

Declaration of Jeremy Cooperstock, Ph.D. in Support of
Petition for *Inter Partes* Review of
U.S. Patent No. 9,727,217 B2

UNITED STATES PATENT AND TRADEMARK OFFICE

BEFORE THE PATENT TRIAL AND APPEAL BOARD

META PLATFORMS, INC.,
Petitioner

v.

IMMERSION CORPORATION,
Patent Owner

Case IPR2023-00946
U.S. Patent No. 9,727,217 B2
Issue Date: August 8, 2017

Title: HAPTICALLY ENHANCED INTERACTIVITY WITH INTERACTIVE CONTENT

DECLARATION OF JEREMY COOPERSTOCK, PH.D.

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I, Jeremy Cooperstock, Ph.D., declare as follows:

I. INTRODUCTION AND QUALIFICATIONS

A. Qualifications and Experience

1. I am a professor in the Department of Electrical and Computer Engineering at McGill University. My Curriculum Vitae is attached as **Exhibit A**.

2. I received my B.Sc. in Electrical Engineering (with Honors) from the University of British Columbia in 1990, my M.Sc. in Computer Science from the University of Toronto in 1992, and my Ph.D. in Electrical and Computer Engineering from the University of Toronto in 1996.

3. I am a member of the Centre for Intelligent Machines, and a founding member of the Centre for Interdisciplinary Research in Music Media and Technology at McGill University. I presently direct a group of approximately 50 researchers at the Shared Reality Lab at McGill, which focuses on computer mediation to facilitate high-fidelity human communication and the synthesis of perceptually engaging, multimodal, immersive environments. I led the development of the Intelligent Classroom, the world's first Internet streaming demonstrations of Dolby Digital 5.1, multiple simultaneous streams of uncompressed high-definition video, a high-fidelity orchestra rehearsal simulator, a simulation environment that renders graphic, audio, and vibrotactile effects in response to footsteps, and a mobile

game treatment for amblyopia.

4. My work on the Ultra-Videoconferencing system was recognized by an award for Most Innovative Use of New Technology from ACM/IEEE Supercomputing and a Distinction Award from the Audio Engineering Society. The research I supervised on the Autour project earned the Hochhausen Research Award from the Canadian National Institute for the Blind and an Impact Award from the Canadian Internet Registry Association, and my Real-Time Emergency Response project won the Gold Prize (brainstorm round) of the Mozilla Ignite Challenge. I am also a recipient of several “best paper” awards from scholarly societies for my research.

5. I have worked with IBM at the Haifa Research Center, Israel, and the Watson Research Center in Yorktown Heights, New York, the Sony Computer Science Laboratory in Tokyo, Japan, and was a visiting professor at Bang & Olufsen, Denmark, where I conducted research on telepresence technologies as part of the World Opera Project. I led the theme of Enabling Technologies for a Networks of Centres of Excellence on Graphics, Animation, and New Media (GRAND) and I am an associate editor of the Journal of the AES, the Frontiers Journal in Virtual Reality, and the Institute of Electrical and Electronics Engineers (IEEE) Transactions on Haptics.

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6. I have carried out significant research involving design and implementation of haptic feedback systems, virtual and augmented reality, and mobile computing applications. My work in these areas has been recognized with several best paper awards. In recognition of my expertise in the domain of haptics, I was invited to serve as an Associate Editor for the IEEE Transactions on Haptics, Associate Editor for the Frontiers in Virtual Reality, and Associate Editor for the World Haptics Conference.

7. My experience in academic and practical situations as well as my hands-on experience with multimedia production systems provides me with an appreciation of the technology involved with U.S. Patent No. 9,727,217 B2.

8. I have been retained by counsel for Petitioner to provide my expert opinion in connection with the above-captioned proceeding as set forth herein.

B. Materials Considered

9. The analysis that I provide in this Declaration is based on my education, research, and experience, as well as the documents I have considered. In forming my opinions, I have read and considered U.S. Patent No. 9,727,217 B2 (“’217 patent”) [EX1001] and its prosecution history. I have cited to the following documents in my analysis below:

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Exhibit No.	Description of Document
1001	U.S. Patent No. 9,727,217 B2 to David M. Birnbaum, Danny A. Grant, and Robert W. Heubel (filed June 2, 2014, issued August 8, 2017) (“ 217 ” or “ 217 patent ”)
1003	U.S. Patent Application Publication No. 2009/0066725 A1 to Atsushi Nogami and Naoki Nishimura (filed September 9, 2008, published March 12, 2009) (“Nogami”)
1004	U.S. Patent Application Publication No. 2007/0088943 A1 to Robert Phelps et al. (filed October 18, 2005, published April 19, 2007) (“Phelps”)
1005	U.S. Patent Application Publication No. 2008/0285854 A1 to Daisuke Kotake et al. (filed August 8, 2007, published November 20, 2008) (“Kotake”)
1006	U.S. Patent No. 7,084,884
1007	Excerpts from <i>Microsoft Computer Dictionary</i> (5th ed. 2002)
1008	Excerpts from <i>Newton’s Telecom Dictionary</i> (24th ed. 2008)
1009	Excerpts from <i>Dictionary of Computer and Internet Terms</i> (6th ed. 1998)
1010	Excerpts from <i>Oxford Dictionary of English</i> (2nd ed. revised 2005)
1011	Joint Claim Construction Statement, <i>Immersion Corp. v. Meta Platforms, Inc.</i> , No. 6:22-cv-00541-ADA (W.D. Tex.) (dated Jan. 21, 2023)

II. PERSON OF ORDINARY SKILL IN THE ART

10. I understand that, under the patent laws in effect before the America

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Invents Act (“AIA”) of 2011, an assessment of claims of a patent filed before the AIA took effect should be undertaken from the perspective of a person of ordinary skill in the art as of the earliest claimed priority date (*i.e.*, the “time the invention was made”). For purposes of the ’217 patent, I have assumed that date to be September 30, 2010, the filing date of the earliest patent application to which the ’217 patent claims priority (Appl. Ser. No. 12/895,161). I am also informed that in the related district court litigation, Patent Owner has asserted that the ’217 patent is entitled to a July 27, 2009 priority date. I express no opinion on whether the ’217 patent is actually entitled to a priority date as early as July 27, 2009. This issue is not relevant here because all prior art relied upon pre-dates that date, and my analysis and conclusions (including POSITA definition) would not change if a date as early as July 27, 2009 were applied. In the event a priority date before September 30, 2010 may later become relevant, for example based on arguments later presented by Patent Owner, I reserve my right to provide opinions on that issue at that time.

11. I have also been advised that to determine the appropriate level of a person having ordinary skill in the art, the following factors may be considered: (1) the types of problems encountered by those working in the field and prior art solutions thereto; (2) the sophistication of the technology in question, and the rapidity with which innovations occur in the field; (3) the educational level of active

workers in the field; and (4) the educational level of the inventor.

12. The '217 patent states that it relates to “haptically enhanced interactivity with interactive content being conveyed to a user by a content output appliance, wherein the content output appliance is under control of one or more processors that control the output of the interactive content based on one or more position parameters of a peripheral being manipulated by the user.” ('217, 1:17-23.)

13. In my opinion, a person of ordinary skill in the art as of September 2010 would have possessed a bachelor's degree in electrical engineering or computer science (or an equivalent degree), and two years of practical or industry experience in the field of human computer interaction, including implementation of computer-based systems and software for providing haptic feedback effects to a user and determining the position and/or orientation of a device used by a user (such as a device worn on the human body). A person could also have qualified as a person of ordinary skill in the art with some combination of (1) more formal education (such as a master's of science degree or higher) and less practical or industry experience, or (2) less formal education and more practical or industry experience.

14. My opinions regarding the level of ordinary skill in the art are based on, among other things, my decades of experience in the field, my understanding of the basic qualifications that would be relevant to an engineer or scientist tasked with

investigating methods and systems in the relevant area, and my familiarity with the backgrounds of colleagues, research associates, and students, both past and present, who have worked on systems for generating haptic feedback effects.

15. Although my qualifications and experience exceed those of the hypothetical person having ordinary skill in the art defined above, my analysis and opinions regarding the '217 patent have been based on the perspective of a person of ordinary skill in the art as of September 2010.

III. STATEMENT OF LEGAL PRINCIPLES

A. Claim Construction

16. I understand that a purpose of claim construction is to determine what a person of ordinary skill in the art would have understood the claim terms to mean. Claim terms are generally given their ordinary and customary meaning, which is the meaning that the term would have to a person of ordinary skill in the art in question as of the effective filing date.

17. I understand that the person of ordinary skill in the art is deemed to read the claim term not only in the context of the particular claim in which the disputed term appears, but in the context of the entire patent, including the specification. I understand that the patent specification, under the legal principles, has been described as the single best guide to the meaning of a claim term, and is thus highly

relevant to the interpretation of claim terms. And I understand for terms that do not have a customary meaning within the art, the specification usually supplies the best context of understanding the meaning of those terms.

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

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

20. I understand that, in *Inter Partes* Review (IPR) proceedings, a claim of a patent shall be construed using the same claim construction standard that would be used to construe the claim in a civil action filed in a U.S. district court (which I understand is called the “*Phillips*” claim construction standard), including construing the claim in accordance with the ordinary and customary meaning of such

claim as understood by one of ordinary skill in the art and the prosecution history pertaining to the patent.

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

22. I understand that in the related district court litigation, the parties dispute the meaning of one term appearing in the challenged claims: “**real space**.” Petitioner asserts that “real space” as used in the ’217 patent means “a three-dimensional area in the real world,” while Patent Owner asserts that the term should be given its “plain and ordinary meaning” but “to the extent that the Court believes that any further construction is necessary, the plain and ordinary meaning includes ‘the three-dimensional real world user surroundings.’” (EX1011 (Joint Claim Construction Statement), p.002.) For purposes of my analysis here, I do not believe express claim constructions are necessary because the prior art renders the claims obvious under these competing claim constructions or any other reasonable construction.

B. Obviousness

23. I understand that a patent claim is obvious if, as of the effective filing date, it would have been obvious to a person having ordinary skill in the field of the technology (the “art”) to which the claimed subject matter belongs.

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

25. I understand that a reference qualifies as prior art for obviousness purposes when it is analogous to the claimed invention. The test for determining what art is analogous is: (1) whether the art is from the same field of endeavor, regardless of the problem addressed, and (2) if the reference is not within the field of the inventor’s endeavor, whether the reference still is reasonably pertinent to the particular problem with which the inventor is involved.

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

27. I understand that when determining whether a patent claim is obvious in light of the prior art, neither the particular motivation for the patent nor the stated purpose of the patentee is controlling. The primary inquiry has to do with the objective reach of the claims, and that if those claims extend to something that is obvious, then the entire patent claim is invalid.

28. I understand one way that a patent can be found obvious is if there existed at the time of the invention a known problem for which there was an obvious

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

ordinary skill in the art can implement a predictable variation, an invention is likely obvious. I understand that combining embodiments disclosed near each other in a prior art reference would not ordinarily require a leap of inventiveness.

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

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

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

31. I understand that, when determining whether a claimed combination is

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

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

IV. THE '217 PATENT

A. Overview of the Specification

33. The '217 patent, entitled “Haptically Enhanced Interactivity With Interactive Content,” states that it “relates to haptically enhanced interactivity with interactive content being conveyed to a user by a content output appliance, wherein the content output appliance is under control of one or more processors that control the output of the interactive content based on one or more position parameters of a peripheral being manipulated by the user.” ('217, 1:17-23.)

34. In the “Background of the Invention” section, the '217 patent

acknowledges the existence of systems where “[u]sers may interact with virtual objects within a virtual environment in a number of manners,” which may include that “users may manipulate a physical object in the real world in order to interact with a virtual object.” (’217, 1:27-30.) The patent states that such interactions “may involve augmented reality technology” and that “visual and/or audio feedback may provide a sense of interaction with virtual objects to users.” (’217, 1:30-37.) The patent asserts: “In existing systems, however, no physical sense of interaction with virtual objects is provided to users.” (’217, 1:40-42.)

35. The patent purports to describe “a system configured to present interactive content to a user that is manipulating a peripheral.” (’217, 1:46-48.) The system may include a “haptics module” that may be “configured to determine haptic feedback to be provided to the user,” where the haptic feedback may be determined based on an “identification of the peripheral” and “one or more position parameters” that are “related to the position of the peripheral.” (’217, 1:48-64.) The patent states: “Haptics may include tactile and/or kinesthetic (force) feedback technology that takes advantage of a user's sense of touch by applying forces, vibrations, motions, and/or other touch feedback to the user.” (’217, 2:67-3:3.)

36. I discuss additional aspects of the ’217 patent as needed in the analysis below.

B. The Challenged Claims

37. This Declaration addresses claims 1-4, 8, 10, 11, and 17-19 of the '217 patent. Claims 1 and 17 are independent claims. Independent claim 1 recites:

1. A system comprising:
 - [a] a manipulatable input device movable through real space in at least three degrees of freedom, the manipulatable input device incorporating a haptic output device;
 - [b] a processor in communication with the haptic output device;
 - [c] a memory on which instructions executable by the processor are stored for causing the processor to:
 - [d] receive one or more sensor signals indicating a position of the manipulatable input device in the at least three degrees of freedom and an identification of the manipulatable input device;
 - [e] establish a communication pathway between the manipulatable input device and the processor;
 - [f] after establishing the communication pathway, determine a feedback parameter based at least in part on the position of the manipulatable input device in the at least three degrees of freedom and the identification of the manipulatable input device; and
 - [g] transmit a haptic signal to the haptic output device, the haptic signal

configured to cause the haptic output device to output a haptic effect according to the feedback parameter.

(’217, 12:49-13:4 (claim 1) (bracketed notations, *e.g.* “[a],” added).) Claim 17 recites a method with steps analogous to the functions recited in claim 1. (’217, 14:7-25 (claim 17).) I address the claims further in my detailed analysis in **Part V** below.

V. APPLICATION OF THE PRIOR ART TO CHALLENGED CLAIMS

38. I have reviewed and analyzed the prior art references and materials listed in **Part I.B** above. In my opinion the challenged claims of the ’217 patent would have been obvious to a person of ordinary skill in the art based on the following combinations of the prior art.

Ground	Claims	Basis for Challenge (Obviousness)
1	1-4, 8, 10-11, 17-19	Nogami in view of Phelps
2	11, 19	Nogami in view of Phelps and Kotake

39. I am informed by counsel that Nogami qualifies as prior art to the challenged claims because it was filed and published before the ’217 patent priority date (September 30, 2010). Moreover, Nogami is an analogous reference in the same field as the ’217 patent. The ’217 patent identifies its “Field of the Invention” as relating to “haptically enhanced interactivity with interactive content being

conveyed to a user by a content output appliance, wherein the content output appliance is under control of one or more processors that control the output of the interactive content based on one or more position parameters of a peripheral being manipulated by the user.” (’217, 1:17-23.) As described in detail below, Nogami discloses such a system for providing interactive content, *i.e.*, a virtual space that includes interactive background and region virtual objects with which the user can interact, and in response to which, haptic stimulation can be provided. Nogami would also have been reasonably pertinent to a number of problems facing the inventors, including how to determine the position/orientation of a peripheral used by the user (such as a head-mounted display), how to generate interactive content for the user and how to generate haptic stimulation based on the user’s interactions with that interactive content. An ordinarily skilled artisan would have had at least a reasonable expectation of success in carrying out Nogami’s teachings, as they involve known image processing and computer graphics techniques, that could have been implemented using conventional programming techniques.

40. Nogami also describes at least 10 “exemplary embodiments” with respect to its system. (Nogami, *e.g.*, ¶¶0046 (“First Exemplary Embodiment”), 0202 (Second), 0214 (Third), 0233 (Fourth), 0240 (Fifth), 0252 (Sixth), 0262 (Seventh), 0268 (Eighth), 0275 (Ninth), 0278 (Tenth), 0284 (“Other Exemplary

Embodiments”).) A person of ordinary skill in the art would have understood Nogami’s description of “embodiments” as describing additional features that may be incorporated into the Nogami’s system, rather than different or separate systems altogether. Nogami confirms as much by stating, after discussing his “Tenth Exemplary embodiment,” that “the above-described exemplary embodiments can be used in combination with each other where appropriate.” (Nogami, ¶0283.) It therefore would have been obvious to an ordinarily skilled artisan implementing the system of Nogami to include and/or combine any of the additional features described in any of Nogami’s variously numbered embodiments.

A. Brief Summary and Overview of the Prior Art

41. The challenged claims of the ’217 patent attempt to lay claim to techniques for using haptic feedback in systems providing augmented reality (“AR”) and/or virtual reality (“VR”) interfaces that were already well-known long before September 2010. The patent asserts that in existing systems, “[u]sers may interact with virtual objects within a virtual environment,” but according to the patent, “no physical sense of interaction with virtual objects is provided to users.” (’217, 1:27-28, 1:40-42.) In fact, the prior art was rich with techniques to provide to users a physical sense of interaction with virtual objects through haptic feedback, including the prior art I discuss below.

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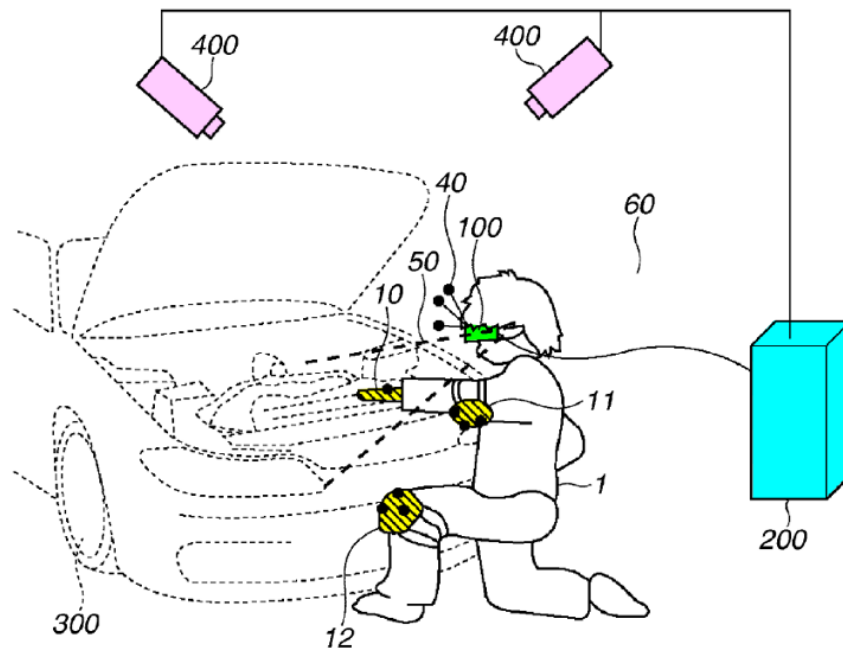
1. Nogami [EX1003]

42. **Nogami**, U.S. Patent Application Publication No. 2009/0066725 A1 to Atsushi Nogami et al., is entitled “Information-Processing Apparatus and Information-Processing Method.” I am informed that Nogami qualifies as prior art because it was filed on September 9, 2008 and published on March 12, 2009, both dates being before the September 30, 2010 priority date of the challenged claims.

43. Nogami discloses “an information-processing apparatus configured to implement an interaction between a virtual space and a user who observes the virtual space and to an information-processing method therefor.” (Nogami, ¶0002.) Nogami acknowledges that virtual reality (VR) systems providing a virtual space using three-dimensional computer graphics that could be output to a head-mounted display (HMD) were known in the art. (Nogami, ¶0004.)

44. Figure 1 of Nogami is an exemplary embodiment of the system when being used by a user:

FIG.1



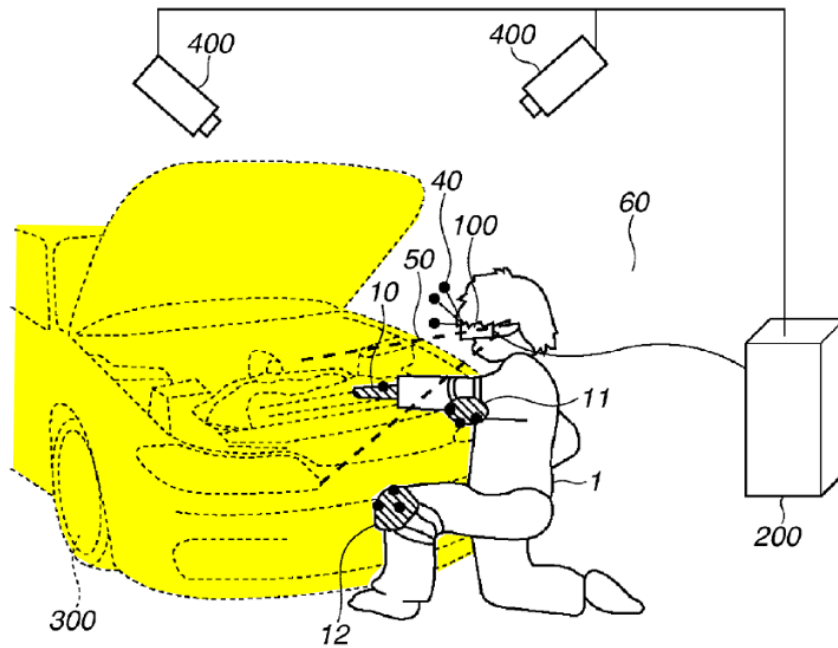
(Nogami, Fig. 1 (highlighting added); *see also id.*, ¶¶0030 (describing Fig. 1), ¶¶0046, 0048-0059 (describing components).) The embodiment illustrated in Figure 1 of Nogami depicts position and orientation sensor 400 as comprising a camera that is physically apart from the HMD 100. (See, e.g., Nogami, ¶0074.) In another embodiment, HMD 100 itself includes a position and orientation sensor. (Nogami, ¶0077 (“[T]he HMD 100...ha[s] a receiver for detecting a change in the magnetic field occurring as the HMD 100...change[s its] position and orientation in the magnetic field.”).)

45. The system in Nogami can display two types of “virtual objects” to the

user through HMD **100**: (1) “region virtual objects”; and (2) “background virtual objects.” (Nogami, *e.g.*, ¶0111-0114; *see also id.*, ¶0056 (explaining that HMD **100** displays the image provided by calculation processing apparatus **200**).) Nogami describes a “region virtual object” as corresponding to a virtual representation of a stimulation generation unit— for example, a user’s glove-shaped stimulation generation unit could have a corresponding glove-shaped “region virtual object.” (Nogami, *e.g.*, ¶0268 (“[T]he region virtual object has a shape similar to that of the stimulation generation unit in the real space. However, the shape is not limited to this.”); *see also id.*, ¶¶0269-0270, 0141 (“[R]egion virtual objects **311** and **312** is a virtual object generated by imitating a shape of the stimulation generation units **10** and **11** corresponding thereto.”).)

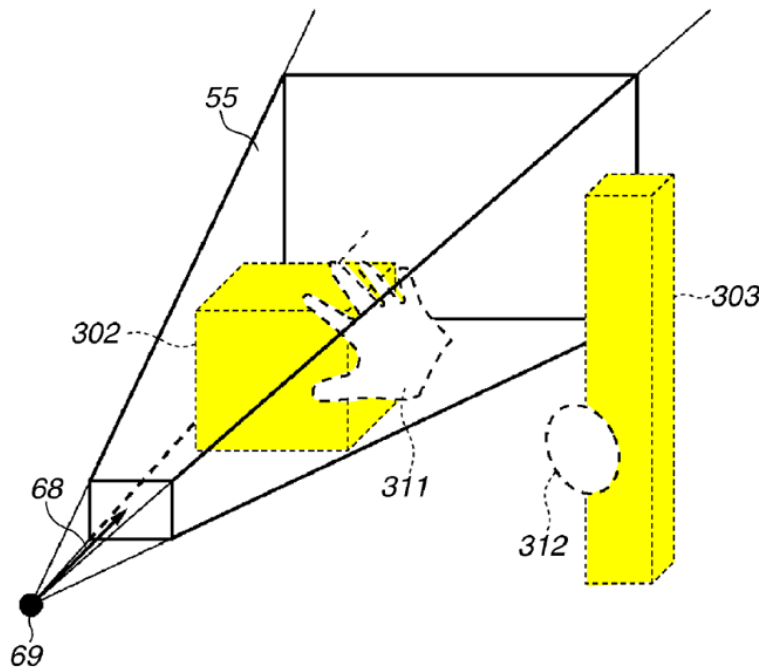
46. A “background virtual object,” on the other hand, corresponds to a virtual representation of another object that the user can interact with in virtual space. (Nogami, *e.g.*, ¶0114.) Figure 1 of Nogami above illustrates an example of a virtual space including a background virtual object in the form of “a virtually expressed imitation image of an automobile in an actual size” (Nogami, ¶50), which I have highlighted in yellow below:

FIG.1



(Nogami, Fig. 1 (highlighting added).) Figure 6 of Nogami provides another example of virtual objects, shapes **302** and **303** (highlighted below):

FIG.6



(Nogami, Fig. 6 (highlighting added); *see also id.*, ¶0140 (“[B]ackground virtual objects **302** and **303** are disposed in the virtual space.”).)

