ability to detect “variability in the properties of the materials being employed, or other deposition errors” and “[a]ny substantial unexpected deviation of the deposit geometry from that predicted by the manufacturing simulation for the current manufacturing step will be captured as an error volume.” *Id.*, [0104],

[0110]. Specifically, the system can “at any step in the manufacturing process, [] compare the state (geometry and other automatically detectable properties) of the simulation to the state of the real object being produced as measured by 3-D scanning (or other) sensors.” *Id.*, [0097]. A POSITA would have understood that in the event of a “misalignment of layers” during the fabrication process, the Bonassar machine vision system would detect this misalignment as an “unexpected deviation of the deposit geometry.” *Id.*, [0110]. As such, the predictable Mazumder-Bonassar system is configured to detect a misalignment of layers.

Claim [19]: The system of claim 16 wherein the machine vision system is configured to detect an unexpected surface hole.

202. As I have discussed above, the Bonassar machine vision system discloses the ability to detect “[a]ny substantial unexpected deviation of the deposit geometry from that predicted by the manufacturing simulation for the current manufacturing step will be captured as an error volume.” *Id.*, [0110], [0097], [0104]. These “discrepancies” and “errors in the manufacturing process” include “undesired gaps.” EX1010, [0097], [0104], [0110]. A POSITA would have understood that Bonassar’s disclosures regarding detecting deviations from the deposit geometry and undesired gaps would have included, or at least rendered obvious, detection of “unexpected surface hole[s]” as such detected “undesired gaps” would, in at least some cases, be located on the surface of the object. As

such a POSITA would have understood that the predictable Mazumder-Bonassar combination provides, or at least renders obvious, a machine vision system that is configured to detect unexpected surface holes.

7.10. Ground 2B: The Combination of Mazumder-Bonassar with Crampton Renders Obvious Claim 8

203. Multiple reasons would have motivated a POSITA to modify the system of Mazumder-Bonassar to implement or augment the scanning functionality in the predictable combination with the functionality of structured light described by Crampton. Similar to Bonassar, Crampton describes implementing “a scanning apparatus for scanning an object to provide a computer model thereof.” EX1009, 5:58-67. Campton directly discloses using “structured light to more quickly scan the surface of the object.” *Id.*, 6:8-9. This structured light technique carries a further benefit of “sens[ing] the colour of the surface of the object, resulting in a model more like the real world object.” *Id.*, 6:1-11.

204. As I have discussed above, the Bonassar system addresses using 3D scanner and sensor data regarding the “3-D scanning (or other) sensors” to “collect 3-dimensional geometry data of the current state of the product being fabricated. EX1010, [0097], [0104]-[0105], [0110]. Bonassar also

addresses that “[o]ther scanning devices may be used in an analogous manner to provide spatial and/or temporal monitoring of other aspects of the substrate, of the state of the material being deposited, and of the article being fabricated.”
Id., [0110].

205. A POSITA would have understood both that it is obvious to implement Bonassar’s 3D scanner using a structured light technique as suggested by Crampton or alternatively to implement an additional scanner using this technique. This would have resulted in a POSITA applying a known technique with understood advantages to a known system to yield the predictable results of increasing the information obtained from scanning the fabricated object.

Claim [8]: The system of claim 1 wherein the three-dimensional scanner obtains three-dimensional data using structured light techniques

206. As I discussed above, Crampton directly provides for using a three-dimensional scanner to obtain three-dimensional data using a structured light technique. EX1009, Abstract, 5:58-67, 6:1-11. A POSITA would have been motivated to implement the structured light technique into the predictable Mazumder-Bonassar combination. Thus, the improved combination would directly provide for this claim.