47. As noted, the system of Nogami can also display a “region virtual object” within that same virtual space – for example, a region virtual object that includes the shape of a virtual work tool, such as a screwdriver or wrench. (Nogami, ¶¶0270-273.) Both the background and region virtual objects are interactive because the user can visually interact with them by changing their position relative to the virtual objects and thereby changing how the objects are displayed to the user. (Nogami, *e.g.*, ¶¶0005, 0027, 0109, 0140-0147 (describing how virtual objects

including region and background virtual objects are generated for display based on current position and orientation information).)

48. The system of Nogami can also produce haptic stimulations for the user. For example, Nogami uses the position and orientation of HMD **100** to define a “view volume” that indicates the range of the virtual space that will be displayed on the HMD **100**. (Nogami, *e.g.*, ¶¶0139-0145.) Nogami refers to a “view volume” as providing an “attention range” for the user, which Nogami generally describes as “a range in which the user **1** can perceive a virtual object with the visual sense and a part thereof.” (Nogami, ¶¶0101, 0147 (“Here the view volume **55** is used as the attention range.”), 0159.)

49. Nogami explains that its system uses the “attention range” to determine “operation setting information” (such as stimulation intensity) to output to the user’s stimulation generation units. (Nogami, ¶¶0102-0103, Fig. 4, ¶¶0118-0122 (describing Fig. 4), Fig. 6, ¶¶0148-0154 (describing Fig. 6).) The operation setting information used differs based on whether virtual contact between a region virtual object and background virtual object occurs in the attention range. (Nogami, ¶¶00148-0154.) Nogami explains that one way to determine whether a stimulation generation unit is within the user’s attention range is to mount a bar code identification on the stimulation generation unit and to process real space images

capturing the user's visual field to recognize the bar code. (Nogami, ¶¶0202-0213; Fig. 11.)

50. I will provide more information about Nogami in my discussion of the claim limitations below.

2. Phelps [EX1004]

51. **Phelps**, U.S. Patent Application Publication No. 2007/0088943 A1 to Robert Phelps et al., is entitled "BIOS Identification, Initialization and Management." I am informed that Phelps qualifies as prior art because it was filed on October 18, 2005 and published on April 19, 2007, both dates being before the September 30, 2010 priority date of the challenged claims.

52. My Declaration cites Phelps for the limited purpose of addressing claim 1[e], which recites "**establish[ing] a communication pathway between the manipulatable input device and the processor,**" and also aspects of claim 1[f] reciting the ability to determine a haptic parameter "**after establishing the communication pathway**" of claim 1[e]. My Declaration relies on Phelps to not only show that the claimed establishment of a communication pathway would have been obvious, but that it would have been obvious to perform that step before the following step of determining a haptic parameter in Nogami.

53. Nogami explains that its calculation processing apparatus **200** can

include “a general-purpose personal computer (PC), for example.” (Nogami, ¶0082.) Nogami further explains that the various hardware components of the calculation processing apparatus **200** are connected via a system bus **211**, but Nogami does not describe this connection in any detail. (Nogami, ¶0096, Fig. 2 (system bus **211**).) But the ability of calculation processing apparatus **200** to establish a communication pathway with various peripheral devices would have been basic knowledge to ordinarily skilled artisans.

54. For example, Phelps describes a well-known process performed by conventional personal computers (PCs) when they are first powered up, in which the core hardware components of the system are initially tested:

When computers are initially turned on or reset, they typically go through a “booting” process. When a computer “boots” a built-in diagnostic program known as a power-on self-test (POST) is performed wherein various tests are run to confirm core components of the computer system are present and functioning properly and wherein the registers within certain hardware devices are initialized.

(Phelps, ¶0002.) This process would have been familiar not only to ordinarily skilled artisans, but laypersons who had ever turned on an IBM PC-compatible personal computer and observed the power-on-self-test (POST) process, which often results in the display of textual statements to the user indicating that various components of

the system have been detected and checked and are “OK” or have “PASSED.”

Phelps continues:

Part of performing the POST involves loading the basic input and output system (BIOS) code into memory. A computer system requires BIOS to control the basic hardware operations, such as interactions with disk drives, hard drives, the keyboard, and other peripheral devices. After performing the POST, the computer typically loads an operating system (OS).

(Phelps, ¶0002.) The BIOS, in turn, is software or instructions used “to identify, initialize, allocate and manage other system hardware.” (Phelps, ¶0003.) “By providing a set of low-level routines the BIOS enables the OS to interface with different hardware devices while in operation, thus facilitating the operation of various software applications.” (Phelps, ¶0003; *see also Microsoft Computer Dictionary* (5th ed. 2002) [EX1007], p.60 (“**BIOS** *n.* Acronym for **basic input/output** system. On PC-compatible computers, the set of essential software routines that tests hardware at startup, starts the operating system, and supports the transfer of data among hardware devices, including the date and time.”) (bold and italics in original).) As I will explain below for claim 1[e], because Nogami identifies the calculation processing apparatus **200** as including a “general-purpose personal computer” (Nogami, ¶0082), it would have been obvious that the calculation

processing apparatus **200** in Nogami would have established a communication pathway using system bus **211**, for example, by loading the BIOS into memory as part of start-up/booting process of the computer.

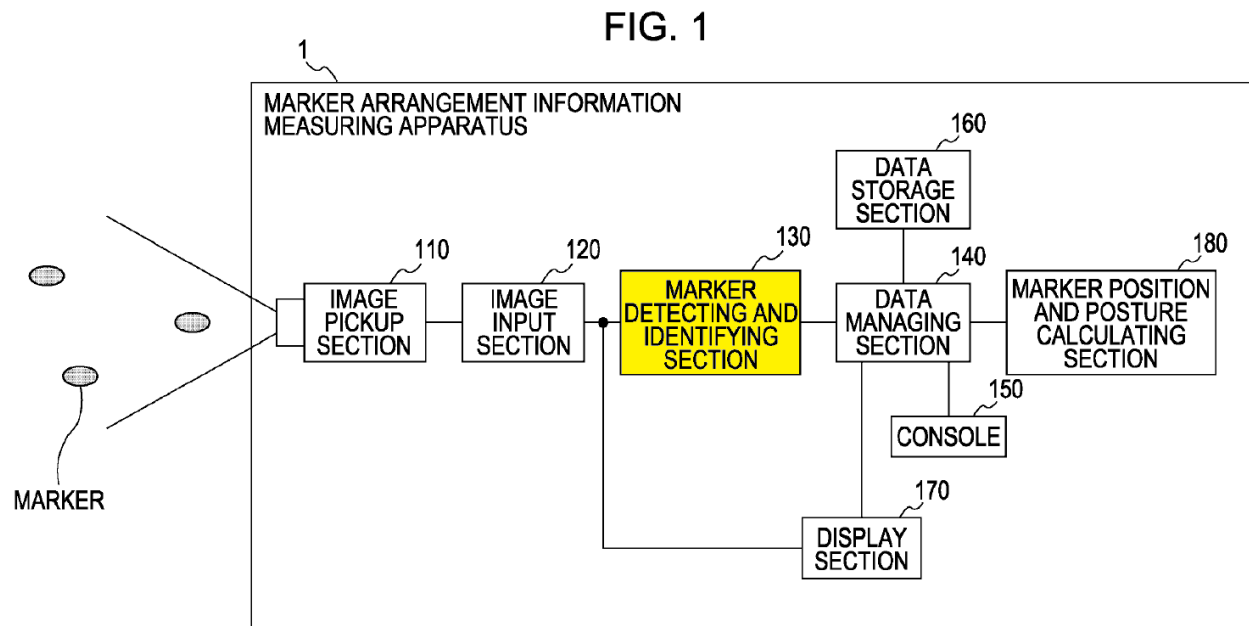
3. **Kotake [EX1005]**

55. **Kotake**, U.S. Patent Application Publication No. 2008/0285854 A1 to Daisuke Kotake et al., is entitled “Marker Arrangement Information Measuring Apparatus and Method.” I am informed that Kotake qualifies as prior art because it was filed on August 8, 2007 and published on November 20, 2008, both dates being before the priority date of the challenged claims.

56. My Declaration cites Kotake primarily as an alternative ground for obviousness of the second part of dependent claim 11, which recites “**an identification sensor configured to identify the manipulatable input device and transmit a second sensor signal.**” As I will explain below for **Ground 1**, Nogami discloses the ability to detect bar code **45** in a real space image captured by imaging unit **101** of the user’s HMD **100**, the bar code identifying the stimulation generation unit. (Nogami, *e.g.*, ¶¶0206-0209.) But as explained in the discussion of claim 11 below for **Ground 1**, Nogami does not provide specific details about how CPU **201** is notified that bar code **45** has in fact been detected in the real space image.

57. Kotake discloses a technique for detecting “markers” appearing in an

image of three-dimensional space captured by a camera. Figure 1 shows a block diagram of a marker arrangement information measuring apparatus **1** used to perform the disclosed technique:



(Kotake, Fig. 1 (highlighting added).)

58. Figure 1 shows an image pickup section **110**, which is “constituted by a video camera and captures an image of a scene or an object on which markers [shown on the left] are arranged.” (Kotake, ¶0046.) In one exemplary embodiment, the markers in the image can take the form of “square markers” that have an outer boundary region or frame and an inner region. (Kotake, ¶0047; *see also id.*, ¶0073 (explaining that other types of markers can be used).) “An image input section **120** takes the image captured by the image pickup section **110** into a computer.”

(Kotake, ¶0046.)

59. The key section of Figure 1, for purposes of my Declaration, is **marker detecting and identifying section 130** shown in yellow highlighting. This section, as its label indicates, detects and identifies markers within the captured image, and outputs a marker detection result:

A marker detecting and identifying section **130** detects each marker from the image taken into the computer by the image input section **120** and identifies the detected marker. A data managing section **140** receives a marker detection result from the marker detecting and identifying section **130**.

(Kotake, ¶0046; *see also id.*, ¶¶0051-0052.) Marker detecting and identifying section **130**, more specifically, “detects the markers contained in the image and reads the identifier specific to each marker for identification of the marker.” (Kotake, ¶0055.) Marker detecting and identifying section **130** also outputs, in addition to the identification of the marker, “image coordinates of four apexes of the marker to the data managing section **140**.” (Kotake, ¶0055.) Data managing section **140**, in turn, can store the marker detection result in data storage section **160**, count the number of times the marker has been detected, cause images to be presented on display section **170**, or perform other operations. (Kotake, *e.g.*, ¶¶0052-0053.) Data managing section **140** can also provide the marker detection result to marker position

and posture calculation section **180**, which “calculates the position and the posture of the marker based on the marker detection result for each of a plurality of images.” (Kotake, ¶0054.)

60. I will provide more information about Kotake in my discussion of **Ground 2** below.

B. Ground 1: Claims 1-4, 8, 10-11, and 17-19 Are Obvious Over Nogami in view of Phelps.

1. Claim 1

61. For reference, claim 1 recites:

1. A system comprising:
 - [a] a manipulatable input device movable through real space in at least three degrees of freedom, the manipulatable input device incorporating a haptic output device;
 - [b] a processor in communication with the haptic output device;
 - [c] a memory on which instructions executable by the processor are stored for causing the processor to:
 - [d] receive one or more sensor signals indicating a position of the manipulatable input device in the at least three degrees of freedom and an identification of the manipulatable input device;
 - [e] establish a communication pathway between the manipulatable input

device and the processor;

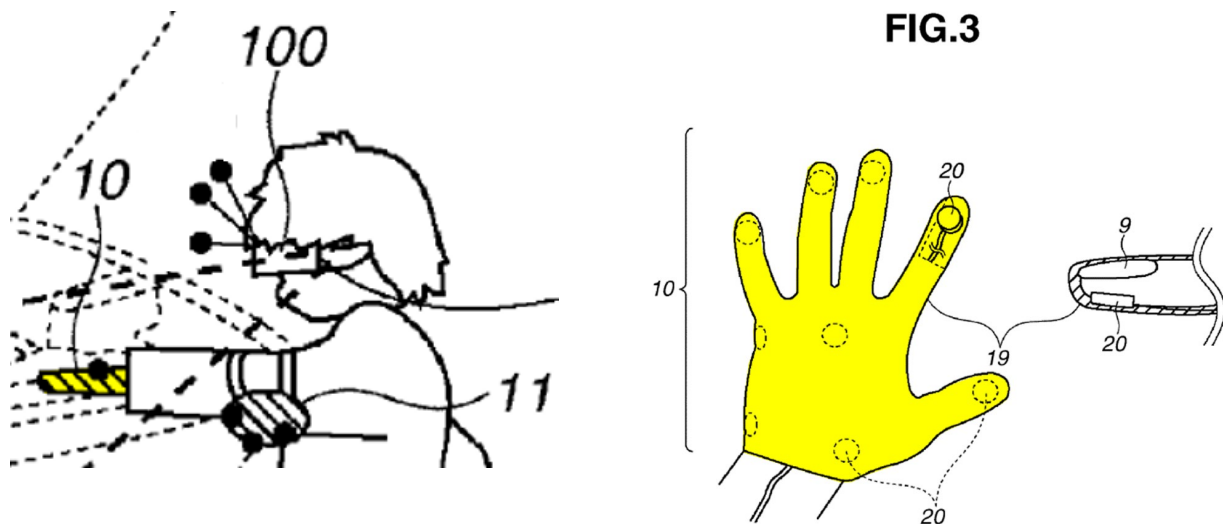
- [f] after establishing the communication pathway, determine a feedback parameter based at least in part on the position of the manipulatable input device in the at least three degrees of freedom and the identification of the manipulatable input device; and
- [g] transmit a haptic signal to the haptic output device, the haptic signal configured to cause the haptic output device to output a haptic effect according to the feedback parameter.

(’217, 14:49-15:4 (claim 1) (bracketed notations, *e.g.* “[a],” added).)

62. The preamble of claim 1 recites “[a] **system comprising**” the identified elements. Nogami discloses a “**system**” comprising the components shown in Figures 1 and 2, including stimulation generation units **10**, **11**, and **12** mounted on the body of user **1**, HMD **100** mounted on the user’s head, position and orientation sensor **400** (alternatively, magnetic receivers), and calculation processing apparatus **200**. (Nogami, Figs. 1, 2; ¶¶0030-0031 (“system” shown in Figs. 1-2), 0046-0059, 0077-0078.) The system components further include subcomponents as described in the text and shown in Figure 2. (*See id.*) I will describe the features of the Nogami system in my discussion below, and explain how those features render obvious the claim limitations.

- (a) “a manipulatable input device movable through real space in at least three degrees of freedom, the manipulatable input device incorporating a haptic output device;” (Claim 1[a])

63. Nogami discloses “a manipulatable input device” in the form of stimulation generation unit **10**, which is a “glove-like” unit “mounted on the hand of the user,” as illustrated in Figures 1 and 3:



(Nogami, Fig. 1 (excerpt), Fig. 3 (highlighting added to both); *see also id.*, Fig. 2, ¶¶0049, 0051-0052, 0060-0061.)

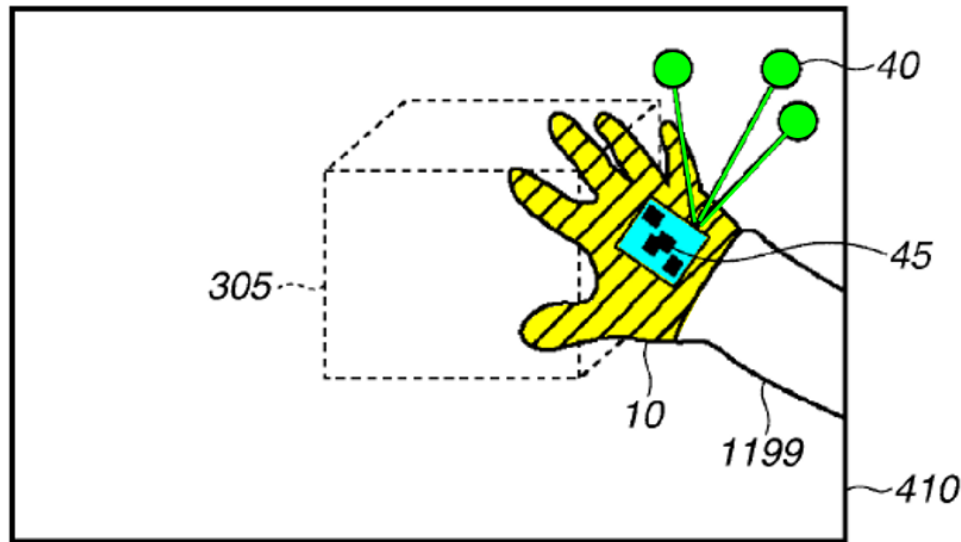
64. Stimulation generation unit **10** also qualifies as an “**input device.**”¹ As

¹ Glove-like input devices were well-known long before the September 2010 priority date of the '217 patent. For example, the 2002 edition of the *Microsoft Computer Dictionary* defines a “data glove” as “[a] data input device or controller in the form of a glove fitted with sensors that convert movement of the hand and fingers into

I will explain in more detail below, stimulation generation unit **10** enables **input** of information in at least two categories in response to user action: (1) device position and orientation information (based on location and movement of the user's hand), as well as (2) device identification information (based on information on the stimulation generation unit worn by the user). For example, Nogami describes an embodiment in which stimulation generation unit **10** includes **marker 40** and **bar code 45**, as illustrated in Figure 11:

commands” and “sensor glove” as [a] hand-worn computer input device for virtual-reality environments. The glove translates finger movements by the user to commands for manipulating objects in the environment.” (EX1007, pp.143, 472.) U.S. Patent No. 7,084,884 B1 to Donald Nelson et al., filed in July 2001 and issued in August 2006, similarly describes commercially available CyberGlove and CyberGrasp input/output devices. (EX1006, 9:42-48, 10:27-32.)

FIG.11



(Nogami, Fig. 11 (highlighting added); *see also id.*, ¶¶0204-0213 (describing Figure 11).)² Marker 40 of stimulation generation unit 10 is used to determine position and orientation information to the system based on the location and position of stimulation generation unit 10 worn by the user. Nogami explains that marker 40 is

² Nogami provides multiple “exemplary embodiment” disclosures that Nogami teaches and motivates combining with each other. Specifically, Nogami provides ten exemplary embodiment disclosures, (Nogami, ¶¶0046-0282) and then teaches that “the above-described exemplary embodiments can be used in combination with each other where appropriate.” (Nogami, ¶0283.) A person of ordinary skill in the art would have understood and found it obvious that Nogami’s teachings for various embodiments that I discuss in my Declaration are complementary and would have been appropriate to implement together in combination.

“made of a retroreflective material” so that it can be detected by an infrared camera included in position and orientation sensors **400**. (Nogami, ¶0074 (“The optical position and orientation acquisition system includes a plurality of position and orientation sensors **400** including a camera having an infrared radiation function and a plurality of markers **40** made of a retroreflective material.”).) “[T]he position and orientation sensor **400** can detect the position and orientation of the” stimulation generation unit **10** on which marker **40** is disposed and can thereby acquire position and orientation information about the marker **40**. (Nogami, ¶0073.) In another embodiment, position and orientation information is provided by a magnetic receiver included in the stimulation generation unit. (Nogami, ¶¶0077-0078.) In either embodiment, position and orientation information is input to the calculation processing apparatus **200** computer system based on the movement, position, and orientation of stimulation generation unit **10** worn by the user. (Nogami, ¶0082 (“In the present exemplary embodiment, the position and orientation information about the HMD **100** and the position and orientation information about the stimulation generation units **10**, **11**, and **12** acquired by the position and orientation sensor **400** are sent to the calculation processing apparatus **200**. The calculation processing apparatus **200** includes a general-purpose personal computer (PC), for example.”).) For this reason, stimulation generation unit **10** qualifies as an “**input device**,” as

claimed.

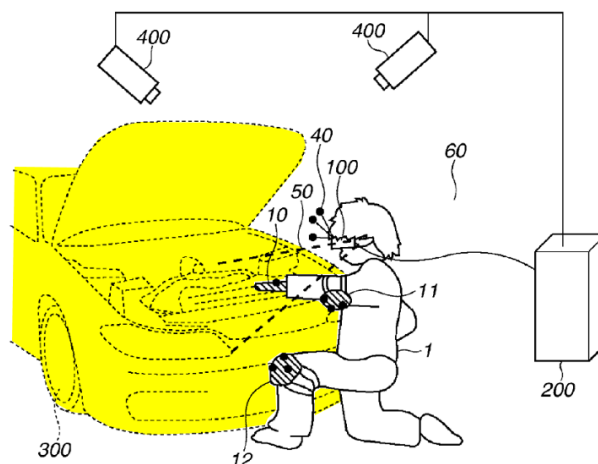
65. Stimulation generation unit **10** also includes **bar code 45** that enables **input** of device identification information into the system. Nogami explains that “[t]he two-dimensional bar code **45** indicates ID information (e.g., an ID) unique to the stimulation generation unit **10**.” (Nogami, ¶0206.) By manipulating the position and orientation of stimulation generation unit **10**, bar code **45** can be captured by imaging unit **101** of the user’s HMD **100**, enabling the system to determine whether stimulation generation unit **10** is within the user’s visual field. (Nogami, ¶0208 (“In the present exemplary embodiment, when the stimulation generation unit **10** is included in the real space image **410** (located within the real space image **410**), the CPU **201** determines that the stimulation generation unit **10** is located within the attention range. More specifically, if the two-dimensional bar code **45** is detected in the real space image **410** and the two-dimensional bar code **45** is successfully recognized, then the CPU **201** determines that a stimulation generation unit **10** indicated by the two-dimensional bar code **45** and identified by the recognition is located within the attention range.”); *see also id.*, ¶¶0209-0210, 0052-0054 (describing real space image captured by imaging unit **101** of HMD **100**).)

66. Stimulation generation unit **10** is also a “**manipulatable input device**” because, for example, the user can move or manipulate stimulation generation unit

10, resulting in inputs of information into the system. (*E.g.*, Nogami, ¶¶0073-0082 (describing acquiring position and orientation information of stimulation generation units), 0080 (“[I]t is useful to acquire the position and orientation information about the stimulation generation units **10**, **11**, and **12** using a publicly known motion capture method.”).) Device manipulation, as I will explain in further detail below, includes **“mov[ing] through real space in at least three degrees of freedom.”**

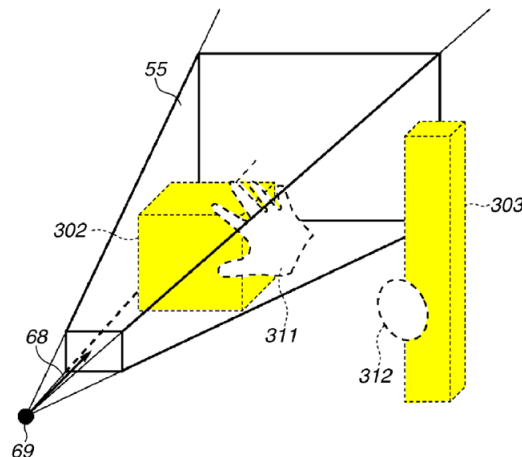
67. As a result of device manipulation, a user can interact with virtual objects, such as by making virtual contact with them. For example, Figure 1 of Nogami illustrates a user interacting with a virtual object in the form of “a virtually expressed imitation image of an automobile in an actual size” (Nogami, ¶50), highlighted in yellow below:

FIG.1



(Nogami, Fig. 1 (highlighting added); *see also id.*, ¶0050 (“The user **1**, in FIG. **1**, is currently performing a verification operation with respect to an operation to be performed on an engine compartment of the automobile.”).) Figure 6 of Nogami provides another example of interacting with virtual objects, shapes **302** and **303** (highlighted below):

FIG.6



(Nogami, Fig. 6 (highlighting added); *see also id.*, ¶¶0140 (“[B]ackground virtual objects **302** and **303** are disposed in the virtual space.... A region virtual object **311** is disposed according to the position and orientation of the stimulation generation unit **10**.”), 0148 (“In the example illustrated in FIG. 6, the region virtual object **311** and the background virtual object **302** contact each other.”), 0211 (describing Fig. 11, “determine whether the corresponding region virtual object and the background virtual object contact each other”).)

68. Nogami's stimulation generation unit **10** is also consistent with the ordinary understanding of the term "**input device**" as well as the '217 patent's description of "**manipulatable input device.**" Generally speaking, an "**input device**" refers to a "peripheral device whose purpose is to allow the user to provide input to a computer system," such as a keyboard, mouse, joystick, stylus, among other devices. (Microsoft Computer Dictionary (5th ed. 2002) [EX1007], p.274 (definition of "input device").) As explained above, Nogami's stimulation generation unit **10** allows input of information relating to position and orientation, as well as device identification, to the computer system. Similarly, although the written description of the '217 patent itself does not recite the term "**manipulatable input device,**" it makes clear that one example is a "peripheral" that "can be manipulated by a user to interact with interactive content. Such manipulation of the peripheral **102** may include translating, rotating, deforming, and/or otherwise moving the peripheral **102.**" ('217, 3:20-25; *see also id.*, 2:57-59 ("FIG. 1 illustrates a system **100** configured to present interactive content to one or more users manipulating one or more peripherals....").) As discussed above, Nogami's stimulation generation unit **10** can be manipulated by a user to interact with various virtual objects, such as by making virtual contact with a virtual automobile.