7.11. Ground 2C: The Combination of Mazumder-Bonassar with Chandhoke Renders Obvious Claim 11

207. As I discussed above in relation to claim 11, the Mazumder-Bonassar combination provides for, or at least renders obvious a pass/fail evaluation of the object being fabricated. However, to the extent that Patent Owner argues that Mazumder and Bonassar's aborting of the fabrication process based on "failure criteria" does not meet this claim, a POSITA would be motivated to modify the Mazumder-Bonassar combination to implement a pass/fail evaluation as suggested by Chandhoke to achieve the known benefits and avoid wasting time or material on a failed object fabrication. The Bonassar machine vision system can detect "variability in the properties of the materials being employed, or other deposition errors" and "[a]ny substantial unexpected deviation of the deposit geometry from that predicted by the manufacturing simulation for the current manufacturing step will be captured as an error volume." *Id.*, [0104], [0110]. Specifically, the system can "at any step in the manufacturing process, [] compare the state (geometry and other automatically detectable properties) of the simulation to the state of the real object being produced as measured by 3-D scanning (or other) sensors." *Id.*, [0097].

208. A POSITA would have understood that in some situations, defects in a fabricated object would be sufficiently severe that the defects could not be

corrected through additive or subtractive detailing. In such a situation, making additional depositions or removing material would be insufficient to correct the fabricated project and any attempts would simply amount to a waste of time and resources. Having the machine vision system provide an automatic pass/fail evaluation (as suggested by Chandhoke) would allow for the fabrication process to be stopped either by the system or by a remote user once an unrecoverable defect is detected. This would provide a known advantage of avoiding the waste of time, deposition material, and power consumption on an unsalvageable project. This would also provide the additional benefits of avoiding unnecessary wear on the Mazumder fabrication apparatus and tools. Additionally, a POSITA would understand that some defects may not be readily detectable with the naked eye and human quality inspection may not identify the defect. A pass/fail evaluation would allow the system to identify such minute, yet unrecoverable defects, and minimize the potential for defective products to be put into circulation or used for other purposes.

Claim [11]: The system of claim 1 wherein the machine vision system provide a pass/fail evaluation of the object being fabricated within the build volume.

209. Implementing the techniques of Chandhoke, in combination with the Mazumder-Bonassar system, provides this claim. Chandhoke describes “a system and method for configuring a hardware device to execute a prototype.” EX1011,

[0015]. The methods disclosed in Chandhoke include “image processing (machine vision) operations for acquiring and analyzing images of an object” using “an image acquisition device.” *Id.*, [0087]. The Chandhoke prototyping environment includes “machine vision, pattern matching, shape matching, or other applications.” *Id.*, [0081]. Once the image of a manufactured object is analyzed, the Chandhoke system can “perform an operation based on this result, such as rejecting a part from an assembly line.” *Id.*, [0125]-[0127]. As an example, Chandhoke describes using the image processing function of the “image acquisition device” to “analyze an image and detect, recognize, or characterize one or more features or characteristics of an object such as . . . possible flaws or lack thereof.” *Id.*, [0173]. Based on this information the “image acquisition device may generate a pass/fail indication after executing to perform the image processing function on the image.” *Id.* Upon determining that the “imaged object is defective” the device may “send a signal, such as a pass/fail indication, to a motion control device which may remove the defective object from the assembly line.” *Id.*, [0174]. Furthermore, Chandhoke describes that objects may be “inspected for defects” and sorted “according to their defect levels.” *Id.*, [0318].

210. The techniques disclosed in Chandhoke directly provide a pass/fail evaluation of an object being fabricated. Implementing the techniques disclosed in

Chandhoke with the machine vision system of the Mazumder-Bonassar would lead to the predictable resulting of using Bonassar's scanner and defect detection to determine when a defect is too severe to salvage using corrective measures. As such, the Mazumder-Bonassar system, in combination with Chandhoke, provides this claim.

7.12. Ground 2D: The Combination of Mazumder-Bonassar with Ridley Renders Obvious Claims 13-14

211. As I discussed above in relation to claims 13 and 14, a POSITA would have understood that the Mazumder-Bonassar combination provides audible and visual alerts to notify the user that an error or failure has been detected for the object being fabricated. However, to the extent that Patent Owner argues that the Mazumder-Bonassar combination's "warning/alarm signal" and "electronic signal to the remote computer" indicating that failure criteria has been met do not render claims 13 and 14 obvious, multiple reasons would have motivated a POSITA to modify the system of Mazumder-Bonassar to modify Bonassar's machine vision error detection system to include an audible and/or visual alert when an error is detected based on the suggestions of Ridley.