69. The stimulation generation unit **10** ("**manipulatable input device**") is

“movable through real space in at least three degrees of freedom.” The concept of “degrees of freedom” is not expressly described in the ’217 patent but was well known to a person of ordinary skill in the art as referring to any of the directions in which independent motion can occur. (Oxford Dictionary of English (2nd ed. revised 2005) [EX1010], p.457 (defining “degree of freedom” as “each of a number of independently variable factors affecting the range of states in which a system may exist, in particular any of the directions in which independent motion can occur.”).) For example, independent motion in the x- and y-planes would be an example of motion in “two degrees of freedom.” Additional independent motion in the z-plane – *i.e.*, motion in a 3-dimensional space – provides an example of motion in “three degrees of freedom.”

70. Nogami makes clear that stimulation generation unit **10** mounted on the user’s hand is movable by the user through real space in at least three degrees of freedom. This is because stimulation generation unit **10** is mounted on the user’s hand, which can move vertically, horizontally, and forward/backward in space, as illustrated in Figures 1, 6 and 11 of Nogami, for example. (Nogami, Figs. 1, 6 & 11.) Nogami also describes an embodiment in which movement of a stimulation generation unit can occur in three degrees of freedom – *i.e.*, along the x, y, and z axes – and is tracked using a transmitter and receivers on the units. (Nogami, ¶0078

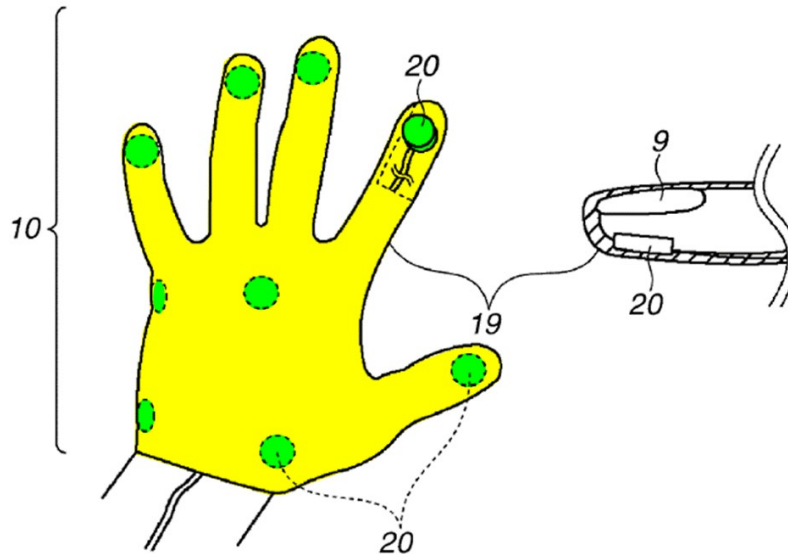
(sensor system can use a “sensor coordinate system” that has an origin point denoting the position of a transmitter and “an x-axis, a y-axis, and a z-axis orthogonal to one another at the origin point”).) Nogami repeatedly refers to a user interacting in a “space” or “volume,” which an ordinarily skilled artisan would have understood as referring to three dimensional space. (E.g., Nogami, ¶¶0004 (“[T]he VR system configures a virtual space using three-dimensional computer graphics (CG) and displays an image in the virtual space on a large-sized display, a mobile apparatus display, or a head-mounted display (HMD). Thus, the VR system can cause a user to feel as if the virtual space is a real space.”), 0005 (“[A] mixed reality system (MR system) has been developed for superposedly displaying a virtual object generated using three-dimensional CG on an image in a real space.”), 0045 (“[A] system is described that implements an interaction between a user and a virtual space...”), 0049 (“[T]he user **1** can experience a virtual space including a virtual object **300** with both a visual sense and a tactile sense...”), 0113 (“[T]he position and orientation of each of the stimulation generation units **10**, **11**, and **12** is reflected in the virtual space. The interaction between each of the stimulation generation units **10**, **11**, and **12** and the virtual space is available in this manner.”), 0144 (“[T]he view volume **55** indicates a range of the virtual space drawn on the display unit **102** of the HMD **100**.”), 0149 (“In the example illustrated in FIG. **6**, the region virtual object

311 is located within the view volume **55**, while the region virtual object **312** is located outside the view volume **55**.”).)

71. As noted in **Section III.A** above, the parties in the related district court litigation dispute the meaning of the term “**real space**.” Petitioner asserts that “real space” as used in the ’217 patent means “*a three-dimensional area in the real world*,” while Patent Owners asserts that the term should be given is “plain and ordinary meaning” but “*to the extent that the Court believes that any further construction is necessary, the plain and ordinary meaning includes ‘the three-dimensional real world user surroundings.’*” (EX1011 (Joint Claim Construction Statement), p.002.) It is not necessary for me to offer an opinion regarding which proposed construction is correct because Nogami discloses this limitation under both proposals. With respect to Petitioner’s proposal, as shown above, stimulation generation unit **10** is movable in a three-dimensional area in the real world. And similarly, as to Patent Owner’s proposal, stimulation generation unit **10** is movable in a three-dimensional real world user surroundings.

72. Lastly, Nogami’s stimulation generation unit **10** (“**manipulatable input device**”) “**incorporat[es] a haptic output device**.” Nogami explains that stimulation generation unit **10** includes **cutaneous sense stimulation units 20**, as shown in Figure 3 below:

FIG.3



(Nogami, Fig. 3 (highlighting added).) Nogami describes stimulation generation unit **10** includes cutaneous sense stimulation units **20**:

Referring to FIG. 3, the stimulation generation unit **10** includes a glove-like shaped main body unit **19** and one or more cutaneous sense stimulation units **20**. Here, it is useful if the main body unit **19** has such a configuration that the cutaneous sense stimulation unit **20** closely contacts the human body **9** of the user **1** (the back of the user's hand in the example in FIG. 3) so that a stimulation generated by the cutaneous sense stimulation unit **20** is transmitted to the human body **1** with an intensity high enough for the user **1** to recognize the vibration.

The cutaneous sense stimulation unit **20** includes a vibration motor, for example. Here, with respect to the cutaneous sense stimulation unit **20**,

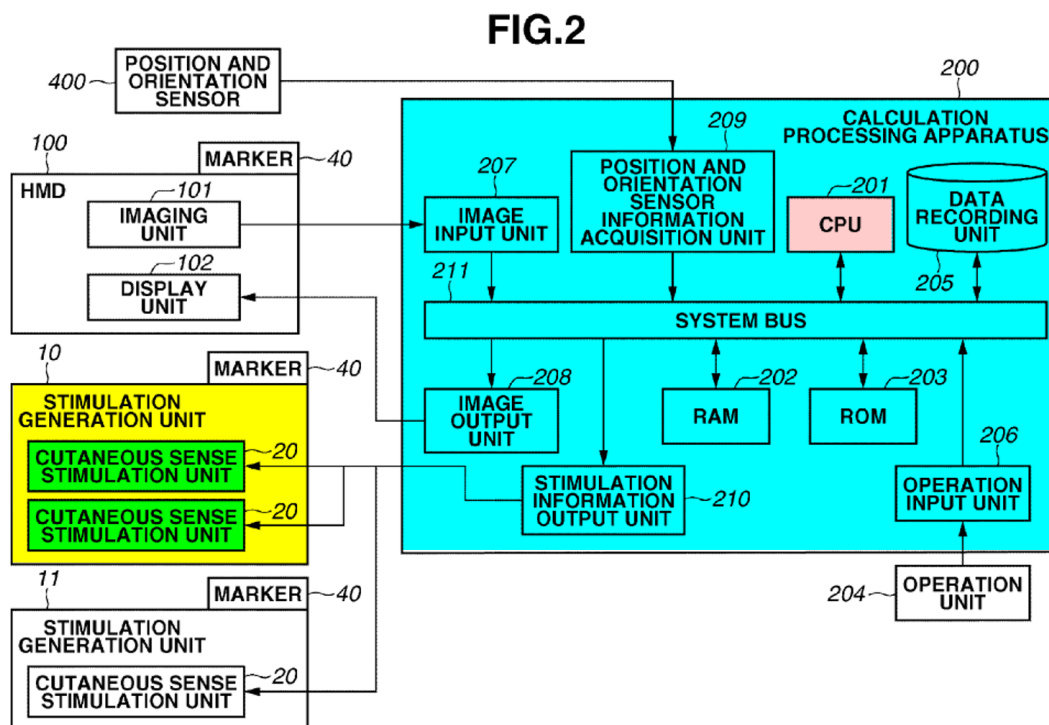
it is useful if a plurality of cutaneous sense stimulation units **20** are mounted on regions of the user's body at the front or the back of the hands and is selected and driven according to user's contact with a virtual object by the body region.

(Nogami, ¶¶0061-0062.) A cutaneous sense stimulation unit **20** incorporated within stimulation generation unit **10** (and any associated electronics within a stimulation generation unit enabling its operation) thus discloses a “**haptic output device**.” This is because sense stimulation unit **20** expresses tactile sense information, consistent with the description of “haptics” in the '217 patent and that term as it was commonly understood. ('217, 2:67-3:3 (“Haptics may include tactile and/or kinesthetic (force) feedback technology that takes advantage of a user's sense of touch by applying forces, vibrations, motions, and/or other touch feedback to the user.”); *see also* Nogami, ¶¶0013 (“A device that expresses tactile sense information is generally called a ‘haptic device’ or a ‘haptic display’. Such a ‘haptic device’ or a ‘haptic display’ includes a force feedback providing apparatus that expresses a reaction from a virtual object and a cutaneous sense providing apparatus (tactile display) that provides a stimulation to a cutaneous sense of a user.”), 0061-0071 (describing stimulation generation unit and cutaneous sense stimulation via vibration and other techniques).) The exemplary types of cutaneous sense stimulation units that Nogami

describes – including “vibration motor,” “voice-coil type device,” and other “actuators” – are consistent with examples of “haptic output devices” disclosed in the ’298 patent. (*Compare* Nogami, ¶¶0067-0069 with ’217, 4:50-57 (“electronic sound transducer,” “actuator”), 7:60-8:1 (“electric motor with an unbalanced mass”).)

(b) “a processor in communication with the haptic output device;” (Claim 1[b])

73. Nogami discloses “a processor,” *i.e.*, central processing unit (CPU) 201. CPU 201 is contained within calculation processing apparatus 200, as shown in Figure 2:



(Nogami, Fig. 2 (highlighting added); *see also id.*, ¶0083 (“A central processing unit (CPU) **201** uses a program and data stored on a random access memory (RAM) **202** or a read-only memory (ROM) **203** to control the operation of the calculation processing apparatus **200**. Furthermore, each of the following processing operations performed by the calculation processing apparatus **200** is performed with the CPU **201** as the main unit of performing the processing.”).)

74. Nogami discloses that CPU **201** is “**in communication with the haptic output device** [cutaneous sense stimulation unit **20** within stimulation generation unit **10**].” As shown above in Figure 2 of Nogami above, CPU **201** communicates with each cutaneous sense stimulation unit **20** via system bus **211** and stimulation information output unit **210**. (*E.g.*, Nogami, ¶0095 (“The stimulation information output unit **210** functions as an interface for connecting the cutaneous sense stimulation unit **20** to the calculation processing apparatus **200**. The operation setting information generated by the calculation processing apparatus **200** is output to a specified cutaneous sense stimulation unit **20** via the stimulation information output unit **210**.”), 0096 (“The above-described components of the calculation processing apparatus **200** are connected to a system bus **211**.”).) Specifically, CPU **201** outputs operation setting information that is communicated to a cutaneous sense stimulation unit **20** of stimulation generation unit when the region virtual object corresponding

to that stimulation generation unit contacts a background virtual object. For example, as Nogami explains with reference to Fig. 4, when a region virtual object corresponding to stimulation generation unit **10** contacts a background virtual object, CPU **201** outputs appropriate operation setting information to cutaneous sense stimulation unit **20** in stimulation generation unit **10**:

In step S4006, the CPU **201** generates operation setting information for controlling an operation of the stimulation generation unit corresponding to the region virtual object contacting the background virtual object. [...]

Suppose, for example, that both the region virtual object disposed according to the position and orientation of the stimulation generation unit **10** and the region virtual object disposed according to the position and orientation of the stimulation generation unit **11** contact the background virtual object.

If the region virtual object disposed according to the position and orientation of the stimulation generation unit **10** is located within the attention range and the region virtual object disposed according to the position and orientation of the stimulation generation unit **11** is not located within the attention range, the operation setting information generated for the stimulation generation unit **10** differs from that generated for the stimulation generation unit **11**. That is, the intensity of the stimulation indicated in each operation setting information mutually differs. The processing in step S4006 will be described in

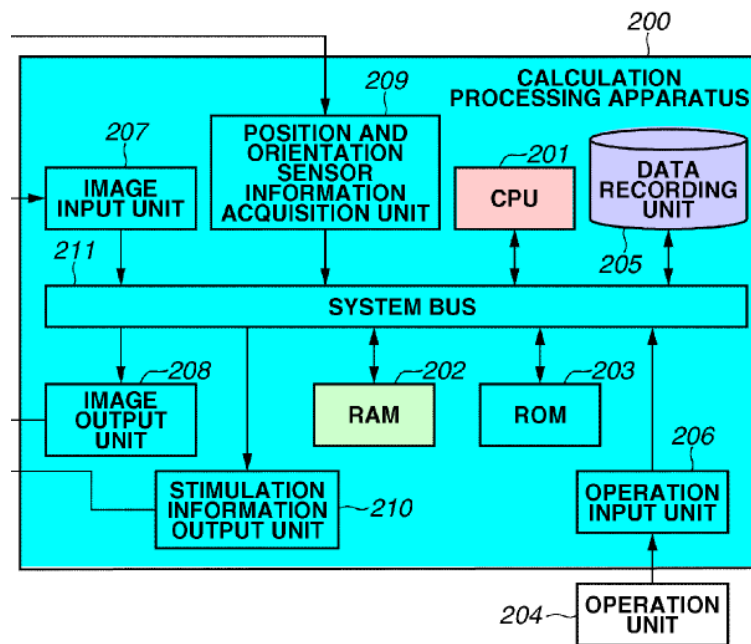
detail below.

In step **S4007**, the CPU 201 outputs, via the stimulation information output unit 210, the operation setting information generated in step S4006 to the stimulation generation unit (in the present exemplary embodiment, the cutaneous sense stimulation unit 20) corresponding to the region virtual object contacting the background virtual object. After receiving the operation setting information, the stimulation generation unit operates to generate a stimulation of the intensity indicated by the operation setting information.

(Nogami, ¶¶0120-0123 (underlining added).)

(c) **“a memory on which instructions executable by the processor are stored for causing the processor to:”**
(Claim 1[c])

75. Nogami discloses **“a memory,”** either (or both) **data recording unit 205** (which may be “a hard disk drive”) or **random access memory (RAM) 202**, as shown in Figure 2:



(Nogami, Fig. 2 (excerpt; highlighting added); *see also id.*, [0088]-[0090].)

76. A person of ordinary skill in the art would have understood and found it obvious that data recording unit 205 and/or RAM 202 is a memory on which “instructions executable by the processor [*i.e.*, CPU 201] are stored for causing the processor to” perform various operations, including the steps recited in the claim. Nogami explains, for example, that its methods can be “achieved by providing a system or a device with a storage medium (or a recording medium) which stores program code of software implementing the functions of the embodiments and by reading and executing the program code stored in the storage device with a computer of the system or the device (a CPU or an MPU).” (Nogami, ¶0284; *see also id.*, ¶¶0285-0286, 0287 (describing reading program code from a

storage medium, writing it to memory, and having a CPU connected to the memory execute the code), 0288.)

77. For example, Nogami explains that **data recording unit 205** stores “an operating system (OS) and a program and data” used by the **CPU 201**. (Nogami, ¶0088.) That “program includes a program for executing each processing according to a flow of processing to be executed by the CPU 201.” (Nogami, ¶0089.) **Data recording unit 205** also “stores publicly known information and information that a person skilled in the art can easily arrive at using in performing the following processing.” (Nogami, ¶0090.) “The program and the data stored in the data recording unit 205 are loaded therefrom to the RAM 202 under the control of the CPU 201.” (Nogami, ¶0090.) “The CPU 201 uses the program and data loaded on the RAM 202 to perform each processing.” (Nogami, ¶0091; *see also id.*, ¶0083 (“[E]ach of the following processing operations performed by the calculation processing apparatus 200 is performed with the CPU 201 as the main unit of performing the processing.”).)

78. I will further address how Nogami’s “**processor**” (**CPU 201**) executes “**instructions**” to cause the processor to perform each claimed step in my analysis of those steps below.

(d) **“receive one or more sensor signals indicating a position of the manipulatable input device in the at least three degrees of freedom and an identification of the manipulatable input device;” (Claim 1[d])**

79. Claim 1[d] requires receipt of **“one or more sensor signals”** indicating:
(1) “a position of the manipulatable input device in the at least three degrees of freedom” and **(2) “an identification of the manipulatable input device.”** I will first address how Nogami discloses **(1)** before turning to **(2)**.

80. To start, CPU **201** (**“processor”**) of Nogami **“receives one or more sensor signals indicating the position of the manipulatable input device [stimulation generation unit 10] in the at least three degrees of freedom.”** As explained below, the sensor signals take the form of signals received by CPU **201** from position and orientation information from sensor **400** in Nogami.

81. As discussed above for claim 1[a], stimulation generation unit **10** includes one or more markers **40** that are tracked by position and orientation sensor **400** to acquire position and orientation information, as Nogami explains:

[O]ne or more marker(s) **40** are provided to each of the stimulation generation units **10, 11, and 12** and the HMD **100**. A position and orientation sensor **400** acquires position and orientation information indicating the position and orientation of the marker **40**. The position and orientation information about the marker **40** acquired by the

position and orientation sensor **400** and a real space image obtained via the HMD **100** are input to a calculation processing apparatus (information-processing apparatus) **200**.

(Nogami, ¶0052; *see also id.*, ¶0073 (“Accordingly, the position and orientation sensor **400** can detect the position and orientation of the HMD **100** and the stimulation generation units **10**, **11**, and **12**, on each of which the marker **40** is disposed.”).) And in another embodiment, as noted, position and orientation information is provided by a magnetic receiver included in the stimulation generation unit. (Nogami, ¶¶0077-0078.) As discussed above for claim 1[a], Nogami also makes clear that the position and orientation information indicates a position and orientation “**in the at least three degrees of freedom**” in real space within which the stimulation generation unit **10** operates – including vertically, horizontally, and forward/backward in space. (Nogami, Figs. 1, 6 & 11, ¶¶0004, 0005, 0045, 0049, 0078, 0113, 0144, 0149.)

82. Nogami discloses that CPU **201** receives this position and orientation information, explaining that “CPU **201** acquires ... position and orientation information about the stimulation generation units **10**, **11**, and **12** sent from the position and orientation sensor **400** via the position and orientation sensor information acquisition unit **209** and stores the acquired information on the RAM

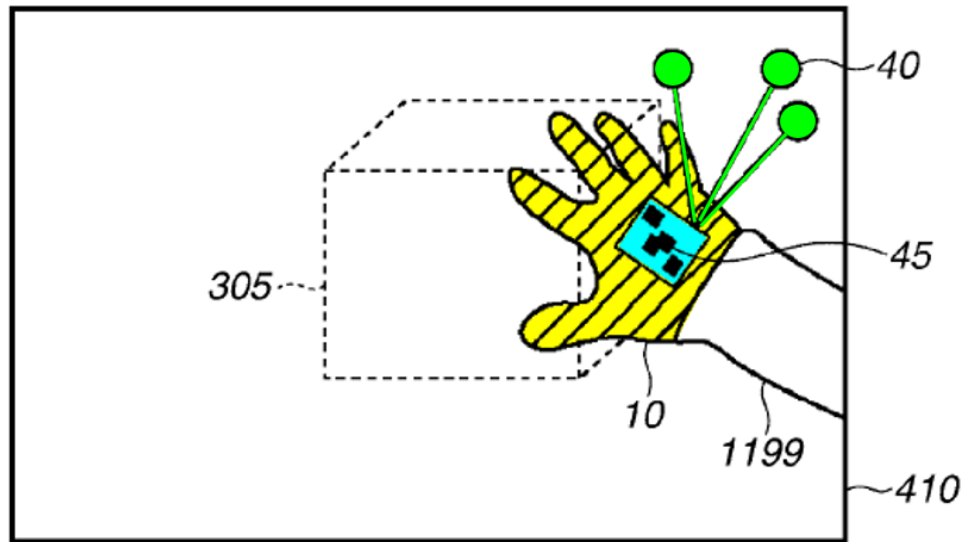
202.” (Nogami, ¶0108.) Moreover, a person of ordinary skill in the art would have understood and found it obvious that in Nogami, as a circuit/computer-based system, the position and orientation information from sensor **400** would have been conveyed to CPU **201** in the form of a “**signal**.” (E.g., Microsoft Computer Dictionary (5th ed. 2002) [EX1007], pp.480 (defining “signal” as “1. Any electrical quantity, such a voltage, current, or frequency, that can be used to transmit information.”), 145 (defining “data signal” as “The information transmitted over a line or circuit. It consists of binary digits that can include actual information or messages and other elements such as control characters or error-checking codes.”), 159 (defining “digital signal” as “A signal, such as one transmitted within or between computers, in which information is represented by discrete states—for example, high and low voltages—rather than by fluctuating levels in a continuous stream, as in an analog signal.”).) For example, Nogami explains that CPU **201** is connected to other system components, including position and orientation sensor information acquisition unit **209**, via system bus **211**. (Nogami, ¶0083-0084, 0096, 0211, Fig. 2.) A “bus” is a well-known key component in computer systems that uses electrical signals to direct data from one component to another. (Dictionary of Computer and Internet Terms (6th ed. 1998) [EX1009], p.65 (defining “bus” and explaining how data is transmitted); Newton’s Telecom Dictionary (24th ed. 2008) [EX1008], p.183

(defining “bus” as “[a]n electrical connection which allows two or more wires or lines to be connected together” and explaining bus data transfer and describing some of their properties); Microsoft Computer Dictionary (5th ed. 2002) [EX1007], pp.77-78 (defining “bus,” explaining that it is “a shared highway that connects different parts of the [computer] system...and enables them to transfer information”).)

83. Thus, a person of ordinary skill in the art would have understood that position and orientation information (either from sensor **400** or a magnetic receiver included in the stimulation generation unit) would be conveyed to CPU **201** in the form of a “**signal.**” The signal in Nogami also qualifies as a “**sensor signal**” because, as noted, it comprises data that was received from and collected by position and orientation sensor **400**.

84. Nogami’s CPU **201** (“**processor**”) also “**receives one or more sensor signals...indicating an identification of the manipulatable input device [stimulation generation unit 10].**” As explained below, the sensor signals here take the form of signals received by CPU **201** from imaging unit **101** of HMD **100** in Nogami. As discussed above for claim 1[a], Nogami discloses that stimulation generation unit **10** includes a **bar code 45** that identifies the unit, as illustrated in Figure 11:

FIG.11



(Nogami, Fig. 11 (highlighting added), ¶0206 (“The two-dimensional bar code **45** indicates ID information (e.g., an ID) unique to the stimulation generation unit **10**.”); *see also id.*, ¶¶0204-0213 (describing Figure 11).) As explained, Nogami discloses that an image of bar code **45** can be included in the real space image captured by imaging unit **101** of HMD **100**. (Nogami, ¶0208 (“In the present exemplary embodiment, when the stimulation generation unit **10** is included in the real space image **410** (located within the real space image **410**), the CPU **201** determines that the stimulation generation unit **10** is located within the attention range. More specifically, if the two-dimensional bar code **45** is detected in the real space image **410** and the two-dimensional bar code **45** is successfully recognized, then the CPU

201 determines that a stimulation generation unit 10 indicated by the two-dimensional bar code 45 and identified by the recognition is located within the attention range.”); see also id., ¶¶0209-0210, 0052-0054 (describing real space image captured by imaging unit 101 of HMD 100).) Nogami explains that its system is configured to process the real space image to recognize the bar code. (Nogami, ¶0208.) A real space image that includes bar code 45 is therefore an image **“indicating an identification of”** stimulation generation unit 10 (**“the manipulatable input device”**) because it includes information indicating the unique identity of stimulation generation unit 10. (Nogami, ¶0206 (**“The two-dimensional bar code 45 indicates ID information (e.g., an ID) unique to the stimulation generation unit 10.”**).)

85. A person of ordinary skill in the art would have understood imaging unit 101 to comprise a **“sensor.”** Nogami explains that imaging unit 101 “captures a moving image of the real space” (Nogami, ¶0054), like an ordinary digital camera. Imaging unit 101 thus comprises a **“sensor”** because, for example, it detects light in order to record image data to send to CPU 201. In fact, the ’217 patent expressly identifies imaging devices as examples of a “sensor.” The ’217 patent states that **“peripheral identification sensor 116”** can take the form of **“imaging device 114,”** which can be a **“a digital camera, a web-camera, an analog camera, a 3D camera, a**

stereo camera” or other imaging device. (’217, 5:1-4, 5:12-13 (“the peripheral identification sensor **116** may be the imaging device **114**”).)

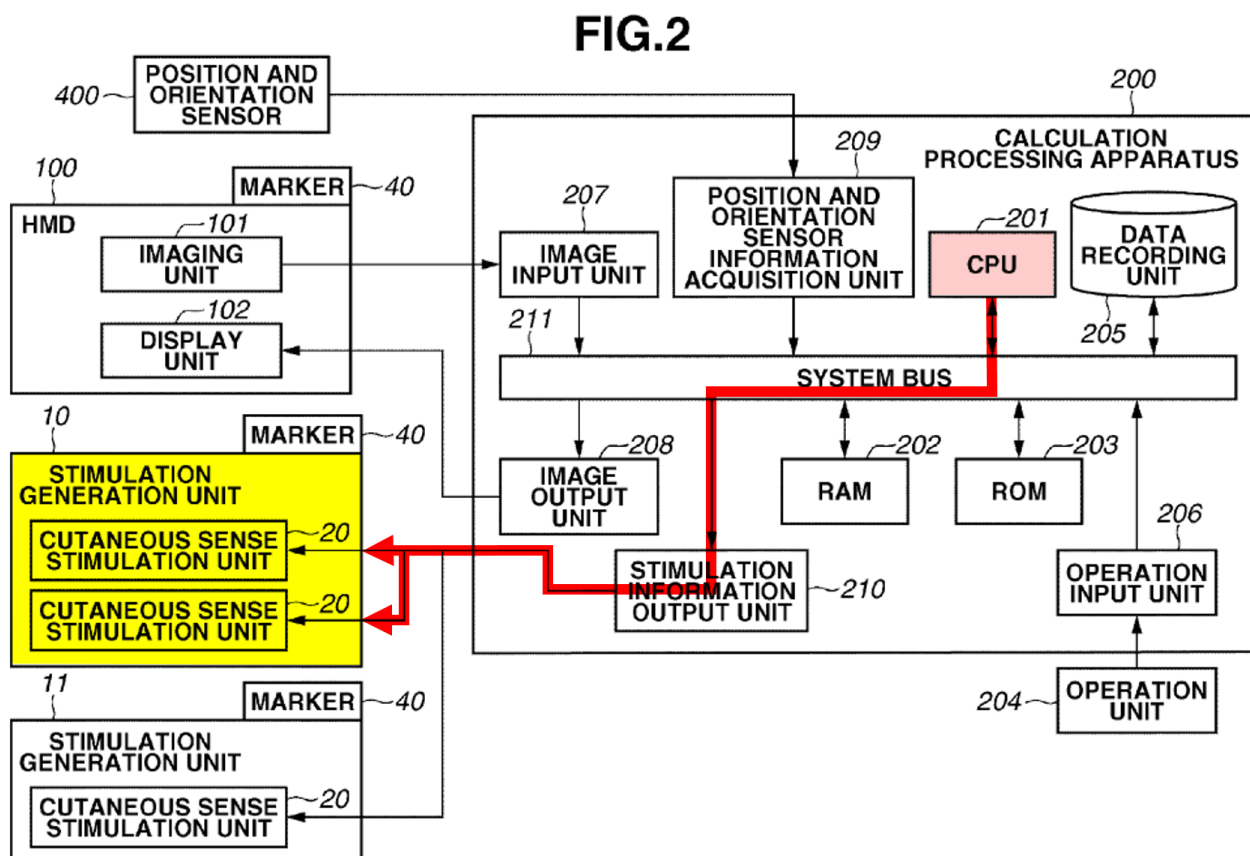
86. A person of ordinary skill in the art would have also understood and found it obvious that the real space image that included bar code information would be conveyed to CPU **201** in the form of a “**signal**,” because Nogami describes a circuit/computer-based system. For example, as explained, a person of ordinary skill in the art would have understood that CPU **201** receives data over system bus **211** from other system components that comprises or is embodied in signals. And because the signal comprises data from, and collected by a sensor (imaging unit **101**), it would be a “**sensor signal**.”

(e) “**establish a communication pathway between the manipulatable input device and the processor;**” (Claim 1[e])

87. A person of ordinary skill in the art would have understood and found it obvious that Nogami’s CPU **201** executes instructions to “**establish a communication pathway between the manipulatable input device** [stimulation generation unit **10**] **and the processor** [CPU **201**].” Claim 1[e] describes a routine and conventional step in a computer-based system of enabling a peripheral to communicate with the CPU of the computer to which the peripheral is connected. As explained below, CPU **201** “**establish[es] a communication pathway**” as

claimed by configuring the system to be able to direct information from CPU **201** to stimulation generation unit **10**.

88. Figure 2 of Nogami illustrates a physical link (indicated in red below) between CPU **201** and stimulation generation unit **10**:



(Nogami, Fig. 2 (highlighting added).)

89. Figure 2 shows a communication link (in red) between CPU **201** and stimulation generation unit **10** that includes system bus **211** between CPU **201** and stimulation information output unit **210**, which in turn communicates with

stimulation generation unit 10. (Nogami, *e.g.*, ¶¶0095 (“The stimulation information output unit **210** functions as an interface for connecting the cutaneous sense stimulation unit **20** [of **stimulation generation unit 10**] to the calculation processing apparatus **200**.”), 0096 (“The above-described components of the calculation processing apparatus 200 are connected to a system bus **211**.”).)

90. It would have been obvious to a person of ordinary skill in the art that the software in Nogami “**establish[es] a communication pathway**” between **stimulation generation unit 10** and **CPU 201**. For example, as explained in more detail below, CPU **201** is capable of transmitting information to stimulation generation unit **10** such as operation setting information. (Nogami, ¶0123 (“[T]he CPU **201** outputs, via the stimulation information output unit **210**, the operation setting information generated in step **S4006** to the stimulation generation unit (in the present exemplary embodiment, the cutaneous sense stimulation unit **20**) corresponding to the region virtual object contacting the background virtual object.”).) It would have been obvious that, in order for information to be transmitted to **stimulation generation unit 10** by **CPU 201**, the processor would have established a communication pathway between these components; otherwise they could not communicate in the manner described in Nogami. Stated more simply, at a minimum, instructions executed by **CPU 201** would have established a

communication pathway as a prerequisite to the step in Nogami of sending operation setting information to **stimulation generation unit 10**.

91. I note that claim 1[f], which I will address below, recites the ability to “**determine a feedback parameter**,” but specifies that this takes place “**after establishing the communication pathway**” as recited in claim 1[e]. But in my opinion, this claimed sequence does not present a material or non-obvious difference from the prior art. Nogami discloses the ability to initialize calculation processing apparatus **200** as part of its initial setup (Step **S4001** in Figure 4), before the other steps in Nogami are performed. (Nogami, ¶0107 (Step **S4001**); Fig. 4.) It would have been obvious that the claimed establishment of a communication pathway would have occurred before, or as part of, initialization step **S4001** in Nogami.

92. For example, Nogami explains that its calculation processing apparatus **200** can include “a general-purpose personal computer (PC), for example.” (Nogami, ¶0082.) **Phelps** describes the well-known process performed by conventional personal computers (PCs) when they are first powered up, which includes checking the various hardware components in the system:

When computers are initially turned on or reset, they typically go through a “booting” process. When a computer “boots” a built-in diagnostic program known as a power-on self-test (POST) is performed

wherein various tests are run to confirm core components of the computer system are present and functioning properly and wherein the registers within certain hardware devices are initialized.

(Phelps, ¶0002.) This process would have been familiar not only to ordinarily skilled artisans, but laypersons who had ever turned on an IBM PC-compatible personal computer and observed the power-on-self-test (POST) process, which often results in the display of textual statements to the user indicating that various components of the system have been detected and checked. Phelps further explains that this process includes loading the BIOS for execution by the processor:

Part of performing the POST involves loading the basic input and output system (BIOS) code into memory. A computer system requires BIOS to control the basic hardware operations, such as interactions with disk drives, hard drives, the keyboard, and other peripheral devices. After performing the POST, the computer typically loads an operating system (OS).

(Phelps, ¶0002.) The BIOS, in turn, is software or instructions “used by a processor of a computer to identify, initialize, allocate and manage other system hardware.”

(Phelps, ¶0003; *see also Microsoft Computer Dictionary* (5th ed. 2002) [EX1007], p.60 (“**BIOS** *n.* Acronym for **b**asic **i**nput/**o**utput **s**ystem. On PC-compatible computers, the set of essential software routines that tests hardware at startup, starts

the operating system, and supports the transfer of data among hardware devices, including the date and time.”) (bold and italics in original).) “By providing a set of low-level routines the BIOS enables the OS to interface with different hardware devices while in operation, thus facilitating the operation of various software applications.” (Phelps, ¶0003.)

93. The disclosures discussed above come from the “Background of the Invention” section of Phelps, and Phelps goes on to describe a more advanced way of organizing BIOS code for greater modularity to more easily accommodate new computer platforms, peripherals, and operating systems. (Phelps, ¶¶0007-0008.) These additional details are not pertinent to my analysis, as I have relied on Phelps for disclosure of basic POST and BIOS loading techniques that would have fallen within the general knowledge of an ordinarily skilled artisan.

94. *Rationale and Motivation to Combine (Nogami with Phelps):* It would have been obvious to combine Nogami with Phelps. The combination would have predictably resulted in calculation processing apparatus **200** of Nogami in which CPU **201**, before or as part of its initialization step **S4001**, would have established a communication pathway between stimulation generation unit **10** (“**the manipulatable input device**”) and CPU **201** (“**the processor**”). I note that the claim does not specify any particular operation that must be performed to establish

the claimed communication pathway. Under the proposed combination, this would have occurred when CPU **201** of calculation processing apparatus **200** in Nogami performs the power-on test and loads the BIOS program code into memory, as disclosed in Phelps. This would, in turn, have enabled CPU **201** in Nogami to communicate with the various hardware components and peripheral devices connected to calculation processing apparatus **200** – including system bus **211**, stimulation information unit **210**, stimulation generation unit **10**, among others. (Phelps, ¶¶0003 (“[T]he BIOS is a collection of instructions... used by a processor of a computer to identify, initialize, allocate and manage other system hardware.”), 0002 (“A computer system requires BIOS to control the basic hardware operations, such as interactions with... peripheral devices.”).) By performing the power-on test and loading the BIOS code into memory, therefore, the processor establishes a communication pathway between at least stimulation generation unit **10** and CPU **201** in Nogami.

95. Claim 1[f] below recites the step of determining a haptic feedback parameter, but requires that it take place “**after establishing the communication pathway**” of claim 1[e]. As explained above, Phelps confirms that the PC (as part of the POST process) loads the BIOS into memory before the computer loads even the operating system (OS) (Phelps, ¶0002), which would typically have been

required to execute application software on a PC. It would have been obvious that, under the proposed combination with Phelps, the BIOS code would have been loaded – thus establishing the communication pathway between stimulation generation unit **10** and CPU **201** – before any of the software described in Nogami that performs the functions of claim 1[f] (as described below) could have been executed. The communication pathway is thus established before the claimed haptic parameter is determined.

96. As I explained in the beginning of **Part V**, Nogami is an analogous reference in the same field as the '217 patent and would have been reasonably pertinent to problems facing the inventors. With respect to Phelps, it is also an analogous reference that would have been reasonably pertinent to problems facing the '217 patent inventors. The '217 patent explains that the components of system **100**, including digital device **106** and the one or more peripheral devices **102** to which it is connected, “may be operatively linked via one or more electronic communication links.” ('217, 3:6-12, Fig. 1.) Phelps would have been pertinent to understanding how such communication links can be established, including the basic software used by the computer to allow the processor to communicate with peripheral devices. Moreover, the disclosures in Phelps that I have relied upon above would also have fallen within basic knowledge of an ordinarily skilled artisan, who

would have understood the central role of a computer's BIOS code in allowing the processor to communicate with and/or control peripheral devices – including haptic output devices such as those in Nogami.

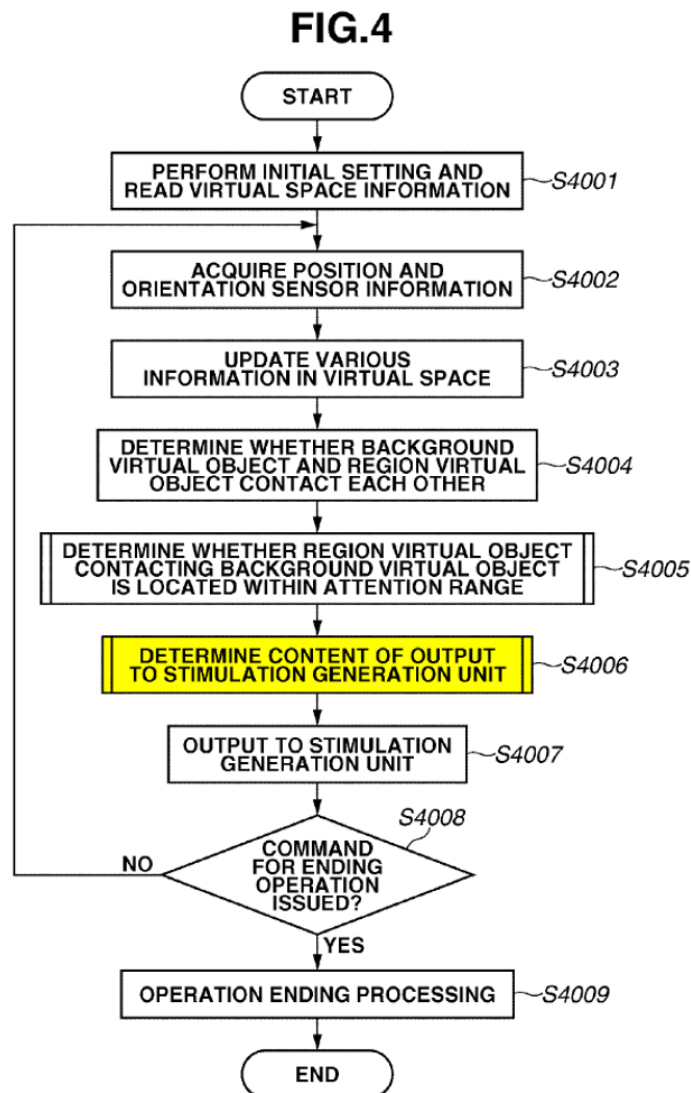
97. An ordinarily skilled artisan would have been motivated to combine Nogami and Phelps to better understand the basic operation of the computer on which Nogami would have been implemented. Nogami explains that “[t]he calculation processing apparatus **200** includes a general-purpose personal computer (PC), for example.” (Nogami, ¶0082.) An ordinarily skilled artisan would have been motivated to consult Phelps to better understand the role of the BIOS in facilitating the ability of a conventional PC, such as calculation processing apparatus **200**, to communicate with other hardware components and peripheral devices. As explained, this would have been basic knowledge of ordinarily skilled artisans. In fact, loading of the BIOS by a conventional PC would have been such basic knowledge that an ordinarily skilled artisan would have understood, even without having to refer to Phelps. An ordinarily skilled artisan would also have had a reasonable expectation of success, as the loading of the BIOS into memory is a basic function that would have been already built-into the conventional PC used to implement Nogami.

(f) “after establishing the communication pathway, determine a feedback parameter based at least in part on the position of the manipulatable input device in the at least three degrees of freedom and the identification of the manipulatable input device; and” (Claim 1[f])

98. As explained below, the functions in claim 1 [f] are performed by CPU 201 in Nogami by determining operation setting information for haptic feedback intensity (“**feedback parameter**”), which is transmitted to stimulation generation unit 10 based on the position and identification of stimulation generation unit 10 (“**manipulatable input device**”).

99. To start, Nogami discloses that CPU 201 “**determine[s] a feedback parameter**” that, as I will explain in detail below, corresponds to “operation setting information” in Nogami that specifies haptic feedback intensity.

100. As discussed, Nogami teaches that, in response to determining that there has been virtual contact between a stimulation generation unit and a background virtual object, CPU 201 determines “operation setting information” to transmit to the stimulation generation unit that describes the appropriate haptic feedback to output. Referring to step S4006 of Figure 4, Nogami explains that “the CPU 201 generates operation setting information for controlling an operation of the stimulation generation unit corresponding to the region virtual object contacting the background virtual object”:



(Nogami, ¶0120, Fig. 4 (highlighting added); *see also id.*, ¶¶0053 (“[T]he calculation processing apparatus **200** outputs operation setting information for controlling an operation of each of the stimulation generation units **10**, **11**, and **12**.”), 0095 (“The operation setting information generated by the calculation processing apparatus **200** is output to a specified cutaneous sense stimulation generation unit **20** via the

stimulation information output unit **210.**”).)

101. This operation setting information includes an indication of the intensity of the stimulation to generate. (Nogami, ¶¶0123 (“After receiving the operation setting information, the stimulation generation unit operates to generate a stimulation of the intensity indicated by the operation setting information.”), 0122 (“[T]he intensity of the stimulation indicated in each operation setting information mutually differs.”).) Nogami’s operation setting information for haptic feedback intensity thus qualifies as a “**feedback parameter**” as claimed. In fact, the ’217 patent expressly identifies haptic feedback intensity as an example of a “**feedback parameter**”: “Feedback parameters may include the type of haptic feedback, the duration of haptic feedback, the intensity or magnitude of haptic feedback, frequency of periodic haptic signal, harmonic content of haptic signal, pattern of haptic pulses or aspects of haptic signal, static and/or changing deformation features, and/or other aspects of haptic feedback.” (’217, 8:16-22.)

102. Claim 1 [f] goes on to require that the feedback parameter be determined based at least in part on: (1) “**the position of the manipulatable input device in the at least three degrees of freedom,**” and (2) “**the identification of the manipulatable input device.**” As explained below, the haptic feedback intensity for a stimulation generation unit in Nogami is based on both (1) the **position** of the

stimulation generation unit (*e.g.* whether the stimulation generation unit makes virtual contact with a virtual object), and **(2) the identification** of the stimulation generation unit (*e.g.* whether the bar code of the stimulation generation unit, which uniquely identifies it, has been detected within the user's attention range or view volume).

103. Turning first to how haptic feedback intensity in Nogami is based in part on **position**, Nogami explains that the position of the stimulation generation unit is used (along with orientation) to determine whether the unit is making virtual contact with a background virtual object. For example, Nogami describes a determination unit “configured to determine whether the virtual object and the stimulation generation unit contact each other based on **position** and orientation information about the virtual object and the positional information about the stimulation generation unit.” (Nogami, ¶0027; *see also id.*, ¶¶0109 (“CPU **201** sets the region virtual object corresponding to each stimulation generation unit **according to the position** and orientation of each of the stimulation generation units **10, 11, and 12**”), 0117 (“[I]n step **S4004**, the CPU **201** determines whether each of the background virtual objects disposed by the above-described processing in the virtual space and each of the region virtual objects disposed in the virtual space in step **S4003** interfere with each other.”), claim 1 (describing “determination unit”).)

104. The operation setting information in Nogami is, in turn, based in part on the determination of whether the stimulation generation unit is making virtual contact with a background virtual object. (Nogami, ¶0027 (“generate operation setting information for controlling an operation of the stimulation generation unit according to a result of determination by the determination unit and to output the generated operation setting information to the stimulation generation unit”); *see also id.*, ¶¶0120-0121 (operation setting information generated based on virtual contact), claim 1 (describing “output unit”).) Because the position of stimulation generation unit determines whether or not virtual contact is made with a background virtual object, the operation setting information in Nogami is, in turn, based at least in part on **“the position of the manipulatable input device in the at least three degrees of freedom,”** as claimed.

105. But the operation setting information in Nogami can also be influenced by the **identification** of the stimulation generation unit with which virtual contact is made. This can occur in at least two independent ways.

106. First Nogami explains that CPU **201** generates operation setting information of different intensities based on whether or not the stimulation generation unit (as represented by its corresponding region virtual object) is within view of the user’s HMD. (*E.g.*, Nogami, ¶0120.) Nogami explains that, in some

embodiments, the view area of the HMD is called the “attention range.” (Nogami, ¶¶0101 (“The attention range **50** is a range in which the user **1** can perceive a virtual object with the visual sense and a part thereof.”), 0164 (“[I]t is useful to set the attention range around the central visual field.”).) Nogami explains that the haptic feedback intensity can vary based on whether or not the stimulation generation unit (as represented by its corresponding region virtual object) is making virtual contact with a virtual object within the user’s attention range. If so, the haptic feedback intensity is lower, because the virtual object is already within the view area of the HMD (attention range of the user). Conversely, if the stimulation generation unit makes making contact outside of the user’s attention range, the haptic feedback intensity is higher. (Nogami, ¶0179 (“[I]t is useful to set the stimulation to be generated in the case of contact outside the attention range to a level higher than that generated in the case of contact inside the attention range.”).) Nogami explains:

In step **S4006**, the CPU **201** generates operation setting information for controlling an operation of the stimulation generation unit corresponding to the region virtual object contacting the background virtual object. The operation setting information can differ according to whether the region virtual object contacting the background virtual object is located within the attention range.

Suppose, for example, that both the region virtual object disposed

according to the position and orientation of the stimulation generation unit **10** and the region virtual object disposed according to the position and orientation of the stimulation generation unit **11** contact the background virtual object.

If the region virtual object disposed according to the position and orientation of the stimulation generation unit **10** is located within the attention range and the region virtual object disposed according to the position and orientation of the stimulation generation unit **11** is not located within the attention range, the operation setting information generated for the stimulation generation unit **10** differs from that generated for the stimulation generation unit **11**. That is, the intensity of the stimulation indicated in each operation setting information mutually differs.

(Nogami, ¶¶0120-0122; *see also id.*, ¶¶0027, claim 1 (describing “determin[ing] whether the stimulation generation unit is included within an attention range” and “generat[ing] operation setting information for controlling an operation of the stimulation generation unit according to a result of determination by the determination unit”).) This determination, as explained below, is based on “**the identification of the manipulatable input device,**” as claimed.

107. For example, one way to determine whether stimulation generation unit **10** is located within the user’s attention range is to use the bar code **45** on stimulation generation unit. As noted, this bar code can be captured by HMD **100**’s imaging

unit. If bar code **45** is recognized in the real space image, then CPU **201** determines that the stimulation generation unit is located within the attention range, and generates corresponding operation setting information (including intensity):

In the present exemplary embodiment, when the stimulation generation unit **10** is included in the real space image **410** (located within the real space image **410**), the CPU **201** determines that the stimulation generation unit **10** is located within the attention range. More specifically, if the two-dimensional bar code **45** is detected in the real space image **410** and the two-dimensional bar code **45** is successfully recognized, then the CPU **201** determines that a stimulation generation unit **10** indicated by the two-dimensional bar code **45** and identified by the recognition is located within the attention range.

In the example illustrated in FIG. **11**, when the two-dimensional bar code **45** is detected and recognized, the CPU **201** can determine that the two-dimensional bar code **45** indicating the stimulation generation unit **10** is located within the real space image **410**. Thus, the CPU **201** sets the operation setting information for the contact within the attention range to the stimulation generation unit **10**.

(Nogami, ¶¶0208-209; *see also id.*, ¶0202 (“[T]he CPU **201** performs image processing on a real space image captured by the imaging unit **101** to determine whether the region virtual object is located within the attention range.”), claim 3.)

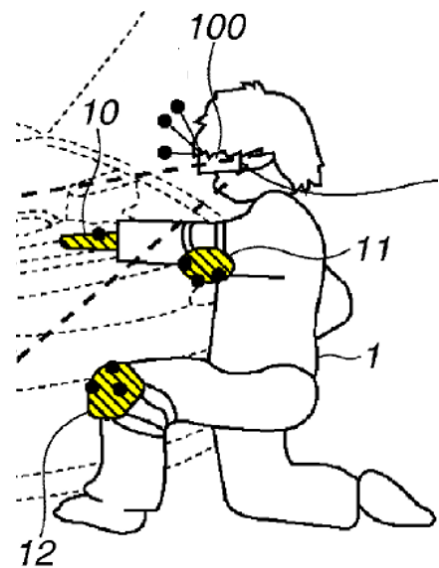
As noted previously, that operation setting information will indicate a lower or

higher intensity, respectively, based on whether stimulation generation unit **10** is inside or outside the user's attention range.

108. Nogami also discloses a second and independent way in which the haptic feedback intensity is based at least in part on **“the identification of the manipulatable input device,”** as claimed.

109. For example, Nogami discloses that stimulation generation units can be worn on various regions of a user's body, such as the user's hand, elbow, and knee.