212. *As a first reason*, providing an audible and/or visual alert in conjunction with Bonassar's machine vision error detection system would

helpfully alert the user that the printing apparatus is taking additional actions that were not part of the original fabrication process. As I discussed in Ground 1B, above, Mazumder discloses comparing sensor data, such as optical sensor data to “pre-determined failure criteria.” EX1004, 6:10-12. Mazumder uses this data and the failure criteria to conduct a “failure analysis” of the object being manufactured. *Id.*, 6:10-23, 5:37-56. The system then takes “corrective action” in response to the failure analysis. *Id.*, 6:10-30. Similarly, Bonassar’s machine vision system detects “discrepancies” and “errors in the manufacturing process” such “undesired gaps,” and “excess material that was accidentally deposited.” EX1010, [0097], [0104], [0110]. Providing an alert to the user would inform the user that the machine may be taking corrective actions such as “depositing material into undesired gaps, or [] modifying subsequent deposition paths” that may not have been part of the original process in order to correct the error. EX1010. [0104]

213. As a second reason, alerting the user that an error has been detected allows for user to visually inspect the object being fabricated. This would provide the opportunity for additional quality control either by direct visual inspection by the user or by visual inspection by someone onsite and the fabrication location. This not only permits a human determination regarding whether the error is severe or minor but would also draw attention to the fact that there was an error in the

fabrication of this particular object. Thus, additional steps can be taken to ensure the final quality of the fabricated object.

214. As a third reason, an audible and/or visual alert would inform the user that the fabrication process may take longer than originally anticipated. By informing the user an error has been detected, and thus the additional steps will need to be performed, the user is also informed that the fabrication process will likely take longer than planned. This permits the user to reschedule other tasks that may be dependent on the completion of the fabrication and to mitigate the impact of the resultant delays.

215. As a fourth reason, alerting the user that an error has been detected allows the user to make a decision regarding whether the fabrication process should be aborted. A user could determine whether the resulting delays or potential for lower quality in the final product is such that the fabrication process should be aborted entirely or restarted from scratch. This would allow a user to make real-time risk assessment regarding the fabrication process based on the occurrence of defects.

Claim [13]: The system of claim 12 wherein the machine vision system creates an audible alert when an error is detected.

216. Ridley demonstrates that in the resulting Mazumder-Bonassar-Ridley combination, the machine vision error detection system of Bonassar's system creates an audible alert when an error is detected. This is demonstrated, for example, by Ridley's system which outputs "a sensible output for providing an indication of a damaged or missing [part]." EX1014, [0021]. This output includes "an audible alarm, or any other type of output which may be sensed by a person or apparatus." *Id.* In another similar example, Ridley demonstrates that in the Mazumder-Bonassar-Ridley combination whenever a portion of the object being fabricated is "is partially or completely broken or missing, the system automatically alerts the [user] by a sensible output." EX1014, [0082]. Thus, the system operator is quickly alerted to a detected defect, error, or break. *Id.*, [0083]. A POSITA would have recognized that the audible alarm described by Ridley, in combination with the Mazumder and Bonassar error detection systems, satisfies claim 13.

Claim [14]: The system of claim 12 wherein the machine vision system creates a visual alert when an error is detected.

217. Ridley demonstrates that in the resulting Mazumder-Bonassar-Ridley combination, the machine vision error detection system of Bonassar's printer apparatus creates a visual alert when an error is detected. As I described above in relation to claim 13, Ridley's system outputs "a sensible output for providing an

indication of a damaged or missing [part].” EX1014, [0021]. This output may include “a visual display.” *Id.* As one example, when a broken or damaged part is detected “the system automatically alerts the [user] by a sensible output in the form of a visual alarm on a touch screen monitor.” *Id.*, [0082]-[0083]. A POSITA would have recognized that the visual alarm described by Ridley, in combination with the Mazumder and Bonassar error detection systems, satisfies claim 14.

7.13. Ground 2E: The Combination of Mazumder-Bonassar with Biton Renders Obvious Claims 2 and 18

218. As I discussed above in relation to claim 2, the Mazumder discloses that its 3D printer utilizes a “direct material deposition” fabrication process. EX1004, 1:62-2:13; 3:11-25. Additionally, Bonassar describes rapid fabrication systems with “a plurality of material deposition tools” and that its teachings are consistent with “a variety of material deposition tools” including “fusible-material extrusion tools for depositing thermally liquefied plastics.” EX1010, [0008], [0057], [0062], [0084]. As a result, a POSITA would have understood that the Mazumder-Bonassar combination includes a fused deposition modeling printer.