(Nogami, ¶0051 (“[T]he stimulation generation unit **10** is mounted on the hand of the user **1**. The stimulation generation unit **11** is mounted on the elbow of the user **1**. The stimulation generation unit **12** is mounted on the knee of the user **1**.”), Fig. 1 (excerpted at right; highlighting added).) But Nogami identifies an issue when multiple stimulation



generation units are worn by a user: the intensity of haptic feedback felt by different regions of the user's body may be different. (Nogami, ¶0279.) “For example, the finger of a human can sensitively react to the stimulation but the knee or the elbow of a human cannot react to the stimulation as sensitive as the finger can do.” (Nogami, ¶0280.)

110. To address the different sensitivities of different body regions, a different intensity (referred to in Nogami as a “reference intensity”) can be applied based on the location of the stimulation generation unit on the body. (Nogami, ¶¶0280-0281.) Nogami explains that “in the case of mounting a cutaneous sense stimulation unit on different regions of the body of a user, it is useful if each region is previously caused to contact the virtual object and a value at which the user feels the intensity of the stimulation as the same is set as a reference intensity for each region.” (Nogami, ¶0280.) In other words, a different “reference intensity” can be provided for each region on the body where a stimulation generation unit is mounted. (Nogami, ¶¶0280-0281.) This “reference intensity” is then used as one of the parameters to determine the haptic feedback intensity when virtual contact occurs. (Nogami, ¶0281.)

111. Nogami does not provide implementation details about how a “reference intensity” value for a region is associated with stimulation generation units worn by the user at that region. But a person of ordinary skill in the art would have found this omission immaterial because this would have been considered nothing more than a trivial implementation detail. It would have been obvious that the stimulation generation unit would have used an identifier associated with the unit in order to identify the appropriate “reference intensity” for the contacted body

region. This would have predictably resulted in **“determine[ing] a feedback parameter [haptic feedback intensity] based at least in part on... the identification of the manipulatable input device [stimulation generation unit].”**

112. As fully explained for claim 1[d], Nogami discloses the claimed identification in the form of a bar code **45** on the stimulation generation unit that indicates the unique identifier associated with the unit. Although Nogami does not specifically disclose use of bar code **45** to assign the appropriate reference intensity to the stimulation generation unit, it would have been obvious to use bar code **45** to identify the stimulation generation unit and then use that identification to assign the appropriate reference intensity. As explained in Nogami, the key purpose of bar code **45** is to allow the system to uniquely identify the stimulation generation unit. (Nogami, *e.g.*, ¶¶0206 (“The two-dimensional bar code **45** indicates ID information (e.g. an ID) unique to the stimulation generation unit **10**.”).) To take a simple example, suppose Nogami uses two different “reference intensity” values for two stimulation generation units worn at two different regions of the user’s body. It would have been obvious based on Nogami to provide a different bar code for each stimulation generation unit in order to allow the CPU to uniquely identify and differentiate the stimulation generation unit making virtual contact, to select the appropriate reference intensity. If Nogami did not use an identifier such as bar code

45, in fact, the system would have been unable to distinguish one stimulation generation unit from another (regardless of region), thus defeating the purpose of Nogami’s region-specific “reference intensity” values.³

113. In summary, Nogami therefore discloses “**a feedback parameter** [haptic feedback intensity] **based at least in part on the position of the manipulatable input device** [*i.e.*, the position of stimulation generation unit **10**],” as well as “**the identification of the manipulatable input device** [*i.e.*, the bar code **45** identification of stimulation generation unit **10**].” This is because, as explained, haptic feedback of an intensity will be triggered if – based on the position of stimulation generation unit **10** – it makes virtual contact with a background virtual object. And the intensity of that haptic feedback may be further varied based on the identification of stimulation generation unit **10**, in two independent ways: (1) by

³ Moreover, more fundamentally, if each stimulation generation unit did not have its own identification, the system in Nogami could not even send output operation setting information to a particular stimulation generation unit because it could not have separately addressed that stimulation generation unit from other stimulation generation units in the system. The concept of an identification for a device is a basic concept in computer science or engineering that provides nothing of patentable significance. It was elementary knowledge of ordinarily skilled artisans that virtually all objects in a computer capable of being operated on or manipulated by a computer – such as an input device, a computer file, and even a location within the computer’s memory – are associated with an identification that allows the computer to identify the object and distinguish it from other objects in the computer.

decreasing the intensity if stimulation generation unit **10** is identified as being within the user's attention or (2) by utilizing a "reference intensity" for the haptic feedback based on the identification of stimulation generation unit **10** which corresponds to the region of the user's body where the unit is worn. The resulting intensity of haptic feedback ("a **feedback parameter**") in Nogami is therefore based at least in part on **both** the **position** and **identification** of stimulation generation unit **10**.

114. Finally, as fully explained for claim 1[e], it would have been obvious that determining the feedback parameter on Nogami would have taken place "**after establishing the communication pathway**," as claimed. Nothing in Nogami suggests that the communication pathway between CPU **201** and stimulation generation unit **10** has not already been fully established by the time by the time the feedback parameter in Nogami is determined. Moreover, a person of ordinary skill in art would have appreciated that the step of establishing a communication pathway between CPU **201** and stimulation generation unit **10** would only need to have been performed once. Accordingly, even if one could read Nogami as initially establishing the claimed communication pathway after the first feedback parameter was determined, it would have been obvious that any second, third, or other subsequent determination of the claimed feedback parameter would have occurred ***after*** the communication pathway had been established, thus meeting the claim.

- (g) **“transmit a haptic signal to the haptic output device, the haptic signal configured to cause the haptic output device to output a haptic effect according to the feedback parameter.” (Claim 1[g])**

115. I largely addressed the limitations of claim 1 [g] in my analysis of claim 1[f] above. As explained, Nogami discloses that operation setting information (“**haptic signal**”) is output and transmitted from CPU **201** to the cutaneous sense stimulation unit(s) **20** (“**haptic output device**”) of the stimulation generation unit corresponding to the region virtual object that is contacting a background virtual object. (Nogami, ¶¶0123 (“In step S4007, the CPU 201 outputs, via the stimulation information output unit 210, the operation setting information generated in step S4006 to the stimulation generation unit (in the present exemplary embodiment, the cutaneous sense stimulation unit 20) corresponding to the region virtual object contacting the background virtual object.”), 0177-0178 (CPU **201** outputs operating setting information to appropriate stimulation generation unit), Fig. 3 (illustrating cutaneous sense stimulation unit **20**).) The stimulation unit (e.g., cutaneous sense stimulation unit **20**) “**output[s] a haptic effect according to the feedback parameter**” because the haptic feedback reflects the specified intensity provided by operation setting information. (E.g., Nogami, ¶¶0123 (“After receiving the operation setting information, the stimulation generation unit operates to generate a

stimulation of the intensity indicated by the operation setting information.”), 0154 (“[T]he CPU **201** generates different operation setting information for the stimulation generation unit **10** and the stimulation generation unit **11** to cause the stimulation generation unit **10** and the stimulation generation unit **11** to generate stimulations of respective different intensity levels.”).)

116. As with the “**one or more sensor signals**” recited in claim 1[d], a person of ordinary skill in the art would have understood and found it obvious that in Nogami, as a circuit/computer-based system, the operation setting information from the CPU **201** would have been conveyed to a stimulation unit in the form of a “**signal**.” (*E.g.*, Microsoft Computer Dictionary (5th ed. 2002) [EX1007], pp.480 (defining “signal” as “1. Any electrical quantity, such a voltage, current, or frequency, that can be used to transmit information.”), 145 (defining “data signal” as “The information transmitted over a line or circuit. It consists of binary digits that can include actual information or messages and other elements such as control characters or error-checking codes.”), 159 (defining “digital signal” as “A signal, such as one transmitted within or between computers, in which information is represented by discrete states—for example, high and low voltages—rather than by fluctuating levels in a continuous stream, as in an analog signal.”).) Because the operation setting information instructs a stimulation unit to output haptic feedback,

the operation setting information qualifies as a “**haptic signal.**” I explained how a stimulation unit (such as a cutaneous sense stimulation unit **20**) is a “**haptic output device**” in my analysis of claim 1[a] above.

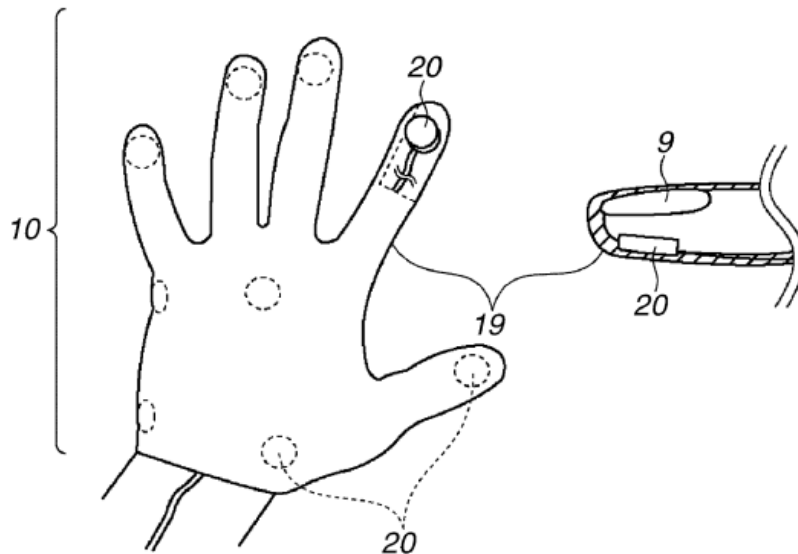
117. For substantially the same reasons as those discussed above, a person of ordinary skill in the art would have understood and found it obvious that CPU **201** would have executed “**instructions**” to carry out this step. (*E.g.*, Nogami, Fig. 4, ¶¶0123 (“[T]he CPU **201** outputs...the operation setting information”), 0091, 0083, 0284-0287.)

2. Claim 2: “The system of claim 1, wherein the manipulatable input device comprises an accessory.”

118. Generally speaking, an “**accessory**” is typically understood as something that can be added to something else to make it more useful, versatile or attractive, or as a small article or item of clothing that is carried or worn to complement a garment or outfit. (Oxford Dictionary of English (2nd ed. revised 2005) [EX1010], p.9 (definition of “accessory”).) And consistent with this ordinary understanding, the written description of the ’217 patent broadly describes an “**accessory**” as “a physical object and/or a physical device configured to be associated with the base device,” where the association can even include “permanently attaching” the accessory to the base device. (’217, 8:45-54.)

119. In Nogami, stimulation generation unit **10** (“**the manipulatable input device**”) comprises an “**accessory**” in the form of glove-like main body unit **19**, shown in Figure 3 below:

FIG.3



(Nogami, Fig. 3; *see also id.*, ¶0061 (describing “glove-like shaped main body unit **19**”).)

120. Nogami’s glove-like unit **19** is an “accessory” consistent with the ordinary understanding of that term noted above. The glove-like unit **19** makes the associated cutaneous sense generation units **20** more useful and versatile because it provides a simple, easy way to place them close to the user’s body. In the same way,

this also makes Nogami's system as a whole more useful and versatile. And glove-like unit **19** is also an “**accessory**” in the sense that it is a small article of clothing worn by the user, as well as one of a number of different wearable options for attaching cutaneous sense stimulation unit(s) **20** and other components. (Nogami, ¶0063 (describing elbow-like shape and knee supporter-like shape).) Moreover, consistent with the '217 patent's description of an “accessory” as being configured to be associated with a base device, Nogami explains that main body unit **19** is configured to be associated with cutaneous sense stimulation unit(s) **20**, as well as bar code **45** and marker **40** and/or magnetic receiver – a “**base device**,” as I explain in my analysis of claim 3 below. (Nogami, ¶0061 (“[I]t is useful if the main body unit **19** has such a configuration that the cutaneous sense stimulation unit **20** closely contacts the human body **9** of the user **1**...”), Fig. 11 (showing bar code **45** and marker **40** configured on glove-like unit **19**), ¶¶0077-0078 (explaining that a magnetic receiver can be included in stimulation generation unit instead of a marker).)

3. Claim 3: “The system of claim 2, wherein the manipulatable input device further comprises a base device.”

121. As discussed previously for claim 2, the written description of the '217 patent describes an exemplary accessory in conjunction with an exemplary base

device. ('217, 8:45-54.) The '217 patent broadly describes a “**base device**,” stating that it may “complement the use of the accessory” and “may include one or more of an actuator **208**, a wireless transmitter/receiver **210**, an actuator control **212**, one or more identifying features **214**, and/or other components” but that this list of exemplary components “is not intended to be limiting.” ('217, 7:45-51, 9:20-24.) A person of ordinary skill in the art would have understood that the '217 patent's broad description of “base device” is consistent with the ordinary meaning of a device that can serve as a main or important physical and/or functional element. (Oxford Dictionary of English (2nd ed. revised 2005) [EX1010], p.134 (defining “base” as “a main or important element or ingredient to which other things are added”).)

122. Like the '217 patent's exemplary description of a “base device” comprising “one or more of an actuator **208**, a wireless transmitter/receiver **210**, an actuator control **212**, one or more identifying features **214**, and/or other components,” Nogami discloses a similar “**base device**” in the form of one or more cutaneous sense stimulation units **20**, marker **40** and/or magnetic receiver, and bar code **45**. (Nogami, ¶0061 (“[I]t is useful if the main body unit **19** has such a configuration that the cutaneous sense stimulation unit **20** closely contacts the human body **9** of the user **1**...”), Fig. 11 (showing bar code **45** and marker **40**

configured on glove-like unit **19**), ¶¶0077-0078 (explaining that a magnetic receiver can be included in stimulation generation unit instead of a marker).) This collection of components, like the exemplary base device in the '217 patent, provides haptic feedback, identifying features, and communication capabilities. As such, this collection of components serves as the main physical and functional element of a stimulation generation unit, enabling the unit to be identified and its position known by the system, and for the unit to provide haptic feedback. In this way, this collection of components also complements the wearable accessory (glove-like unit **19**) by being physically associated with the accessory and by providing the components for the user to interact with the system using the accessory.

4. Claim 4: “The system of claim 3, wherein the base device comprises the haptic output device.”

123. I addressed claim 4 in my analysis of claim 3 above. As explained, the “**base device**” comprises cutaneous sense stimulation unit(s) **20** (“**the haptic output device**”).

5. Claim 8: “The system of claim 2, wherein the accessory comprises a wearable accessory or clothing.”

124. I addressed claim 8 in my analysis of claim 2 above. As explained, glove-like unit **19**, which a user wears on their hand, comprises a “**wearable accessory**.” (Nogami, Figs. 1, 3 & 5, ¶0034 (“FIG. 5 illustrates an example of a

state of a real space in which an arm of a user wearing a plurality of stimulation generation units, position and orientation sensors, and an HMD are included.”.)

6. Claim 10: “The system of claim 1, wherein the haptic effect is further based on interactive content.”

125. As discussed for claim 1[f] and 1[g], Nogami discloses that haptic effects are provided in response to a user’s virtual contact with virtual objects. (*E.g.*, Nogami, Fig. 4, ¶¶0108-0123 (describing user’s interaction with virtual objects resulting in haptic feedback).)

126. Nogami’s virtual objects are “**interactive content**.” The ’217 patent broadly describes “interactive content” as including, among other things, “a virtual object” that may be output visually and/or haptically to be perceived by a user. (’217, 2:60-64 (“Interactive content may include a representation of the real world, [...] a representation of a user, a representation of a real-world object, a virtual object, real and/or artificial sounds, other content, and/or combinations thereof.”), 4:41-42 (“Interactive content may be outputted visually, audibly and/or haptically.”).) Nogami similarly discloses that “the user 1 can experience a virtual space including a virtual object 300 with both a visual sense and a tactile sense.” (Nogami, ¶0049.) The user can visually interact with a background virtual object by changing their position relative to the object, thereby changing how the object is

displayed to the user. (Nogami, *e.g.*, ¶¶0005 (“In the case of using an HMD in such a conventional system, a user can feel a greater sense of immersion into a virtual space because the virtual space is displayed according to a viewpoint of the user and a direction of a line of sight (visual axis) of the user.”), 0027 (“...generate an image in a virtual space including a virtual object based on position and orientation information about a viewpoint of a user...”), Fig. 6 & 0140-0147 (describing how virtual objects including background virtual objects are generated for display based on current position and orientation information as well as shape and size of the object).) A user can also interact with the background virtual object by touch, *e.g.*, by experiencing haptic feedback based on the system calculating that a stimulation generation unit, via its corresponding region virtual object, has made contact with the background virtual object. (Nogami, *e.g.*, ¶0097 (“[T]he calculation processing apparatus **200** detects whether the stimulation generation unit **10**, **11**, or **12** contacts a virtual object.”); *see also id.*, ¶¶0098-0103, Fig. 4 (*e.g.*, steps **S4004** – **S4007**), 0117-0123 (describing steps **S4004** – **S4007**).) This can in turn result in a haptic stimulation being generated. (Nogami, ¶¶0122-0123, Fig. 4 (Step **S4006**, **4007**).)

127. Nogami therefore discloses that “**the haptic effect is further based on interactive content,**” as claimed.

7. **Claim 11: “The system of claim 1, further comprising: a position sensor configured to detect the position of the manipulatable input device in the at least three degrees of freedom and transmit a first sensor signal; and an identification sensor configured to identify the manipulatable input device and transmit a second sensor signal.”**

128. My analysis for claim 1[d] largely addressed the first part of claim 11[a] relating to the claimed “**position sensor.**” As discussed, Nogami discloses that the position and orientation of a stimulation generation unit can be acquired in various ways, including using position and orientation sensor **400**, and alternatively, using a magnetic receiver mounted on a stimulation generation unit. (*E.g.*, Nogami, ¶¶0073 (“[T]he position and orientation sensor **400** acquires position and orientation information about the marker **40**. Accordingly, the position and orientation sensor **400** can detect the position and orientation of the HMD **100** and the stimulation generation units **10**, **11**, and **12**, on each of which the marker **40** is disposed.”), 0077-0078 (describing magnetic receivers).) Either of these ways discloses a “**position sensor**” because they are devices that detect a physical property (*e.g.*, light or electromagnetic radiation) in order to determine position information to send to CPU **201**. (*E.g.*, Oxford Dictionary of English (2nd ed. revised 2005) [EX1010], p.1608 (defining “sensor” as “a device which detects or measures a physical property and records, indicates, or otherwise responds to it”).)

129. And as explained for claim 1[d], a person of ordinary skill in the art would have understood and found it obvious that the position and orientation sensor in Nogami “**detects the position of the manipulatable input device** [stimulation generation unit **10**] **in the at least three degrees of freedom**” and “**transmit[s] a first sensor signal** [position and orientation information conveyed from the position sensor to CPU **201**].” (Nogami, Figs. 1, 6 & 11, ¶¶0004, 0005, 0045, 0049, 0078, 0108 0113, 0144, 0149.) For example, as discussed, referring to Figure 4, Nogami explains that “[i]n step **S4002**, the CPU **201** acquires position and orientation information about the HMD **100** and position and orientation information about the stimulation generation units **10**, **11**, and **12** sent from the position and orientation sensor **400** via the position and orientation sensor information acquisition unit **209** and stores the acquired information on the RAM **202**.” (Nogami, ¶0108.) Now turning to the remaining aspects of claim 11, Nogami also discloses and renders obvious “**an identification sensor configured to identify the manipulatable input device and transmit a second sensor signal.**” As explained for claim 1[d], CPU **201** receives a real space image from imaging unit **101** of HMD **100** that includes bar code **45**. (Nogami, Fig. 11, ¶¶0205-0209.) “The two-dimensional bar code **45** indicates ID information (e.g., an ID) unique to the stimulation generation unit **10**.” (Nogami, ¶0206.) Identification of stimulation generation unit **10** (“**manipulatable**

input device”) therefore occurs, as explained previously, when bar code **45** is detected in the real space image. (Nogami, ¶¶0208-0209.) As also explained for claim 1, the functions performed in Nogami may be performed by software executed by CPU **201**. (Nogami, *e.g.*, ¶¶0083 (“[E]ach of the following processing operations performed by the calculation processing apparatus **200** is performed with the CPU **201** as the main unit of performing the processing.”), 0284 (“The present invention can also be achieved by providing... program code of software implementing the functions of the embodiments and by reading and executing the program code... with a computer of the system or the device (a CPU or an MPU).”).) Accordingly, for purposes of claim 11, the “**identification sensor**” in Nogami corresponds to the combination of imaging unit **101** of HMD **100** which captures a real space image, and CPU **201** along with software that (when executed) detects bar code **45** to identify stimulation generation unit **10** in the image. A person of ordinary skill in the art would have understood that this collection of components qualifies as an “**identification sensor**,” consistent with the ’217 patent’s description of a “peripheral identification sensor” configured to identify devices using image recognition as well as the broad ordinary understanding of “sensor.” (’217, 5:13-20; Oxford Dictionary of English (2nd ed. revised 2005) [EX1010], p.1608 (defining “sensor” as “a device which detects or measures a physical property and records,

indicates, or otherwise responds to it”).) Nogami explains that the detection of bar code **45** can occur by either “perform[ing] the image processing for the entire real space image **410**,” or performing image processing “for a predetermined area only by masking an area not to be image-processed.” (Nogami, ¶0210.)

130. Moreover, the inclusion of CPU **201** and software executed by CPU **201** as part of the claimed “**identification sensor**” is consistent with exemplary embodiments in the ’217 patent. For example, Figure 4 of the ’217 patent shows a flowchart of method **400** for carrying out the alleged invention, with step **406** corresponding to the function performed by the identification sensor. (’217, Fig. 4, Step 406 (“Identify Peripheral Manipulated by User from Among Plurality of Possible Peripherals.”).) The ’217 patent makes clear that “the method **400** [of Figure 4] may be implemented in or more processing devices... [which] may include one or more devices executing some or all of the operations of the method **400** in response to instructions stored electronically on an electronic storage medium. The one or more processing devices may include one or more devices configured through hardware, firmware, and/or software to be specifically designed for execution of one or more of the operations of the method.” (’217, 11:51-64.)

131. The claimed identification sensor in claim 11 also has to “**transmit a second sensor signal.**” Nogami explains that CPU **201** “determines that the

stimulation generation unit **10** is located within the attention range,” which occurs “if the two-dimensional bar code **45** is detected in the real space image **410** and the two-dimensional bar code **45** is successfully recognized....” (Nogami, ¶0208.) The “**second sensor signal**” in Nogami thus corresponds to a signal sent by the “**identification sensor**” software identified above, the signal indicating that bar code **45** corresponding to stimulation generation unit **10** was successfully detected in the real space image. (Nogami, ¶¶0208-0209.) Nogami does not specify internal details about how portions of the software in Nogami communicate with one other, but it would have been obvious that the “**identification sensor**” software would have transmitted at least a “**second sensor signal**” to other portions of the software to notify them that bar code **45** for stimulation generation unit **10** was successfully recognized. (Nogami, ¶0208.) For example, CPU **201** in Nogami takes specific action in direct response to bar code **45** having been recognized, including setting operation setting information for stimulation generation unit **10**. (Nogami, ¶¶0208-0209.) It would have been obvious that, in order for CPU **201** to invoke processes in response to bar code **45** having been detected, that the software that detected bar code **45** would have sent some type of signal to indicate that bar code **45** was recognized. Claim 11 does not place any restrictions on the format or composition of the “**second sensor signal**,” and an ordinarily skilled artisan would have

understood that the second sensor signal in Nogami could have been implemented in any number of ways including by providing a variable or value provided to other portions of the software, *e.g.*, as a return value provided from a procedure, a parameter passed into a procedure, or through any number of well-known interprocess communication or information sharing techniques that would have been elementary to ordinarily skilled artisans and even beginning programmers.

132. I also note that nothing in the '217 patent requires that the “**second sensor signal**” be transmitted externally to another device. In the exemplary embodiment in the '217 patent, in fact, identification sensor **116** transmits the second sensor signal to processor **112** and/or other software modules within the same device **106**. ('217, Fig. 1 (showing components of digital device **106** including peripheral identification sensor **116** and processor **122**), 5:21-24 (“The peripheral identification sensor **116** may provide an identification of the peripheral **102**, such as by an output signal, to the processor **112** and/or other modules thereof, and/or other components of the system **100**.”).)

8. Claim 17

133. Claim 17 is a method claim that recites method steps comprising substantially the same functions that are performed by the system recited in claim 1, which are disclosed and rendered obvious for the same reasons as claim 1.

134. For reference, claim 17 recites:

1. A method comprising:

- (a) receiving, by a processor, one or more sensor signals indicating a position of a manipulatable input device in at least three degrees of freedom and an identification of the manipulatable input device, wherein the manipulatable input device incorporates a haptic output device;
- (b) establishing, by the processor, a communication pathway between the manipulatable input device and the processor;
- (c) after establishing the communication pathway, determining by the processor a feedback parameter based at least in part on the position of a manipulatable input device in the at least three degrees of freedom and the identification of the manipulatable input device; and
- (d) transmitting, by the processor, a haptic signal to the haptic output device, the haptic signal configured to cause the haptic output device to output a haptic effect according to the feedback parameter.

('217, 14:7-25 (claim 17).)

135. The preamble of claim 17 recites “[a] **method comprising**” the identified steps. Nogami discloses and renders obvious the method recited in claim 17 as follows.

- (a) **“receiving, by a processor, one or more sensor signals indicating a position of a manipulatable input device in at least three degrees of freedom and an identification of the manipulatable input device, wherein the manipulatable input device incorporates a haptic output device;” (Claim 17[a])**

136. For purposes of my analysis, claim 17[a] is an amalgam of claim 1[a]-1[d], which together similarly recite a “manipulatable input device incorporating a haptic output device” (claim 1[a]), “receiving one or more sensor signals indicating a position of the manipulatable input device in at least three degrees of freedom and an identification of the manipulatable input device” (claim 1[d]), and that the receiving step is performed by the “processor” (claim 1[b]-1[c]). As explained above for claim 1[a]-1[d], Nogami discloses and renders obvious receiving, by a processor (CPU **201**), one or more sensor signals indicating a position of a manipulatable input device (stimulation generation unit **10**) in at least three degrees of freedom and an identification of that device (as indicated by bar code **45** on unit **10**), wherein the unit **10** incorporates a haptic output device (cutaneous sense stimulation unit **20**). (Nogami, *e.g.*, Figs. 1-3, 6 & 11, ¶¶0049-0054, 0060-0062, 0073-0083, 0108, 0140-0149, 0204-0213.)

(b) “establishing, by the processor, a communication pathway between the manipulatable input device and the processor;” (Claim 17[b])

137. For purposes of my analysis, claim 17[b] is a combination of claim 1[c] and 1[e], which together similarly recite that the “processor” (claim 1[c]) “establish[es] a communication pathway between the manipulatable input device and the processor” (claim 1[e]). As explained above for claim 1[e], Nogami discloses and renders obvious, establishing, by CPU **201**, a communication pathway between the stimulation generation unit **10** and CPU **201**. (Nogami, *e.g.*, Fig. 2, ¶¶0082, 0123.)

(c) “after establishing the communication pathway, determining by the processor a feedback parameter based at least in part on the position of a manipulatable input device in the at least three degrees of freedom and the identification of the manipulatable input device;” (Claim 17[c])

138. For purposes of my analysis, claim 17[c] is a combination of claim 1[c] and 1[f], which together similarly recite that the “processor” (claim 1[c]) “after establishing the communication pathway, determine[s] a feedback parameter based at least in part on the position of the manipulatable input device in the at least three degrees of freedom and the identification of the manipulatable input device” (claim 1[f]). As explained above for claim 1[f], Nogami discloses and renders obvious,

CPU **201**, after establishing the communication pathway, determining haptic feedback intensity based on the position of stimulation generation unit **10** in the at least three degrees of freedom and the identification of unit **10**. (Nogami, *e.g.*, Fig. 2, ¶¶0027, 0095, 0101, 0109, 0117, 0120-0123, 0164, 0179, 0202, 0209-0210, claim 1.)

(d) **“transmitting, by the processor, a haptic signal to the haptic output device, the haptic signal configured to cause the haptic output device to output a haptic effect according to the feedback parameter.” (Claim 17[d])**

139. For purposes of my analysis, claim 17[d] is a combination of claim 1[c] and 1[g], which together similarly recite that the “processor” (claim 1[c]) “transmit[s] a haptic signal to the haptic output device, the haptic signal configured to cause the haptic output device to output a haptic effect according to the feedback parameter” (claim 1[g]). As explained above for claim 1[g], Nogami discloses and renders obvious CPU **201** transmitting a haptic signal to cutaneous sense stimulation unit(s) **20** of stimulation generation unit **10** to cause the cutaneous sense stimulation unit(s) **20** to output haptic feedback according to the specified intensity. (Nogami, *e.g.*, ¶¶0123, 0154, 0177-0178.)

9. Claim 18

140. Claim 18 recites “[t]he method of claim 17, further comprising” the

following two steps.

- (a) **“identifying the manipulatable input device from a plurality of manipulatable input devices based on the one or more sensor signals; and” (Claim 18[a])**

141. As explained above for claim 1[d], Nogami discloses and renders obvious **“identifying the manipulatable input device”** (stimulation generation unit **10**) based on the **“sensor signal”** embodying a real space image with bar code **45** identification information conveyed to CPU **201**. (Nogami, *e.g.*, Fig. 11, ¶¶0204-0213, 0052-0054; *see also id.* ¶¶0206 (bar code **45** “indicates ID information (*e.g.*, an ID) unique to the stimulation generation unit **10**”).)

142. Nogami further discloses **“a plurality of manipulatable input devices.”** As discussed for claim 1 above, Nogami discloses that a user can wear a plurality of stimulation generation units on their body, such as on their hand, elbow, and knee – stimulation generation units **10**, **11**, and **12**, respectively. (Nogami, Fig. 1, ¶¶0051, 0058, 0063.) Each of these stimulation generation units is a **“manipulatable input device”** because, as explained for claim 1[a], each one enables position and orientation input to be provided to the system based on the position and movement of the user’s hand. (Nogami, *e.g.*, Figs. 1, 3, 5, 6, 11, ¶¶0049-0054, 0060-0061, 0073-0083, 0140-0154, 0204-0213.) In any case, because a user could have been wearing multiple stimulation generation units, using bar code

information **45** to specifically identify stimulation generation unit **10** would have predictably resulted in **“identifying the manipulatable input device [stimulation generation unit **10**] from a plurality of manipulatable input devices [stimulation generation units **10**, **11** and **12**] based on the one or more sensor signals.”**

143. I note that Nogami provides an exemplary illustration of bar code **45** mounted specifically on stimulation generation unit **10**, which as shown in Figure 11 is worn on the user’s right hand. (Nogami, Fig. 11, ¶¶206-210.) Although not necessary to satisfy the claim limitation, it would also have been obvious that other stimulation generation units in Nogami would also have had their own unique bar codes. The purpose served by bar code **45** – enabling CPU **201** to determine whether or not stimulation generation unit **10** is within the user’s attention range – would have been applicable to other stimulation generation units capable of appearing within the attention range and making contact with a background virtual object. (Nogami, ¶0202 (“Various methods can be used for determining whether the region virtual object is located within the attention range. In the second exemplary embodiment of the present invention, the CPU **201** performs image processing on a real space image captured by the imaging unit **101** to determine whether the region virtual object is located within the attention range.”).) It would therefore have been obvious to implement Nogami such that other stimulation generation units (beyond

stimulation generation unit **10**) would have included their own unique bar codes. For example, if the user was wearing stimulation generation unit **10** on their right hand, and another stimulation generation unit on their left hand, it would have been obvious to provide distinct bar codes for each stimulation generation unit to enable CPU **201** to determine for each unit whether it was within the attention range when it made virtual contact with a background virtual object. A person of ordinary skill in the art would thus have appreciated that the same advantages of using a bar code identification on stimulation generation unit **10** would also apply to other stimulation generation units – a visual confirmation that a specific stimulation generation unit is within the user’s attention range so that the system can determine appropriate haptic feedback to provide for that stimulation generation unit.

144. A person of ordinary skill in the art would have therefore understood and found it obvious that, because a user may be wearing multiple stimulation generation units, using bar code information to specifically identify stimulation generation unit **10** would have predictably resulted in **“identifying the manipulatable input device [stimulation generation unit 10] from a plurality of manipulatable input devices [stimulation generation units 10, 11 and 12] based on the one or more sensor signals.”**

**(b) “adjusting interactive content output to a user via a content output appliance based at least in part on the identification of the manipulatable input device.”
(Claim 18[b])**

145. As explained below, Nogami discloses and renders obvious claim 18[b] in two separate ways: **(1)** adjusting haptic feedback output by stimulation generation unit **10** based on whether the unit is identified as being within the user’s attention range; and **(2)** adjusting virtual object imagery output to the user’s HMD **100** based on whether the unit is identified as being within the user’s attention range.

146. For purposes of my analysis, I note that the written description of the ’217 patent broadly describes a **“content output appliance”** as a device that can output interactive content “visually, audibly and/or haptically” to a user:

The content output appliance **112** may be configured to output interactive content to the user. Interactive content may be outputted visually, audibly, and/or haptically. Interactive content may be provided to the content output appliance **112** for outputting from the electronic storage **110**, the processor **122** and/or modules thereof, the external resources **104**, and/or other sources. According to exemplary implementations, the content output appliance **112** may include an electronic display (e.g., monitor or screen), an electronic sound transducer (e.g., speaker), and/or other content output appliances. The content output appliance **112** may output interactive content that is haptically perceivable.

(’217, 4:40-51.) And as discussed for claim 1, the ’217 patent also broadly describes **“interactive content”** as including, among other things, content that can be visually and/or haptically perceived by a user. (’217, 2:60-64 (“Interactive content may include a representation of the real world, [...] a representation of a user, a representation of a real-world object, a virtual object, real and/or artificial sounds, other content, and/or combinations thereof.”), 4:41-42 (“Interactive content may be outputted visually, audibly and/or haptically.”).) Thus, the ’217 patent makes clear that **“interactive content output to a user”** includes both visual and haptic output related to interaction with a virtual object.

147. Turning to the first way in which Nogami discloses and renders obvious this limitation, the **“content output appliance”** corresponds to one or more cutaneous sense stimulation units **20**, which may be included as part of a stimulation generation unit. (Nogami, ¶¶0061, 0062.) Cutaneous sense stimulation units **20** can output a stimulation that is “transmitted to the human body **1** with an intensity high enough for the user **1** to recognize the vibration.” (Nogami, ¶0061.)

148. As explained for claim 1, a user experiences haptic feedback when the system determines that a stimulation generation unit has made contact with a background virtual object. (Nogami, *e.g.*, ¶0097 (“[T]he calculation processing apparatus **200** detects whether the stimulation generation unit **10**, **11**, or **12** contacts

a virtual object.”); *see also id.*, ¶¶0049 (“the user **1** can experience a virtual space including a virtual object **300** with both a visual sense and a tactile sense”), 0098-0103, Fig. 4 (*e.g.*, steps **S4004** – **S4007**), 0117-0123 (describing steps **S4004** – **S4007**.) This can in turn result in a haptic stimulation being generated. (Nogami, ¶¶0122-0123, Fig. 4 (Step **S4006**, **4007**).)

149. I note that nothing in the stimulation generation unit **10** in Nogami, in this first mapping, includes both the “**manipulatable input device**” and a “**content output appliance**.” Nothing in the claim language or written description of the ’217 patent precludes a particular device from including both of these claim limitations. In this case, I have relied on different aspects of stimulation generation unit **10** to perform the functions of these claim limitations. The functions of the “**content output appliance**” are carried out by the one or more cutaneous sense stimulation units **20**, whereas the functions of the “**manipulatable input device**” are provided by the marker **40** and bar code **45**, which enable the system to determine the position, orientation, and identity of stimulation generation unit **10**.

150. Similarly, nothing in the claim or in the ’217 patent written description precludes a device that provides haptic feedback – such as Nogami’s cutaneous sense stimulation unit(s) **20** – from qualifying as both a “**haptic output device**” (recited in claim 17 from which claim 18 depends) and a “**content output appliance**.” In

fact, as noted above, the '217 patent expressly states that a content output appliance can be a device that provides haptic output. ('217, 4:40-51.)

151. Nogami further discloses that the haptic feedback, which is based on the virtual contact with a background virtual object (“**interactive content output to a user**”), is “**adjust[ed]...based at least in part on the identification of the manipulatable input device.**” This is because, as explained for claim 1[f], the haptic feedback that stimulation generation unit **10** output is adjusted based on whether identifying bar code **45** is recognized as being within the user’s attention range. (Nogami, ¶¶0101, 0120-0122, 0164, 0179, 0202-0210.) As noted for claim 1[f], the intensity of the haptic feedback provided to the user (“**interactive content output to a user**”) is adjusted to be either high or low based on, respectively, whether the manipulatable input device (*i.e.* stimulation generation unit) is inside or outside the user’s attention range. Because that determination depends on bar code **45**, the adjustment is “**based at least in part on the identification**” of stimulation generation unit **10**.

152. Turning to the second way in which Nogami discloses and renders obvious this limitation, Nogami’s HMD **100** comprises a “**content output appliance**” because, consistent with the written description of the '217 patent, HMD **100** is a device that outputs interactive content visually to a user. (Nogami, *e.g.*,

¶¶0045, 0057 (“a publicly known method can be used as the method for visually presenting a real object and a virtual object”), 0093 (“[A] combined image generated by the calculation processing apparatus **200** is output to the display unit **102** of the HMD **100** via the image output unit **208**.”).)

153. For purposes of my analysis here, the “**interactive content**” includes a virtual work tool, such as a screwdriver or wrench, corresponding to a user’s stimulation generation unit that can be displayed to the user. Nogami explains:

[A]s the region virtual object disposed according to the position and orientation of the glove-like shaped stimulation generation unit, a virtual object having a shape like a hand holding a work tool can be used. In this case, the virtual object can be actually displayed as well as used in the processing for determining the presence of an interference with the background virtual object and the processing for determining whether the contact has occurred within the attention range. Accordingly, the user can perform a work and a verification using a virtual work tool. . . .

[T]he CPU **201** sets a shape of a work tool such as a screwdriver or a wrench as the shape of the region virtual object to set the shape different from that of the actual stimulation generation unit and displays the same.

(Nogami, ¶¶0270, 0272; *see also id.* ¶¶0271-0273.) A user can visually interact with the virtual work tool by, for example, changing the relative positions of HMD **100**

or the stimulation generation unit associated with the virtual work tool. (Nogami, *e.g.*, ¶¶0005, 0027, 0109, 0140-0147 (describing how virtual objects including region virtual objects are generated for display based on current position and orientation information).)

154. With respect to **“adjusting interactive content output to a user”** via HMD **100**, Nogami teaches that the virtual object imagery output to a user’s HMD **100** is based on whether or not virtual objects are within the user’s attention range. (Nogami, ¶¶0143-0144, 0101.) Nogami explains, for example, that the view volume corresponding to the user’s attention range, “indicates a range of the virtual space drawn on the display unit **102** of the HMD **100**.” (Nogami, ¶0144.) A person of ordinary skill in the art would have therefore understood and found it obvious that the collection of virtual objects displayed to a user would depend on which virtual objects the system identified as being within the user’s attention range. As the user’s attention range changed, the system might identify different virtual objects as being within the attention range and adjust the user’s display accordingly.

155. Nogami further discloses and renders obvious that the virtual object imagery displayed to a user (**“interactive content output to a user”**) is **“adjust[ed]...based at least in part on the identification of the manipulatable input device.”** This is because, as explained for claim 1[f], Nogami teaches using

the bar code **45** identification of stimulation generation unit **10** to determine whether the stimulation generation unit is within the user's attention range. (Nogami, ¶¶0202-0213.) It would have been obvious that, in order to display the virtual work tool associated with stimulation generation unit **10** when that unit is within the attention range (*e.g.*, by displaying a virtual screwdriver or wrench), the system would have relied at least in part on the identification of stimulation generation unit **10**, among other reasons, to distinguish it from other stimulation generation units.

156. For example, suppose the user is wearing two stimulation generation units: (1) stimulation generation unit **10** on the right hand, which is associated with a virtual screwdriver, and (2) a second stimulation generation unit on the left hand associated with a virtual wrench (or no tool at all). It would have been obvious that, by correctly displaying the virtual screwdriver when stimulation generation unit **10** worn on the right hand appears within the attention range, the system has adjusted the display at least in part on the identification of stimulation generation unit **10**. Accordingly, if stimulation generation unit **10** was associated with a virtual screwdriver and the bar code for stimulation generation unit **10** was recognized as being within the user's attention range, then the system would update the imagery displayed to the user to include an image of that tool based on having identified stimulation generation unit **10** as the unit that entered the attention range.

10. Claim 19: “The system of claim 11, wherein the identification sensor is configured to identify the manipulatable input device based on a visual characteristic of the manipulatable input device.”

Claim 19 does not add anything that my analysis above has not already addressed. The “**identification sensor**” in Nogami is configured to “**identify the manipulatable input device** [stimulation generation unit **10**] **based on a visual characteristic of the manipulatable input device** [bar code **45** representing a unique identification of stimulation generation unit **10**].” (*E.g.*, Nogami, ¶¶0206 (“The two-dimensional bar code **45** indicates ID information (e.g., an ID) unique to the stimulation generation unit **10**.”), 0208 (“[I]f the two-dimensional bar code **45** is detected in the real space image **410** and the two-dimensional bar code **45** is successfully recognized, then the CPU **201** determines that a stimulation generation unit **10** indicated by the two-dimensional bar code **45** and identified by the recognition is located within the attention range.”), Fig. 11 (illustrating stimulation generation unit **10** with bar code **45**).)

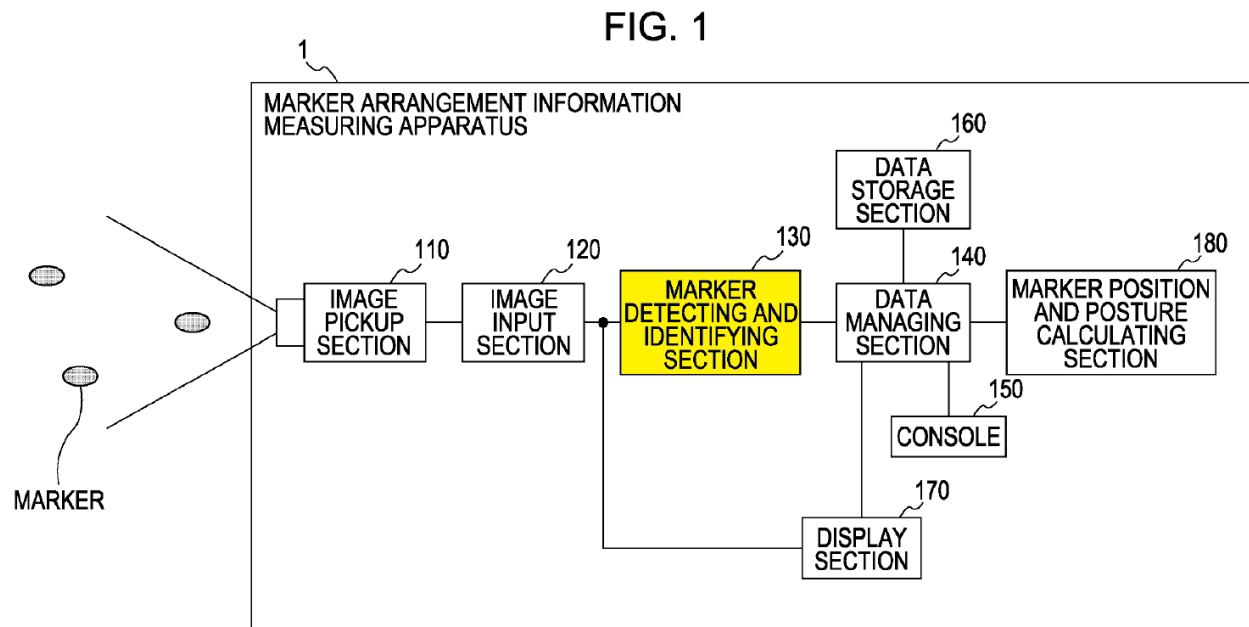
C. Ground 2: Claims 11 and 19 Are Obvious Over Nogami and Phelps in View of Kotake.

157. I explained above for **Ground 1** how Nogami in view of Phelps renders obvious claims 11 and 19. **Ground 2** provides as an alternative basis for obviousness of the second part of dependent claim 11, which recites “**an**

identification sensor configured to identify the manipulatable input device and transmit a second sensor signal.” With respect to all other aspects of claim 11, as well as the limitations of claim 19, the analysis for **Ground 1** applies.

158. With respect to the claimed identification sensor, as explained above for **Ground 1**, Nogami discloses the ability to detect bar code **45** in a real space image captured by imaging unit **101** of the user’s HMD **100**, the bar code identifying the stimulation generation unit. (Nogami, *e.g.*, ¶¶0206-0209.) As explained, Nogami does not provide specific details about how CPU **201** is notified that bar code **45** has in fact been detected in the real space image. I have thus provided **Ground 2** which cites to **Kotake**, which provides more detail about how a marker in an image can be detected, and how a CPU can be notified of this fact.

159. Kotake discloses a technique for detecting “markers” appearing in an image of three-dimensional space captured by a camera. Figure 1 shows a block diagram of a marker arrangement information measuring apparatus **1** used to perform the disclosed technique:



(Kotake, Fig. 1 (highlighting added).)

160. Figure 1 shows an image pickup section **110**, which is “constituted by a video camera and captures an image of a scene or an object on which markers [shown on the left] are arranged.” (Kotake, ¶0046.) In one exemplary embodiment, the markers in the image can take the form of “square markers” that have an outer boundary region or frame and an inner region. (Kotake, ¶0047; *see also id.*, ¶0073 (explaining that other types of markers can be used).) “An image input section **120** takes the image captured by the image pickup section **110** into a computer.” (Kotake, ¶0046.)

161. The key section of Figure 1, for purposes of my Declaration, is **marker detecting and identifying section 130** shown in yellow highlighting. This section, as

its label indicates, detects and identifies markers within the captured image, and outputs a marker detection result:

A marker detecting and identifying section **130** detects each marker from the image taken into the computer by the image input section **120** and identifies the detected marker. A data managing section **140** receives a marker detection result from the marker detecting and identifying section **130**.

(Kotake, ¶0046; *see also id.*, ¶¶0051-0052.) Marker detecting and identifying section **130**, more specifically, “detects the markers contained in the image and reads the identifier specific to each marker for identification of the marker.” (Kotake, ¶0055.) Marker detecting and identifying section **130** also “outputs, as detection data, image coordinates of four apexes of the marker to the data managing section **140**.” (Kotake, ¶0055.) Data managing section **140**, in turn, can store the marker detection result in data storage section **160**, count the number of times the marker has been detected, cause images to be presented on display section **170**, or perform other operations. (Kotake, *e.g.*, ¶¶0052-0053.) Data managing section **140** can also provide the marker detection result to marker position and posture calculation section **180**, which “calculates the position and the posture of the marker based on the marker detection result for each of a plurality of images.” (Kotake, ¶0054.)

162. Kotake further explains that his techniques can be implemented by

supplying program code (software) that can be executed using a CPU in a computer. (Kotake, ¶0199, 0203, 0200 (“In that case, the program code (software) serves= [sic] to implement the functions of the above-described exemplary embodiments.”).) But Kotake also explains that, alternatively, the supplied program code can be provided and executed in a separate “function extension board” or “function extension unit.” (Kotake, ¶0203 (“In addition, the supplied code read can be written in a memory which is provided in a function extension board inserted in the computer or in a function extension unit connected to the computer, and a part or the whole of the actual processing can be executed by a CPU or the like, which is incorporated in the function extension board or the function extension unit, in accordance with commands from the program code.” (Kotake, ¶0203.)

163. *Manner, Rationale, and Motivation to Combine (Ground 1 Prior Art with Kotake).* As I explained for **Ground 1**, Nogami itself already discloses detection of bar code **45** in a real space image captured by imaging unit **101** of the user’s HMD **100**, but does not disclose details about how CPU **201** is notified that this has occurred. (Nogami, ¶¶0206-0209.) It would have been obvious to combine Nogami with Kotake, predictably resulting in the system of Nogami that included an identification sensor that analyzed the real space image from imaging unit **101** in Nogami to detect and identify bar code **45**. That identification sensor would, in turn,

“transmit a second sensor signal,” by outputting information to CPU **201** identifying bar code **45**, analogous to the “marker detection result” data output by marker detecting and identifying section **130** to data managing section **140**.

164. It would also have been obvious that the bar code detection functionality in Nogami could have been performed by components separate from CPU 201, such as “a function extension board inserted in the computer or in a function extension unit connected to the computer” as disclosed in Kotake (Kotake, ¶0203), which would have performed the bar code **45** detection and transmitted the identification to CPU **201**. The **“identification sensor”** would thus have included, under the proposed combination, imaging unit **101** of HMD **100** which captures the real space image, along with a “function extension board” or “function extension unit” that would have performed the function of detecting bar code **45** in the image and outputting the identification to CPU **201**. The proposed combination therefore renders obvious **“an identification sensor configured to identify the manipulatable input device,”** *i.e.* stimulation generation unit **10**, and **“transmit a second sensor signal,”** *i.e.*, data identifying bar code **45** detected in the real space image, as required by claim 11. Although not required by claim 11, the second sensor signal could also optionally include the location of bar code **45** in the real space image.

165. Kotake is an analogous reference in the field of augmented reality systems. (Kotake, ¶¶0004-0006.) Kotake would also have been reasonably pertinent to problems facing the '217 patent inventors, including how to identify items within an image and notify the processor that such items have been identified. The '217 patent describes a peripheral identification sensor **116**, which corresponds to the claimed identification sensor, that “may be configured to generate an output signal that conveys information that identifies the peripheral **102**,” and that “[t]he peripheral identification sensor **116** may identify the peripheral **102** visually in some implementations.” ('217, 5:5-11.) Kotake’s teachings of detecting and identifying markers in real space images would have been reasonably pertinent to the problem faced by the inventors of how to identify objects – including a manipulatable user input device – appearing in visual image data captured by a camera.