219. Additionally, as I discussed above in relation to claim 18, a POSITA would have understood that in the event of a “misalignment of layers” during the fabrication process, the Bonassar machine vision system would detect this

misalignment as an “unexpected deviation of the deposit geometry.” *Id.*, [0110]. Thus, the predictable Mazumder-Bonassar system is also configured to detect a misalignment of layers.

220. However, to the extent that the Patent Owner argues that neither Mazumder nor Bonassar specifically use the terms “fused deposition modeling” or “misalignment of layers,” multiple reasons would have motivated a POSITA to modify the system of Mazumder-Bonassar to include both fused deposition modeling and the specific detection of misalignment of the fabrication layers based on the suggestions of Biton.

221. As a first reason, both Mazumder and Bonassar describe rapid fabrication devices that use deposition based three-dimensional printing techniques. EX1004, 1:62-2:13; 3:11-25; EX1010, [0008], [0057], [0084]. For example, Mazumder describes using a “laser-aided, computer-controlled direct material deposition system 10, which is used to fabricate, repair or modify three-dimensional products by applying Sequentially layers of material 20 on a Substrate 30.” EX1004, 3:11-25. Similarly, Bonassar describes using various “material modification tools” and “material deposition tools” to enable the deposition and/or modification and/or measurement of one or more deposited materials in very rapid succession.” EX1010, [0071]. Biton specifically describes “fused deposition

modeling (FDM)” as a useful type of deposition process in the art of rapid prototyping. EX1008, [0015], [0104], [0109]. Furthermore, Biton describes that the “primary advantage to additive fabrication is its ability to create rapidly almost any two or three-dimensional shape or geometric feature.” *Id.*, [0010]. A POSITA would have known to implement the Mazumder-Bonassar combination with the teachings of Biton to take advantage of the remote control techniques described in Mazumder and the scanning and error detection and correction techniques described by Bonassar in additional types of fabrication devices, including the specific “fused deposition modeling (FDM)” printer described by Biton. This combination would allow for the advantages of the combination to be applied with a wider variety of fabrication devices.

222. As a second reason, particularly by the time leading up to 2010, FDM was a well-known deposition technique. Implementing FDM in the Mazumder-Bonassar combination, as suggested by Biton, would have been implementing a known technique with known advantages without the need for undue experimentation.

223. As a third reason, and related to implementing the “camera-aided alignment system” described in Biton, Bonassar’s machine vision system identifies “[a]ny substantial unexpected deviation of the deposit geometry from that

predicted by the manufacturing simulation” and adjusts the fabrication process to address such deviations. EX1010, [0110], [0104], [0097]. To the extent that the error detection system in Bonassar does not use the specific term “misalignment of layers,” it would have been obvious to a POSITA to consider the misalignment of layers as one of the “deviations” that the Bonassar system should detect based on Biton’s suggestion. As described by Biton, “once the misalignment is measured, the system manager may shift the coordinates of the next layer by the proper amount to correct of the misalignment.” EX1008, [00118]. [00119]. Implementing the detection of misalignment would merely require including misalignment as a variance that the Bonassar system is set to detect during the fabrication process.

224. As a fourth reason, a POSITA would have been motivated to implement the suggestion of Biton with Bonassar’s system to add to the “corrections” that could be taken to minimize any issues with “deviation” in the fabrication process. Biton’s suggestion allows for correction based on misalignment to ensure that any error accumulation is “negligible” and enable fabrication of “numerous layers and delicate features in a highly accurate manner.” EX1008, [0118]. Implementing Biton’s suggestion in the Bonassar system would lead to the advantage of providing additional corrective measures that Bonassar could utilize to minimize any damages or problems based on detected errors.

225. As demonstrated below, the predictable combination of the Mazumder-Bonassar combination and Biton renders obvious claims 2 and 18.