166. An ordinarily skilled artisan would have been motivated to combine Nogami and Kotake in the manner described above. As noted, I have relied on Kotake primarily for the proposition that it would have been obvious to implement Nogami to include an “**identification sensor**” that is separate from CPU **201** and that outputs a second sensor signal identifying bar code **45** to CPU **201**. The motivation to implement Nogami in this way would have been straightforward – to reduce the burden on CPU **201**. An ordinarily skilled artisan would have appreciated

that identifying bar code **45** in a real space image would have been a potentially complex and time-consuming task for CPU **201**, which is also responsible for performing the other functions of Nogami's system. An ordinarily skilled artisan would have been motivated to offload this function, for example, to "a function extension board inserted in the computer or in a function extension unit connected to the computer," as described in Kotake. (Kotake, ¶0203.) It was well-known that graphics cards installed in conventional personal computers were frequently used in lieu of the CPU to perform image processing and other related tasks, including computer vision tasks. This would have provided a clear benefit to Nogami of relieving CPU **201** of the potentially complex and time-consuming task of analyzing the real space image to identify bar code **45**, freeing up CPU **201** to focus on other tasks. In fact, an ordinarily skilled artisan would have recognized Kotake's description of using "a function extension board inserted in the computer," as referring to well-known specialized circuit boards such as graphics cards, which often had processors specifically designed to perform image processing tasks more efficiently than the main CPU in the computer.

167. Moreover, in light of the limited purpose for which I have cited Kotake, the superficial differences between Kotake and Nogami would have been irrelevant to the proposed combination. For example, although Kotake discloses the use of a

square marker in an image, an ordinarily skilled artisan would have found his teachings applicable to any type of marker that is sufficiently distinctive and recognizable to a camera, such as bar code **45** of Nogami. Moreover, although Kotake primarily discloses marker identification for purposes of calibrating the markers themselves, his invention “is not limited to the calibration of the marker, and it can also be applied to the case of calibrating other information by using markers.” (Kotake, ¶0197.) As noted, I have not relied upon Kotake for teachings about how to recognize bar code **45** in the real space image, as those are already provided by Nogami.

168. An ordinarily skilled artisan would have had at least a reasonable expectation of success, as the proposed combination would have involved nothing more than having the same functions already performed by CPU **201** performed by other components of the system, which could have been implemented using well-known techniques. An ordinarily skilled artisan could have practiced the proposed combination based on the disclosures of the prior art without undue experimentation.

VI. NO SECONDARY CONSIDERATIONS OF NONOBVIOUSNESS

169. As explained in **Part III.B**, I understand that “secondary considerations” may be used as indicia of nonobviousness, provided that any such

Declaration of Jeremy Cooperstock, Ph.D. in Support of
Petition for *Inter Partes* Review of
U.S. Patent No. 9,727,217 B2

consideration has a nexus to the invention claimed. I understand from Petitioner's counsel that Patent Owner in the related district court litigation has not yet identified any evidence related to secondary considerations with a nexus to the claimed invention. Nor am I aware of information, such as commercial success, unexplained results, long felt but unsolved need, industry acclaim, simultaneous invention, copying by others, skepticism by experts in the field, and failure of others, suggesting that the claims addressed in this Declaration are not obvious. To the extent Patent Owner later provides information it claims relates to secondary considerations, I reserve the right to supplement my analysis and opinions to comment on it.

VII. CONCLUSION

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

171. I hereby declare that all statements made herein of my own knowledge are true and that all statements are made on information and belief are believed to be true, and further that these statements were made with the knowledge that willful false statements and the like so made are punishable by fine or imprisonment, or both, under 18 U.S.C. § 1001.

Dated: May 22, 2023

. Respectfully submitted,

A handwritten signature in black ink, appearing to read "Jeremy Cooperstock", written in a cursive style.

Jeremy Cooperstock
Paris, France

EXHIBIT A

CURRICULUM VITAE

Jeremy R. Cooperstock
Version as of December 22, 2022

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M.Sc. Computer Science, University of Toronto, 1992.
Thesis: "Neural Network Operated Vision-Guided Mobile Robot Arm
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B.A.Sc. Electrical Engineering, Computer Engineering Option, University of
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AWARDS AND DISTINCTIONS

2022	Honorable Mention, “The Sound of Hallucinations: Toward a more convincing emulation of internalized voices” (top 5% of papers), Human Factors in Computing Systems (CHI) [C2]
2022	Finalist, Best Applications Paper Award, “Speaking Haptically: from Phonemes to Phrases with a Mobile Haptic Communication System”, Transactions on Haptics [J2]
2019	Honorable Mention, “Detecting Perception of Smartphone Notifications using Skin Conductance Responses” (top 5% of papers), Human Factors in Computing Systems (CHI) [C31]
2019	San Diego Opera, Opera Hack award, Hamsafar! (\$10,000, with 5 co-awardees)
2018	Best poster presentation award, “Enhanced Pressure-Based Multi-modal Immersive Experiences”, Augmented Human [CP9]
2015	Gerald W. Farnell Teaching Scholar, Faculty of Engineering (\$12,500)
2014	US Ignite Best App in Education, Augmented Reality for Improved Training of First Responders
2013	Canadian National Institute for the Blind, Hochhausen Access Technology Research Award (\$10,000)
2013	Best paper award, “Vibrotactile Rendering of Splashing Fluids”, Transactions on Haptics [J15]
2013	Best use of sound award, “The Walking Straight Mobile Application: Helping the Visually Impaired Avoid Veering, International Conference on Auditory Displays [C58]
2012	Mozilla Foundation and NSF Gold Prize in the Mozilla Ignite Challenge (out of 305 submissions in the Brainstorming Round) (\$5,000) for Real-Time Emergency Response
2012	Canadian Internet Registry Association .CA Impact Award (Applications category) for In-Situ Audio Services Project (\$5,000)
2011	Best paper award, “What’s around me? Spatialized audio augmented reality for blind users with a smartphone”, Mobile and Ubiquitous Systems [C69]
2010	Best paper award, “Design of a Vibrotactile Display via a Rigid Surface”, Haptics Symposium [C78]
2009, 2010	Nominee, NSERC Brockhouse Canada Prize
2009	Best paper award, “SoundPark: Exploring Ubiquitous Computing through a Mixed Reality Multi-player Game Experiment”, 9e Conférence Internationale sur Les NOuvelles TEchnologies de la REpartition [C88]
2005	ACM/IEEE Supercomputing, Most Innovative Use of New Technology for Wide Screen Window on the World: Life Size HD Videoconferencing
2001	Audio Engineering Society Citation Award for pioneering the technology enabling collaborative multichannel performance over the broadband internet

WORK EXPERIENCE

CAREER HIGHLIGHTS

Haptic Information Delivery (2018-2021) My lab’s haptics research has resulted in prominent visibility in the preeminent journal, IEEE Transactions on Haptics, and the two top-tier international conferences in the field, IEEE Haptics Symposium and IEEE World Haptics Conference, with a dozen publications in these forums between 2020 and 2021. Given my recognition in the field, I was invited to serve on the editorial boards of all of these bodies, in addition to the specialty section on haptics of the Frontiers Journal in Virtual Reality. Specific examples of significant contributions include the performance attained through use of our two-actuator apparatus and phonemic encoding for tactile communication of natural language [C28, J2, C6], which outperformed the previously cited best results on this task, achieved by Facebook Research Labs. A second contribution relates to the high recognition rates we attained for multi-dimensional tacton delivery (3 parameters, each at 3 levels), targeting clinical patient-monitoring scenarios. This work inspired studies of wearable vibrotactile devices for physiological monitoring of patients [C27, C16]. While our results were achieved initially using a set of three actuators [C40, C37, C29, C19], we subsequently demonstrated equivalent recognition performance via only a single vibrotactile actuator, with a novel parameter encoding scheme [C18]. We further demonstrated achievement of the highest information transfer rates reported in the literature for such a single-actuator device [C13].

Physiological Sensing (2017-2020) Our research for detection of smartphone notifications was recognized by an Honourable Mention (top 5% of papers) from the top-tier ACM Conference on Human Factors in Computing ([C31]), and led to a recent patent filing ([P2]). This work has the potential to serve as not only for more intelligent, context-sensitive notification delivery, but also, as a tool that can be exploited to combat the prevalent and adverse effects of Internet addiction, driven largely by “fear of missing out.”

Real-Time Emergency Response (rtER) (2012-2013) provides an envisionment of the future of next-generation 911 (NG-911) technologies, supporting enhanced situational awareness for first responders through the use of citizen-supplied smartphone video streams and other relevant data [J13]. Our work was recognized by the *Gold Prize* from the Mozilla Ignite Fund, featured on the web site of the White House Office of Science and Technology, and prompted the launch of a funding program by the U.S. Department of Justice.

Autour (2009-2018) is an “eyes-free” app for the blind, which provides a rich, spatialized audio representation of one’s environment [J21, C69, C60, C57]. The project further motivated a rigorous analysis of smartphone sensor reliability, resulting in what was the first comprehensive examination of practical limits on smartphone sensors, including the problems of gyro drift [C60].

Mobile Treatment Device for Amblyopia (2009-2012, in collaboration with ophthalmologist R. Hess) is a patented prototype Mobile Treatment Device for Amblyopia [P7] (“lazy eye”). Initial trials [J20], based on the popular Tetris game, provided highly promising early results [J27, J23], not only restoring the use of both eyes in a majority of patients but even resulting in binocular (3D) depth perception in some. Most significantly, the treatment has been found to work successfully

on adult populations, whereas the prevailing wisdom had been that treatment was only possible on children. The technology has now been acquired by Novartis, who are commercializing the system.

Natural Interactive Walking (2008-2017) investigated multimodal interaction with virtual ground surfaces, resulting in important findings of tactile discrimination ability [J22] and the role of vibrotactile stimulation in perception of compliance [J28]. Our “Ecotile” prototype (patent [P4]) was showcased at numerous venues including SIGGRAPH, and led to related research involving limb modeling [C71, C55, C49], foot-water interaction [J15], and variable-friction walking interfaces [C65, C56, J6].

Ultra-Videoconferencing (2002-2006) is our low-latency, high-fidelity network transport, used for distance music teaching with Maestro Pinchas Zuckerman, cross-continental jazz jams, and remote sign language interpretation. The *Globe and Mail* described Cooperstock’s 2001 demonstration as “a watershed event for the elite club of the world’s computer network engineers.” Ultra-Videoconferencing garnered my research group a prestigious Citation Award from the Audio Engineering Society and the Award for Most Innovative Use of New Technology from ACM/IEEE Supercomputing (2005). This research directly constituted the basis for subsequent funding of \$2.2M from Valorisation Recherche Quebec and over \$4M from Canarie, and influenced the designs of similar telepresence videoconferencing systems from Cisco, HP, and Polycom. Our follow-up work on **Open Orchestra** (with HQP N. Bouillot, A. Olmos, T. Knight, M. Tomiyoshi), resulted in an immersive simulator for orchestral training, used by professional and semi-professional musicians [J19].

ACADEMIC EXPERIENCE

Jan 2018–present	McGill University, Montreal, QC Full Professor, Electrical and Computer Engineering. Director, Shared Reality Lab Member, McGill Institute for Aerospace Engineering Member, International Laboratory on Learning Systems Associate Member, Faculty of Music, Department of Theory Founding Member, Centre for Interdisciplinary Research in Music, Media and Technology Member, Centre for Intelligent Machines
Feb 2022–present	York University, Ontario Affiliate Member, Vision: Science to Applications (VISTA)
Sep 2018–Jun 2019	Technion–Israel Institute of Technology, Haifa, Israel Visiting Professor, Industrial Engineering and Management
Sep 2018–Jun 2019	IDC, Herzliya, Israel Visiting Professor, Department of Computer Science
May 2003–Dec 2017	McGill University, Montreal, QC Associate Professor, Electrical and Computer Engineering
Aug 2011–Jul 2012	University of Auckland, New Zealand Invited Professor, Department of Computer Science
May–June 2009	Bang & Olufsen, Denmark Visiting Professor, World Opera Project
Jan 2009–present	Bielefeld University, Germany Virtual Member, Center of Excellence Cognitive Interaction Technology (CITEC)
Feb 2008	Arizona State University Visiting Scholar, School of Arts, Media and Engineering
Sep 2004–Aug 2005	Université de Paris VI, Paris France Invited Professor, Laboratoire des Instruments et Systemes d'Ile-de-France
Nov 1997–May 2003	McGill University, Montreal, QC Assistant Professor, Electrical and Computer Engineering.

INDUSTRIAL AND CONSULTING EXPERIENCE

Sep 2019–Oct 2021	RedPill Canada VR, Montreal Director and Advisor
Apr–Jun 2019	(Confidential project as consulting expert) Providing expert report on topics concerning Human-Computer Interaction.
Aug–Nov 2014	Menya Solutions and DRDC-Valcartier Providing expert advice related to human-computer interfaces, visualization, and collaboration.
Aug 2012	Tamaggo Inc. Provide guidance and advice on digital imagery
May 2012	York University Review draft application to Canada Excellence Research Chairs program
May 2002 –Nov 2003	Solicitor General of Canada Media streaming configuration and user interface design.
May 2001	National Research Council Instructor of short course in Soft Computing, Institut des Matériaux Industriels.
Jan–Sep 1999	Audio Engineering Society Technical leader of demonstration of multichannel and multimedia audio distribution
Jan–Aug 1999	Ontario Science Center Scientific Director of Timescape Millenium Exhibit
Jul 1998	Nortel Instructor of short course in videoconferencing systems for the Nortel International SL-1 User's Association (ILUA), Long Beach
Sep 1996–Oct 1997	Sony Computer Science Laboratory Visiting Researcher, Sony Computer Science Laboratory, Tokyo, Japan. Developed speech-interface controlled VCR with visual tape database functionality. Wrote two patent applications, one filed.
Jun–Aug 1990	Fibronics Research Visiting Researcher, Fibronics Advanced Research Center, Haifa, Israel. Developed and tested an FDDI-to-token ring bridge.
May–Aug 1989	IBM T.J. Watson Research Center Research Intern, IBM T.J. Watson Research Center, Yorktown Heights, NY. Improved implementation of a VLIW architecture simulator.

LITIGATION AND EXPERT WITNESS EXPERIENCE

Parties I represented are marked by an asterisk.

Sep 2022–ongoing	Apple* v. Taction Technologies, Inc Involved in <i>Reexamination Requests</i> of U.S. Patent Nos. 10,659,885 and 10,820,117 in the United States Patent and Trademark Office.
Aug 2022–ongoing	Westwood One, LLC v. Local Radio Networks, LLC* United States District Court, Northern District of Indiana, Case No. 1:21-cv-00088-HAB-SLC. Involved in litigation matters related to U.S. Patent Nos. 7,412,203 and 7,860,448
Jan–May 2022	iFIT Inc. f/k/a ICON Health & Fitness* v. Peloton Interactive United States District Court, District of Delaware, Civil Action No. 20-cv-1386-RGA
Sep 2021–ongoing	Brazos* v. Google United States District Court, Western District of Texas Waco Division, Case Nos. 6:20-CV-00571-ADA through 6:20-CV-00585-ADA
Sep 2021–ongoing	AmLaw 100 Firm* Providing independent expert consulting services for an AmLaw 100 Firm on behalf of an owner of patents covering smartphone-based vehicle operation detection. Deposition testimony on expert report.
Jan 2021–ongoing	GUI Global Products, Ltd. v. Apple* United States District Court, Southern District of Texas, Case No. 4:20-cv-2652 and <i>Inter Partes</i> Review of U.S. Patent Nos. 10,259,020, 10,259,021, 10,562,077, and 10,589,320 in the United States Patent and Trademark Office. Deposition testimony on expert report (2 depositions)
Dec 2020–Feb 2021	Expert consultation re possible litigation in IT-related matter Work done on behalf of Sheridan Ross P.C.
Nov 2020–ongoing	Koss v. Apple* Civil Action No. 6:20-cv-00665, Western District of Texas. Involved in <i>Inter Partes</i> Review of U.S. Patent Nos. 10,206,025, 10,469,934, 10,506,325, 10,491,982, and 10,298,451 before the United States Patent and Trademark Office. Deposition testimony on expert reports (4 depositions).
Oct 2020–Oct 2021	ByteDance* and TikTok* v. Triller <i>Inter Partes</i> Review of U.S. Patent No. 9,691,429 before the United States Patent and Trademark Office. Deposition testimony on expert report.
Sep 2020–ongoing	Content Square v. Quantum Metric* and Decibel Insight* United States District Court, Massachusetts District Court, Case No. 1-20-cv-11184 and Delaware District Court, Case No. 20-cv-00832. Involved in invalidity arguments and petitions for <i>Inter Partes</i> Review. Deposition testimony on expert reports (5 depositions).

Sep 2020–ongoing	Wiesel v. Apple* United States District Court, Eastern District of New York, Case No. 1:19-cv-7261. Engaged for source code review of products related to the Apple Watch (case presently stayed).
Aug–Oct 2020	Finish Time* v. Garmin United States District Court, District of Maine, Case No. 2:20-cv-00184. Involved in review of infringement arguments, discovery, related to fitness applications.
Dec 2019–Nov 2022	Pinn v. Apple* United States District Court, Central District of California, Case No. 8:19-cv1805, <i>Inter Partes</i> Review IPR2020-00999, Post Grant Review PGR2020-00066 and PGR2020-00073. Involved in preparation of expert witness declarations, code analysis involving multiple products related to earbuds and charging circuitry. Deposition testimony on expert reports, in-court trial testimony.
Oct 2019	Apple* v. Qualcomm <i>Inter Partes</i> Review, Case no. IPR2018-01279. Deposition testimony on expert witness declaration related to multimedia messaging.
Mar 2019–Feb 2022	Cruz Hernandez* v. Air Canada and Lufthansa Canadian Transportation Agency Case no. 20-01712, Petitioner before the Agency regarding passengers' rights to compensation under EC 261/2014
May 2018–May 2019	Samsung* v. Immersion Civil Action No. 2:2018-cv-00055 in the Eastern District of Texas and <i>Inter Partes</i> Review, case no. IPR2018-01499. Consulted on technical details and involved in preparation of two expert witness declarations related to haptic feedback effects and force feedback in a multimodal system.
May 2016–Nov 2017	Cooperstock* v. Air Canada Petitioner before the Canadian Transportation Agency. Brought successful complaint against Air Canada for the airline's making false or misleading statements to the public, Decision No. 105-C-A-2017 (otc-cta.gc.ca/eng/ruling/105-c-a-2017)
Jan–May 2014	St. Lewis v. Rancourt* Provided expert report on web server location, Ontario Superior Court File No. 11-51657
Mar–Sep 2013	Cooperstock* v. United Airlines Brought and argued successful appeal regarding anti-SLAPP legislation before the Quebec Court of Appeal, Decision 2013 QCCA 1670 (goo.gl/pgz301). Argued appeal in person (September 26, 2013)
Nov 2012–Aug 2017	United Airlines v. Cooperstock* Pro se litigant, Federal Court File No. T-2084-12. Deposition as litigant (August 2013) and testified at trial (December 2016).

Nov 2012–Jan 2017 **United Airlines v. Cooperstock***
Pro se litigant, Quebec Superior Court File No. 500-17-074743-124.
Deposition as litigant (October 2014) and testified at trial (April 2016).

Sep 2012 **Lukács* v. Air Canada**
Provided expert report on database query and execution times, Canadian Transportation Agency File No. M4120-3/11-06673, Decision No. 204-C-A-2013

May 2007–Jan 2008 **Market Maker c. Brim Solutions***
Provided expert witness report and in-court testimony (October 2007) on software-related intellectual property case. Quebec Superior Court File No. 500-17-036750-076.

Feb–Oct 2004 **Crawford Adjusters Canada**
Provided analysis of artifacts in high definition video

Jul 2002–May 2016 **Court of Quebec, Small Claims Division**
Brought 14 consumer rights complaints before the Court, 11 of which were successful

RESEARCH DISSEMINATION

Notes on publication strategy: In my research field, papers in the ACM CHI (H5-index=87), UIST (H5-index=46), DIS (H5-index=33), and Mobile HCI (H5-index=28) conferences are considered to be top-tier, archival publications, competitive with the top HCI journals in terms of impact and visibility. Overall acceptance rates for these conferences are typically in the 20-25% range. As a measure of research impact, my publications have garnered over 5000 citations to date (Google Scholar) with approximately half of these since 2017, an h-index of 36, and i10-index of 105. HQP under my supervision (names in bold) are typically given first authorship on co-authored work.

ARTICLES IN REFEREED PUBLICATIONS

- [J1] **Nathan Duarte**, R. K. Arora, G. Bennett, M. Wang, M. P. Snyder, J. R. Cooperstock, and C. E. Wagner. “Deploying wearable sensors for pandemic mitigation: a counterfactual modelling study of Canada’s second COVID-19 wave.” In: *PLOS Digital Health* PDIG-D-22-00126R1 (Sept. 2022). DOI: <https://doi.org/10.1371/journal.pdig.0000100>. URL: <https://journals.plos.org/digitalhealth/article?id=10.1371/journal.pdig.0000100>.
- [J2] **M. F. de Vargas**, **D. Marino**, **A. Weill–Duflos**, and J. R. Cooperstock. “Speaking Haptically: from Phonemes to Phrases with a Mobile Haptic Communication System.” In: *Transactions on Haptics* 14.3 (July 2021), pp. 479–490. DOI: [10.1109/TOH.2021.3054812](https://doi.org/10.1109/TOH.2021.3054812). URL: <https://ieeexplore.ieee.org/document/9337220>. 🏆 Finalist, Best Applications Paper Award.
- [J3] **P. Vyas**, **F. Al-Taha**, **J. R. Blum**, **A. Weill–Duflos**, and J. R. Cooperstock. “Ten Little Fingers, Ten Little Toes: Can Toes Match Fingers for Haptic Discrimination?” In: *Transactions on Haptics* 13.1 (2020). DOI: [10.1109/TOH.2020.2966969](https://doi.org/10.1109/TOH.2020.2966969). URL: <https://ieeexplore.ieee.org/document/8960637>. Also presented at Haptics Symposium 2020.
- [J4] **E. Sulmont**, E. Patitsas, and J. R. Cooperstock. “What Is Hard About Teaching Machine Learning to Non-Majors? Insights From Classifying Instructors’ Learning Goals.” In: *Transactions on Computing Education, Special Issue on Machine Learning Education* 19.4 (Aug. 2019). URL: <http://dl.acm.org/authorize?N682238>.
- [J5] **J. Blum**, **P. Fortin**, **F. Al-Taha**, **P. Alirezaee**, **M. Demers**, **A. Weill–Duflos**, and J. R. Cooperstock. “Getting Your Hands Dirty Outside the Lab: A Practical Primer for Conducting Wearable Vibrotactile Haptics Research.” In: *IEEE Transactions on Haptics, Special Issue on Wearable and Hand-held Haptics* 12.3 (July 2019), pp. 232–246. DOI: [10.1109/TOH.2019.2930608](https://doi.org/10.1109/TOH.2019.2930608). URL: <https://ieeexplore.ieee.org/document/8770138>.
- [J6] **G. Millet**, **M. Otis**, **D. Horodniczy**, and J. R. Cooperstock. “Design of Variable-Friction Devices for Shoe-Floor Contact.” In: *Mechatronics* 46 (2017), pp. 115–125. URL: <https://www.sciencedirect.com/science/article/abs/pii/S0957415817301034>.