Claim [2]: The system of claim 1 wherein the three-dimensional printer is a fused deposition modeling printer.

226. Biton demonstrates that in the resulting Mazumder-Bonassar-Biton combination, the system includes utilizing a fused deposition modeling printer. As I described above, Biton specifically discloses “fused deposition modeling (FDM)” as a deposition process in the art of rapid prototyping. EX1008, [0015], [0104], [0109]. Biton further describes that the “primary advantage to additive fabrication is its ability to create rapidly almost any two or three-dimensional shape or geometric feature.” *Id.*, [0010]. As such, the predictable Mazumder-Bonassar-Biton is specifically configured to implement fused deposition modeling.

Claim [18]: The system of claim 16 wherein the machine vision system is configured to detect a misalignment of layers.

227. Biton demonstrates that in the resulting Mazumder-Bonassar-Biton combination, the Bonassar machine vision system is configured to detect a misalignment of layers. Biton specifically describes a system for detecting, measuring, and correcting for “misalignment.” EX1008, [00118], [00119]. The system may then “shift the coordinates of the next layer by the proper amount to correct for the misalignment” and the system “enables alignment for every layer

(or even sub-layer) fabricated, [and] thus errors accumulation is negligible.” *Id.* A POSITA would have recognized that this detection of layer misalignment satisfies claim 18.

7.14. Ground 2F: The Combination of Mazumder-Bonassar with Bakhadyrov Renders Obvious Claim 19

228. As I discussed above in relation to claim 19, a POSITA would have understood that, based on Bonassar’s disclosures regarding detecting deviations from the deposit geometry and undesired gaps, the predictable Mazumder-Bonassar combination provides, or at least renders obvious, a machine vision system that is configured to detect unexpected surface holes. However, to the extent Patent Owner argues that “undesired gaps” are not expressly described as “unexpected surface holes,” multiple reasons would have motivated a POSITA to modify the system of Mazumder-Bonassar to include the void detection technique in order to detect unexpected surface holes based on the suggestions of Bakhadyrov.

229. As a first reason, Bonassar’s machine vision system already describes the ability to detect “[a]ny substantial unexpected deviation of the deposit geometry from that predicted by the manufacturing simulation for the current manufacturing step will be captured as an error volume.” EX1010, [0110], [0097],

[0104]. The system identifies “discrepancies” and “errors in the manufacturing process” include “undesired gaps.” *Id.*, [0097], [0104], [0110]. To the extent the Bonassar system does not use the specific term “unexpected surface hole,” as one of the unexpected gaps that the system detects, a POSITA would understand that it would be obvious and beneficial to include detecting unexpected surface holes or “voids” based on Bakhadyrov’s suggestion. EX1015, 1-6. The Bonassar system is meant to detect these discrepancies and errors in order to identify “corrections” and “modified manufacturing plans” which can compensate for these errors. EX1010, [0097], [0110]. By implementing Bakhadyrov’s image processing techniques for void detection, this would add to the “discrepancies” and “errors” that the Bonassar system could detect and subsequently correct. In the event that the surface holes constitute an unrecoverable error, the Bonassar system would also be able to reject the fabricated object and conserve materials if necessary.

230. *As a second reason*, implementing Bakhadyrov’s suggestion in the Bonassar machine vision system would increase the efficiency of the inspection process described by Bonassar. Bakhadyrov’s techniques make the “inspection process much faster and more affordable.” EX1015, 1, 4. This is accomplished by using “[c]omputation efficient algorithm” to achieve a “quick and precise quality inspection.” *Id.*, 1, 2, 4. Thus, using Bakhadyrov’s techniques with the Bonassar

machine vision system would result in predictable results of increased efficiency in the fabrication process.

231. As a third reason, implementation of Bkhadrov's void detection techniques to the Mazumder-Bonassar combination would have resulted in a process that "significantly increase[d] the resulting quality" of the objects being fabricated, including "better smoothness" of the surfaces of such objects. EX1015, 4, 1.

232. As demonstrated below, the predictable combination of Bakhadyrov with the Mazumder-Bonassar combination renders obvious claim 19.

Claim [19]: The system of claim 16 wherein the machine vision system is configured to detect an unexpected surface hole.

233. Bakhadyrov demonstrates that in the Mazumder-Bonassar-Bakhadyrov combination, the machine vision system of Bonassar is configured to detect an unexpected surface hole. In particular, Bakhadyrov describes a "machine vision setup" for a "Direct Layered Manufacturing (LM)" system for conducting a "surface quality inspection" of manufactured objects/parts. EX1015, Abstract, 2. This includes the detection of "surface voids" which "on the surface can be characterized as defects." *Id.*, 2. Bakhadyrov directly describes the "Machine Vision setup has been designed for detection of surface defects (voids) in indirect

and ‘zero-offset’ direct LM process.” *Id.*, 4. As a result, the Mazumder-Bonassar system in predictable combination with Bakhadyrov, directly discloses that the system is configured to detect an unexpected surface hole.

8. Secondary Considerations.

234. At this stage of these proceedings, it is my understanding that Petitioner has no burden to identify and rebut secondary considerations. Rather, it is my understanding that Patent Owner must first present a prima facie case for such consideration, which Petitioners should then have the chance to rebut. That said, I have considered evidence of secondary considerations that I am aware of at this time, and I am currently unaware of any evidence of secondary considerations that would support a finding of non-obviousness. If additional evidence of secondary considerations becomes available, I would ask to be able to opine on it at that time.

9. Availability for Cross-Examination

235. In signing this declaration, I recognize that the declaration will be filed as evidence in a contested case before the Patent Trial and Appeal Board of the United States Patent and Trademark Office. I also recognize that I may be subject to cross examination in the case and that cross examination will take place

within the United States. If cross examination is required of me, I will appear for cross examination within the United States during the time as mutually agreed between the parties.

10. Right to Supplement

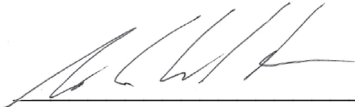
236. I reserve the right to supplement my opinions in the future to respond to any arguments that the Patent Owner may raise. This declaration represents only those opinions that I have formed to date. I reserve the right to revise, supplement, and/or amend my opinions stated herein based on new information that becomes available to me and on my continuing analysis of the materials already provided.

11. Jurat

237. I 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 further that these statements were made with the knowledge that willful false statements and the like so made are punishable by fine or imprisonment, or both, under Section 1001 of Title 18 of the United States Code.

12-23-2024

Date


Andrew Wolfe, Ph.D.

Appendix A

Andrew Wolfe Ph.D.

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Santa Clara, CA 95050
(408) 394-1096 (mobile)
Email: awolfe@awolfe.org

Education:

Ph.D. in Electrical and Computer Engineering, Carnegie Mellon University, 1992
Visiting Graduate Student, Center for Reliable Computing, Stanford University, 1988-1989
M.S. in Electrical and Computer Engineering, Carnegie Mellon University, 1987
B.S.E.E. in Electrical Engineering and Computer Science, The Johns Hopkins University, 1985

Recent Employment:

Lecturer, Asst. Teaching Professor [September 2013-present]
Santa Clara University

Teaching graduate and undergraduate courses on embedded computing, mechatronics, real-time systems, computer architecture, design, and community service. Faculty Senate President 2023-24.

Consultant, [October 2002-present]
Wolfe Consulting

Consultant on processor technology, computer systems, consumer electronics, software, design tools, and intellectual property issues. Testifying and consulting expert for IP and other technology-related litigation matters.

Sample clients include:

Google	Apple	Samsung
Sony	Huawei	HTC
AT&T	Verizon Mobile	T-Mobile
IBM	Motorola/Lenovo	Nintendo
Activision	AMD	Western Digital
Sonos	Qualcomm	LG
Netflix	Roku	Tivo
Synaptics	Sawstop	3M
Medigus	TCL	ZTE
Egnyte	Acer	Waymo

Chief Technical Officer, [1999-2002]; Sr. VP of Business Development, [2001-2002]; VP, Systems Integration, S3 Fellow, [1998 – 1999]; Director of Technology, S3 Fellow, [1997 - 1998]
SONIC|blue, Inc., Santa Clara, CA (formerly S3 Inc.)

Strategic Business Development:

Developed and implemented strategy to reposition S3 from PC graphics into the leading networked consumer electronics company.

- Acquired Diamond Multimedia and coordinated integration of communications, Rio digital music, and workstation graphics divisions into S3.
- Identified and negotiated acquisitions to grow digital media businesses including Empeg, ReplayTV, and Sensory Science.
- Identified and negotiated strategic investments including Comsilica, Intellon, KBGear Interactive, Entridia, DataPlay and others.

- Developed strategy for integrated graphics/core-logic products and established a joint venture with Via Technologies to design and market these products.
- Negotiated divestiture of graphics chip business to Via and the workstation graphics division to ATI.

Product Planning and Development:

- Drove roadmap development within SONICblue product divisions.
- Managed Business Development for all product lines.
- Led New Product Development and Corporate Vision processes.
- Acting co-General Manager of Rio digital music business in 2nd half of 2001. Responsible for all areas of product development, business development, and cost management.
- Managed development of the Savage/MX and Savage/IX mobile 3D graphics accelerators and Savage/NB system logic products.

Public Relations, Public Policy and Investor Relations:

- Present company products and strategy at industry events such as CES, Comdex, and Microprocessor Forum.
- Discuss new products and initiatives with the press.
- Promote issues of interest to SONICblue to industry groups and in Washington.
- Brief analysts, and investors on company progress. Participate in quarterly conference calls.

IP Management and Licensing:

- Negotiated and managed partnership agreements including a critical cross-licensing agreement with Intel.
- Renegotiated technology-licensing agreements with IBM for workstation graphics products.
- Evaluated outside technology opportunities, managed video research and development, and managed corporate IP strategy with legal staff including patent filings, cross licensing, and litigation.

Consulting Professor, [1999-2002]

Stanford University, Stanford, CA

Teaching computer architecture and microprocessor design.

Assistant Professor [1991 - 1997]

Princeton University, Princeton, NJ

Teaching and research in the Electrical Engineering department. Research in embedded computing systems, multimedia, video signal processors, compiler optimization, and high performance computer architecture. Principal investigator or project manager for ~\$6M in funded research.

Visiting Assistant Professor, [1992]

Carnegie Mellon University, Pittsburgh, PA

Research and preparation of teaching materials on advanced microprocessor designs including new superscalar and superpipelined processor architectures.

Founder and Vice President and Consultant, [1989 - 1995]

The Graphics Technology Company, Inc., Austin, TX

Founded company to develop touch-sensitive components and systems for the first generation of PDA devices and interactive public systems. Obtained financing from Gunze Corp., Osaka, Japan. Company is now part of 3M.

Senior Electrical Engineer, [1989]

ESL - TRW, Advanced Technology Division, Sunnyvale, CA

Designed the architecture for an Intel i860-based multiple-processor digital signal processing system for advanced military applications. Designed several FPGA interface chips for VME-bus systems.

Design Consultant, [1986 -1987]

Carroll Touch Division, AMP Inc., Round Rock, TX

Developed several new technologies for touch-screen systems. Designed the first ASIC produced for AMP, a mixed-signal interface chip for controlling touch-screen sensors. Developed the system electronics, system firmware, and customer utility software for numerous products including those based on the new ASIC.

Senior Design Engineer, [1983 -1985]

Touch Technology Inc., Annapolis, MD

Advisory Boards:

Director, Turtle Beach Corporation (NASDAQ:HEAR) (formerly Parametric Sound Corporation), KBGear Interactive, Inc., Comsilica, Inc., Rioport.com, various S3 subsidiaries.

Technical Advisory Boards, Ageia, Inc., Intellon, Inc., Comsilica, Inc., Entridia, Inc., Siroyan, Ltd., BOPS, Inc, Quester Venture Funds

Carnegie Mellon University Silicon Valley Advisory Board; Johns Hopkins University Tech Transfer Advisory Board

Awards:

IEEE Fellow - for contributions in hardware code compression of embedded software, power consumption analysis, and optimization, 2022
IEEE Computer Society Distinguished Contributor - 2021
Micro Test-of-Time Award (in recognition of one of the ten most influential papers of the first 25 years of the symposium), 2014
Business 2.0 “20 Young Executives You Need to Know”, 2002
Walter C. Johnson Prize for Teaching Excellence, 1997.
Princeton University Engineering Council Excellence in Teaching Award, Spring 1996
AT&T/Lucent Foundation Research Award, 1996.
Walter C. Johnson Prize for Teaching Excellence, 1995
IEEE Certificate of Appreciation, 1995, 2001.
AT&T Foundation Research Award, 1993.
Semiconductor Research Corporation Fellow, 1986 - 1991.
Burroughs Corporation Fellowship in Engineering, 1985 - 1986.

Professional Activities:

Program Chair: Micro-24, 1991, Hot Chips 13, 2001.
General Chair: Micro-26, 1993, Micro-33, 2000.
Associate Editor: IEEE Computer Architecture Letters; ACM Transactions in Embedded Computing Systems
Speaker at CES, WinHec, Comdex, Intel Dev. Forum, Digital Media Summit, Microprocessor Forum, etc.
Keynote speaker at Micro-34, ICME 2002
IEEE B. Ramakrishna Rau Award committee – 2012-2016
IEEE Computer Society Awards Committee – 2015
Director – IEEE Consultants Network of Silicon Valley – 2022-present
CES Awards Judge – 2016
Entrepreneurship Mentor – Draper University

Over 50 refereed publications.**Publications since January 2006:**

Wolfe, A., “Retrospective on Code Compression and a Fresh Approach to Embedded Systems”, IEEE MICRO, July/Aug. 2016, Invited paper.

Michael Kreienkamp, Olivia McConaghy, Sally L. Wood, Andrew Wolfe, Julia A. Scott, 2024 NYC Neuromodulation Conference, Transcranial Photobiomodulation Control System Compatible with EEG, abstract and poster. June 2024 <https://neuromodec.org/nyc-neuromodulation-2024/poster-list.html#A83D>

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- U.S. Pat. 8,193,941 – *Snoring Treatment*, June 5, 2012
- U.S. Pat. 8,203,541 – *OLED display and sensor*, June 19, 2012
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- U.S. Pat. 8,244,982 – *Allocating processor cores with cache memory associativity*, August 14, 2012
- U.S. Pat. 8,260,996 – *Interrupt Optimization for Multiprocessors*, Sept. 4, 2012
- 101185761 (KR) – *Noise Cancellation for Phone Conversation*, Sept. 19, 2012
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Expert testimony by deposition or at trial – April 15, 2018 - -present

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Joe Andrew Salazar v HTC Corporation	E.D. Texas	2:16-cv-010986-JRG-RSP
Hitachi Maxell, Ltd. v. ZTE Corporation and ZTE (USA), Inc.	E.D. Texas	5:16-cv-00179 5:16-cv-00178
INTER PARTES REVIEW OF U.S. PATENT NO. 7,663,506 (Mediatek v AMD)	PTAB	IPR2017-00101 IPR2017-00102
Papst Licensing GmbH & Co. KG v. Samsung Electronics Co.,Ltd. and Samsung Electronics America, Inc.	E.D. Texas	6:15-CV-1102
HTC Corporation v. Telefonaktiebolaget LM Ericsson	E.D. Texas	6: 18-cv-00243-JRG
Seven Networks, LLC v ZTE (USA) Inc and ZTE Corporation	N. D. Texas - Dallas	3:17-CV-1495
AGIS Software Development, LLC v. HTC Corporation	E. D. Texas	2:17-cv-514
Barbaro Technologies, LLC v. Niantic, Inc	N.D. CA	3:18-cv-02955-RS
Immersion Corp. v. Samsung Electronics America, Inc. et al	E.D. Texas	2:17-cv-00572
INTER PARTES REVIEW OF U.S. PATENT NO. 7,171,526 (Northstar Innovations – Micron)	PTAB	IPR2018-01004 IPR2018-01005
CISCO SYSTEMS, INC., vs. UNILOC USA, INC., UNILOC 2017 LLC and UNILOC LICENSING USA LLC	N.D. CA	3:18-cv-04991-SI
INTER PARTES REVIEW OF U.S. PATENT NO. 8,020,014 (Intel/VLSI)	PTAB	IPR2018-01661 IPR2018-01312
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