- [J7] **P. Fortin** and J. R. Cooperstock. “Laughter and Tickles: Toward Novel Approaches for Emotion and Behavior Elicitation.” In: *IEEE Transactions on Affective Computing* 8.4 (2017). TAFFCSI-2016-07-0124.R1, pp. 508–521. URL: <http://ieeexplore.ieee.org/document/8052511/>.
- [J8] E. Aguilera, J. J. Lopez, and J. R. Cooperstock. “Spatial Audio for Audioconferencing in Mobile Devices: Investigating the Importance of Virtual Mobility and Private Communication and Optimizations.” In: *Journal of the Audio Engineering Society* 64.5 (May 2016), pp. 332–341. URL: <http://www.aes.org/e-lib/browse.cfm?elib=18138>.
- [J9] **D. El-Shimy** and J. R. Cooperstock. “User-Driven Techniques for the Design and Evaluation of New Musical Interfaces.” In: *Computer Music Journal* 40.2 (2016), pp. 35–46. URL: http://www.mitpressjournals.org/doi/pdf/10.1162/COMJ_a_00357.
- [J10] **F. Tordini**, A. Bregman, and J. R. Cooperstock. “Prioritizing foreground selection of natural chirp sounds by tempo and spectral centroid.” In: *Multimodal User Interfaces, Special Issue on Auditory Display* 10.3 (Sept. 2016). Ed. by B. Katz and G. Marentakis, pp. 221–234. URL: <http://link.springer.com/article/10.1007%2Fs12193-016-0223-x>.
- [J11] R. F. Hess, **L. To**, J. Zhou, **G. Wang**, and J. Cooperstock. “3D Vision: the haves and havenots.” In: *i-Perception* 6.3 (July 2015). DOI: [10.1177/2041669515593028](https://doi.org/10.1177/2041669515593028). URL: <http://ipe.sagepub.com/content/6/3/2041669515593028.full.pdf+html>.
- [J12] **N. Hieda** and J. R. Cooperstock. “Digital Facial Augmentation for Interactive Entertainment.” In: *EAI Endorsed Transactions on e-Learning* 15.8 (Aug. 2015). DOI: [10.4108/icst.intetain.2015.259444](https://doi.org/10.4108/icst.intetain.2015.259444).
- [J13] **J. Blum**, **A. Eichhorn**, **S. Smith**, **M. Sterle-Contala**, and J. R. Cooperstock. “Real-Time Emergency Response: Improved Management of Real-Time Information During Crisis Situations.” In: *Multimodal User Interfaces* 8.2 (July 2014). JMUI-D-13-00047R3, pp. 161–173. DOI: [10.1007/s12193-013-0139-7](https://doi.org/10.1007/s12193-013-0139-7). URL: <http://www.springer.com/alert/urltracking.do?id=L4b94d11Mf77f37Sb05893a>.
- [J14] **D. Dansereau**, N. Brock, and J. R. Cooperstock. “A Particle Filter for Predicting an Orchestral Conductor’s Baton Movements.” In: *Computer Music J.* 37.2 (Apr. 2013), pp. 28–45. URL: http://www.mitpressjournals.org/doi/pdf/10.1162/COMJ_a_00173.
- [J15] **G. Cirio**, M. Marchal, A. Lécuyer, and J. R. Cooperstock. “Vibrotactile Rendering of Splashing Fluids.” In: *Transactions on Haptics* 6.1 (May 2013), pp. 117–122. URL: http://ieeexplore.ieee.org/xpls/abs_all.jsp?arnumber=6226398. 🏆 Best paper award.
- [J16] F. Grond, **A. Olmos**, and J. Cooperstock. “Making Sculptures Audible through Participatory Sound Design (Artists’ statement).” In: *Leonardo Music J.* 23 (Dec. 2013), pp. 12–13. DOI: [doi:10.1162/LMJ_a_00140](https://doi.org/10.1162/LMJ_a_00140). URL: <http://srl.mcgill.ca/publications/2013-LEONARDO.pdf>.
- [J17] **J. Blum**, **M. Bouchard**, and J. R. Cooperstock. “Spatialized audio environmental awareness for blind users with a smartphone.” In: *Mobile Networks and Applications* 18.3 (June 2013), pp. 295–309. DOI: [10.1007/s11036-012-0425-8](https://doi.org/10.1007/s11036-012-0425-8). URL: <http://srl.mcgill.ca/publications/2012-MONET.pdf>.

- [J18] **S. Pelletier** and J. R. Cooperstock. “Real-time free viewpoint video from a range sensor and color cameras.” In: *Machine Vision and Applications* 24.4 (May 2013), pp. 739–751. URL: <http://link.springer.com/article/10.1007%2Fs00138-012-0428-2>.
- [J19] **A. Olmos, N. Bouillot, T. Knight, N. Mabire, J.Redel,** and J. R. Cooperstock. “A High-Fidelity Orchestra Simulator for Individual Musicians’ Practice.” In: *Computer Music Journal* 36.2 (2012), pp. 55–73. URL: http://www.mitpressjournals.org/doi/pdf/10.1162/COMJ_a_00119.
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- [J21] **D. El-Shimy,** F. Grond, **A. Olmos,** and J. R. Cooperstock. “Eyes-Free Environmental Awareness for Navigation.” In: *Multimodal User Interfaces, Special Issue on Interactive Sonification* 5.3-4 (2012), pp. 131–141. DOI: [10.1007/s12193-011-0065-5](https://doi.org/10.1007/s12193-011-0065-5). URL: <http://www.springerlink.com/content/857h542884084ql2/>.
- [J22] B. L. Giordano, **Y. Visell,** H. Yao, V. Hayward, J. R. Cooperstock, and S. McAdams. “Identification of walked-upon materials in auditory, kinesthetic, haptic and audio-haptic conditions.” In: *Acoustical Society of America* 131.5 (May 2012). URL: <http://srl.mcgill.ca/publications/2012-JASA.pdf>.
- [J23] R. F. Hess, B. Thompson, J. M. Black, G. Maehara, P. Zhang, W. R. Bobier, **L. To,** and J. R. Cooperstock. “An iPod treatment for amblyopia: An updated binocular approach.” In: *Optometry* 83.2 (Feb. 2012), pp. 87–94. URL: <http://www.ncbi.nlm.nih.gov/pubmed/23231369>.
- [J24] **S. Pelletier** and J. R. Cooperstock. “Preconditioning for Edge-Preserving Image Super-Resolution.” In: *IEEE Transactions on Image Processing* 21.1 (June 2012), pp. 67–79. URL: <http://ieeexplore.ieee.org/stamp/stamp.jsp?tp=&arnumber=5898412>.
- [J25] **Z. Qi** and J. R. Cooperstock. “Toward Dynamic Image Mosaic Generation With Robustness to Parallax.” In: *IEEE Transactions on Image Processing* 21.1 (Jan. 2012), pp. 366–378. URL: <http://ieeexplore.ieee.org/stamp/stamp.jsp?tp=&arnumber=5959979>.
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- [J27] **L. To,** B. Thompson, **J.R. Blum,** G. Maehara, R. Hess, and J. R. Cooperstock. “A game platform for treatment of amblyopia.” In: *IEEE Transactions on Neural Systems and Rehabilitation Engineering* 19.3 (Feb. 2011), pp. 280–289. URL: <http://ieeexplore.ieee.org/stamp/stamp.jsp?tp=&arnumber=5713843>.
- [J28] **Y. Visell,** B. Giordano, **G. Millet,** and J. R. Cooperstock. “Vibration Influences Haptic Perception of Surface Compliance During Walking.” In: *PLoS ONE* 6.3:e17697 (Mar. 2011). DOI: [doi:10.1371/journal.pone.0017697](https://doi.org/10.1371/journal.pone.0017697). URL: <http://dx.plos.org/10.1371/journal.pone.0017697>.

- [J29] **R. Pellerin, N. Bouillot, T. Pietkiewicz**, M. Wozniowski, Z. Settel, E. Gressier-Soudan, and J. R. Cooperstock. “SoundPark: Exploring Ubiquitous Computing through a Mixed Reality Multi-player Game Experiment.” In: *Studia Informatica Universalis* 8.3 (2010). Special Issue: Best Papers from NOTERE 2009, 21 pages. URL: <http://srl.mcgill.ca/publications/2009-NOTERE.pdf>.
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- [J31] **G. Wang**, L. Mercier, D. L. Collins, and J. R. Cooperstock. “A Comparative Study of Monoscopic and Stereoscopic Display for a Probe-Positioning Task.” In: *Studies in Health Technology and Informatics* 142 (Jan. 2009). Ed. by J. D. Westwood, S. W. Westwood, R. S. Haluck, H. M. Hoffman, G. T. Mogel, R. Phillips, R. A. Robb, and K. G. Vosburgh, pp. 417–419. URL: <http://srl.mcgill.ca/publications/2009-MMVR-Wang.pdf>.
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- [CP1] **M. F. de Vargas, D. Marino, A. Weill-Duflos**, and J. R. Cooperstock. “Speaking Haptically: from Phonemes to Phrases with a Mobile Haptic Communication System.” In: *World Haptics Conference*. Virtual Conference: IEEE, July 2021.

- [CP2] J. Cooperstock and **J.R. Blum**. “Touch me like it matters: exploring location and encodings for explicit and implicit communication.” In: *Haptics Symposium, Interactive Session associated with the Cross-Cutting Challenge on Using the Skin as a Medium of Communication*. Washington, DC, Mar. 2020.
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- [CP8] **J. Blum**, J. R. Cooperstock, and J. Cauchard. “Pseudo-Ambience: Filling the Gap Between Notifications and Continuous Information Displays.” In: *UbiTtention Workshop on Smart & Ambient Notification and Attention Management*. Singapore: ACM, Oct. 2018. URL: <http://dl.acm.org/authorize?N682234>.
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- [CP13] **F. Tordini** and J. R. Cooperstock. “Auditory salience modeling via streaming: A behavioural view.” In: *Milestones in Music Cognition: BKN 25*. Montreal, Canada, July 2014.

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- [B1] **T. Kim**, **J. Blum**, **P. Alirezaee**, **A. Arnold**, **P. Fortin**, and J. R. Cooperstock. “Usability of Foot-Based Interaction Techniques for Mobile Solutions.” In: *Mobile Solutions and Their Usefulness in Everyday Life*. Springer International Publishing AG, Jan. 2019, pp. 309–329. DOI: https://doi.org/10.1007/978-3-319-93491-4_16. URL: https://link.springer.com/chapter/10.1007/978-3-319-93491-4_16.
- [B2] **M. Wozniowski**, Z. Settel, and J. R. Cooperstock. “Sonic Interaction via Spatial Arrangement in Mixed Reality Environments.” In: *Sonic Interaction Design*. Ed. by K. Franinovic and S. Serafin. MIT Press, 2013, pp. 329–340. URL: <http://xplorebcapaz.ieee.org/xpl/login.jsp?tp=&arnumber=6504636>.
- [B3] M. Marchal, **G. Cirio**, **Y. Visell**, F. Fontana, S. Serafin, J. R. Cooperstock, and A. Lécuyer. “Multimodal Rendering of Walking over Virtual Grounds.” In: *Human Walking in Virtual Environments*. Ed. by Y. Visell, A. Lécuyer, F. Steinicke, and J. Campos. Springer Verlag, 2013, pp. 263–295. URL: <http://www.springer.com/engineering/robotics/book/978-1-4419-8431-9>.
- [B4] **Y. Visell** and J. R. Cooperstock. “Interacting with augmented floor surfaces.” In: *Human Walking in Virtual Environments*. Ed. by Y. Visell, A. Lécuyer, F. Steinicke, and J. Campos. Springer Verlag, 2013, pp. 377–399. URL: <http://www.springer.com/engineering/robotics/book/978-1-4419-8431-9>.
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OTHER REFEREED PUBLICATIONS

- [O1] **N. Hieda** and J. R. Cooperstock. *SharedFace2*. International Conference and Exhibition of Virtual Technologies and Uses: Laval Virtual ReVolution (refereed interactive demonstration). Laval, France, Apr. 2015.
- [O2] **Y. Visell**, **G. Millet**, and J. R. Cooperstock. *Haptic Display via a Vibrating, Rigid Surface*. Demonstration in IEEE Haptics Symposium. Waltham, MA, USA, Mar. 2010.
- [O3] **A. Law**, **J. Ip**, **B. Peck**, **Y. Visell**, P. Kry, and J. R. Cooperstock. *A Multimodal Floor for Virtual Environments*. Demonstration in SIGGRAPH Emerging Technologies. Aug. 2009.
- [O4] **M. Wozniowski**, Z. Settel, and J. R. Cooperstock. *Ménagerie Imaginaire*. Artwork Performance in New Interfaces for Musical Expression (NIME). New York, NY, USA, June 2007.

NON-REFEREED CONTRIBUTIONS

- [N1] J. Cooperstock. “Situating UbiComp Education within or distinct from HCI?” In: *Ubiquitous Computing Education: Why, What, and How*: ed. by A. Girouard, A. L. Kun, A. Roudaut, and O. Shaer. Vol. 9. 6. Dagstuhl, Germany: Schloss Dagstuhl–Leibniz-Zentrum fuer Informatik, Mar. 2019. URL: <http://drops.dagstuhl.de/opus/volltexte/2019/11460>.
- [N2] **E. Sheepy**, M. Orjuela-Laverde, and J. R. Cooperstock. “Encouraging active and collaborative learning in two engineering courses.” In: *Supporting Active Learning and Technological Innovation in Studies of Education*. Montreal, Canada, June 2016.
- [N3] J. R. Cooperstock and G. Lukács. *How to complain to airlines*. CBC Marketplace blog. Mar. 2014. URL: <http://www.cbc.ca/marketplace/blog/plane-wrong-how-to-complain-to-airlines>.
- [N4] **F. Tordini** and J. R. Cooperstock. “Auditory salience modeling via streaming: A behavioural view.” In: *Milestones in Music Cognition: BKN 25*. Montreal, Canada, July 2014.

- [N5] J. R. Cooperstock. “Overcoming Complexity in the Teaching and Learning Environment.” In: *Materials Science and Technology*. Ralph Lloyd Harris Memorial Symposium. Montreal, Oct. 2013.
- [N6] J. R. Cooperstock. *From Rehearsal to Performance: Ensemble Learning in Open Orchestra and Distributed Rehearsal for World Opera*. Presentation in Music Anywhere, Anytime: International Symposium on Synchronous Distance Learning. Oct. 2011.
- [N7] **Benovoy, M.**, J. Cooperstock, and M. Levine. *Real-Time Facial Recognition*. Phase II Project Report for Department of National Defence. 2010.
- [N8] M. Levine, **Benovoy, M.**, and J. Cooperstock. *An Automatic Real-Time Facial Recognition System*. Phase I Project Report for Department of National Defence. 2009.
- [N9] **N. Bouillot**, E. Cohen, J. R. Cooperstock, A. Floros, N. Fonseca, R. Foss, M. Goodman, J. Grant, K. Gross, S. Harris, B. Harshbarger, J. Heyraud, L. Jonsson, J. Narus, M. Page, T. Snook, A. Tanaka, J. Trieger, and U. Zanghieri. “AES White Paper AESTD1003V1: Best Practices in Network Audio.” In: *Journal of the Audio Engineering Society* 57.9 (Sept. 2009), pp. 729–741. URL: <http://www.aes.org/e-lib/browse.cfm?elib=14839>.
- [N10] V. N. Salimpoor, **M. Benovoy**, G. Longo, J. R. Cooperstock, and R. J. Zatorre. *Qualifying the Chills Response: Differences between Transient and Prolonged Chills in Response to Music*. Presentation in Auditory Perception, Cognition, and Action Meeting. Chicago, IL, USA, 2008.
- [N11] J. Cooperstock. “Plus de largeur du bande, s’il vous plaît.” In: *L’interdisciplinarité dans les sciences et technologies de la musique (invited)*. Montreal: Association francophone pour le savoir (ACFAS), May 2006.
- [N12] J. Cooperstock. “Integrating Communication with Interaction: Computer Vision Challenges for Interactive and Intelligent Environments.” In: *Workshop on Computer Vision for Interactive and Intelligent Environments (invited)*. Lexington, KY, USA, Nov. 2005. URL: <http://srl.mcgill.ca/publications/2005-CV4IIE.pdf>.
- [N13] J. Cooperstock, J. Roston, and Woszczyk. “Broadband Networked Audio: Entering the Era of Multisensory Data Distribution.” In: *18th International Congress on Acoustics (invited)*. Kyoto, Apr. 2004.
- [N14] **Cayouette, F.**, **Sud, D.**, **Patel, K.**, **Sarikaya, D.**, and J. Cooperstock. “McGill Reddogs Final Report.” In: *Robocup*. 2002.
- [N15] J. Cooperstock. “Classroom of the Future: Enhancing Education through Augmented Reality.” In: *HCI International, Conference on Human-Computer Interaction (invited)*. New Orleans, 2001.
- [N16] **Sud, D.**, **Cayouette, F.**, **Gu, J.**, and J. Cooperstock. “McGill Reddogs Final Report.” In: *Robocup*. 2001.
- [N17] A. Saroyan, R. Harris, and J. R. Cooperstock. *Applying pedagogical principles to teaching and learning with technology*. Multi-cultural perspectives on the use of technology in education. Montreal, QC, Canada, 2000. URL: <http://www.education.mcgill.ca/NAFTA>.

PATENTS

- [P1] **P. Fortin, J. Blum, Antoine Weill–Duflos**, and J. R. Cooperstock. “System and Method for Wearable Device Contact Force Estimation and Adjustment Feedback.” provisional application US 05001770-936USPR (United States). 2021.
- [P2] **P. Fortin**, S. Kim, and J. R. Cooperstock. “Closed-loop XR Stimulus Presentation and Perception Feedback using Multi-Channel Physiological Signals.” application US 2020P00157WO (United States). 2021.
- [P3] J. R. Cooperstock and **J. Blum**. “Improving Haptic Feedback on Wearable Devices through Accelerometer Measurements.” provisional application US 62/237,772; US 62/416,910 (United States). 2015.
- [P4] J. R. Cooperstock, **Y. Visell, A. Law**, and K. Franinovic. “Floor-based Haptic Communication System.” US 9,041,521 (United States). May 2015.
- [P5] J. R. Cooperstock, **J. Blum, M. Bouchard, A. Olmos, S. Panëels**, and **D. El-Shimy**. “Spatialized audio augmented reality for blind users with a smartphone.” provisional application US 61/727,828 (expired) (United States). 2012.
- [P6] J. R. Cooperstock, **G. Millet**, and **M. Otis**. “Floor-Based Variable Friction Display.” provisional application US 61/577,148 (expired) (United States). 2011.
- [P7] J. R. Cooperstock, **L. To**, and R. Hess. “A Tetris-style gaming approach to treat amblyopia.” US 8,066,372 (United States). Nov. 2011.
- [P8] J. Roston, J. R. Cooperstock, J. MacDougall, and **S. Spackman**. “Remote sign language interpretation system.” US 60/463,332; CA 2,426,161; US 7,395,200 (United States). Feb. 2003.
- [P9] **S. Spackman, S. Pelletier**, and J. R. Cooperstock. “High-resolution Video Synthesis.” application 2,435,791 filed July 24, 2003 (expired) (Canada). 2003.
- [P10] J. R. Cooperstock, **Y. Zhang**, and **S. Spackman**. “Adaptive Compression for the Storage, Transmission, and Arbitrary Quality Reconstruction of Spatial Data.” US 60/339,816, provisional application filed Dec. 17, 2001 (expired) (United States). 2001.
- [P11] J. R. Cooperstock and **S. Arseneau**. “A robust person tracking method and system.” US 60/234,197 provisional application, filed Sept. 20, 2000 (expired) (United States). 2000.
- [P12] J. R. Cooperstock. “Pixel Count-Sensitive PDA Tool Mechanism with Cut/Paste and/or Copy/Paste Function.” P09-022797, filed in Japan by Sony Corp. (Japan). Feb. 1997.

TECHNOLOGY TRANSFER

License agreement signed in 2014 with amblyotech.com to commercialize amblyopia treatment (protected under US patent 8,066,372 “Binocular vision assessment and/or therapy”). The technology was subsequently [acquired by Novartis](#) in April 2020.

RESEARCH DEMONSTRATIONS

- [D1] 3D Printed Haptic Illusions and Demonstrations. IEEE World Haptics, Tokyo, Japan (conducted by Antoine Weill–Duflos and Pascal Fortin), July 2019.
- [D2] Distributed Musical Practice and Performance, I Medici di McGill, Oscar Peterson Hall, Montreal, April 28, 2008.
- [D3] Wide Screen Window on the World: Life Size HD Videoconferencing. Supercomputing 2005, Bandwidth Challenge, Seattle, November 16, 2005.
- [D4] Streaming DSD Audio comes to the AES. Audio Engineering Society 117th Convention, San Francisco, October 31, 2004.
- [D5] Cross-continental low-latency ultra-videoconferencing. McGill-Stanford jazz jam, June 13, 2002.
- [D6] Remote master’s class using SDI video and multichannel audio. McGill-National Research Council session with Pinchas Zukerman, March 25, 2002.
- [D7] SDI video and multichannel audio. CANARIE’s 7th Advanced Networks Workshop, Toronto, November 28, 2001.
- [D8] Low-latency distributed violin duet in full-frame video. RISQ 2001 Conference, Montreal, November 5, 2001.
- The Globe and Mail noted that *“Cooperstock’s demonstration was a watershed event for the elite club of the world’s computer network engineers. No one had ever before been able to demonstrate that, under the right conditions, it is possible for natural, normal human interaction to occur over the Internet.”*
- [D9] The Recording Studio that Spans a Continent. Audio Engineering Society 109th Convention, Los Angeles, September 23, 2000.
- The Audio Engineering Society noted that this *“Landmark demonstration shows cost effective and high performance transmission systems for high quality 24-bit, 96kHz uncompressed multichannel audio are on horizon”*
- [D10] Dolby Digital 5.1 audio with MPEG-2 video around the world. Internet Global Summit INET 2000 Conference, Yokohama, July 20, 2000.
- CBC Radio noted that *“McGill University in Montreal has made Internet history by setting up the first intercontinental netcast of a live concert in surround sound and full-screen video.”*
- [D11] Dolby Digital 5.1 audio with MPEG-2 video. CANARIE’s 5th Advanced Networks Workshop, Toronto, November 29, 1999.
- [D12] First real-time Multichannel Audio Internet demo. Audio Engineering Society 107th Convention, New York, September 26, 1999.
- The Learning Technologies Networked noted that *“The performance marked the first real time multichannel audio Internet transmission, a feat made possible by software developed at McGill University by a team under the leadership of Professor Jeremy Cooperstock.”*

INVITED TALKS

Invited Talks to Industry, Students, and the Public

- [T1] “Using smartphones to answer ‘What’s around me?’, ‘Am I crossing the street safely?’ and ‘Where’s the entrance?’”, Accessible Coding Demonstrations for Youth with Visual Impairment, Science Odyssey 2021, May 1, 2021.
- [T2] “From flight simulators to the passenger experience: what can we learn from pilot-training tools to improve airline customer service”, AIST–NRC Collaboration Meeting on Improving Client-Agent Interaction, January 17, 2020.
- [T3] “I Feel the Earth Move (Under My Feet): Haptic Interaction for Telepresence and Information Delivery”, Department of Information Engineering and Computer Science, University of Trento, July 4, 2019.
- [T4] “I Feel the Earth Move (Under My Feet): Haptic Interaction for Telepresence and Information Delivery”, Department of Industrial Engineering and Management, Ben Gurion University, March 11, 2019.
- [T5] “I Feel the Earth Move (Under My Feet): Haptic Interaction for Telepresence and Information Delivery”, Information Systems, University of Haifa, November 7, 2018.
- [T6] “What’s around me? Audio augmented reality for blind users with a smartphone, Pint of Science, Montreal, May 15, 2018.
- [T7] Presenter at Canadian National Institute for the Blind’s TechnoVision+ Conference, Montreal, May 5, 2017.
- [T8] “Innovations for Gaming, AR, Simulation & Training”, Innovations for gaming, augmented reality, simulation and training, and other applications, Centre d’entreprises et d’innovation de Montreal (CEIM), April 8, 2016.
- [T9] “Enhanced Human: Wearable computing that transforms how we perceive and interact with our world”, Department of Computer Science, Technion–Israel Institute of Technology, February 11, 2016.
- [T10] “Is Humanity Smart Enough for AI?”, McGill Science Outreach Program, Freaky Friday public outreach lecture, October 23, 2015.
- [T11] “Delivering a Compelling User Experience in a Computer-Mediated Environment”, HCIN 5300, Interactive Entertainment Technologies, Carleton University, March 7, 2014.
- [T12] “Multimedia as a Building Block: How audio, video and haptics integrate in a Shared Reality”, Multimedia Systems, GLIS 633, School of Information Studies, McGill University, February 13, 2014.
- [T13] “Are we there yet? Cognitive Science Challenges in Telepresence and Virtual Reality”, Student Association of Cognitive Science, Cognitive Science Research Day, McGill University, November 13, 2013.

- [T14] “Telepresence doesn’t quite cut it: Multimodal Challenges in Virtual and Shared Reality”, Institute of Telecommunications and Multimedia Applications, Universidad Politècnica de València, July 10, 2013.
- [T15] “Telepresence doesn’t quite cut it: Multimodal Challenges in Virtual and Shared Reality”, Dawson College, First Choice Science speakers series, April 17, 2013.
- [T16] “Dangerous AI or dangerous us?”, Academia Week Artificial Intelligence event, Science Undergraduate Society, McGill University, January 24, 2013.
- [T17] “They don’t use Skype on the Holodeck”, Department of Computer Science, University of British Columbia, July 4, 2012.
- [T18] “But can the Holodeck do a good Shiraz?”, School of Computer Science and IT, Royal Melbourne Institute of Technology, February 17, 2012.
- [T19] “But can the Holodeck do a good Shiraz?”, School of Information Technologies, University of Sydney, February 15, 2012.
- [T20] “Distributed Music Performance and Latency Issues”, School of Drama, Fine Art and Music, University of Newcastle (Australia), February 13, 2012.
- [T21] “But can the Holodeck do a good Pinot noir?”, Department of Computer Science, University of Otago, January 23, 2012.
- [T22] “Shared Reality: Toward perceptually convincing computer-mediated environments”, Department of Computer Science, University of Auckland, August 25, 2011.
- [T23] “This is your brain on Shared Reality: Toward perceptually convincing computed-mediated environments”, Vanier College, Science Week Presentation, March 24, 2011.
- [T24] “This is your brain on Shared Reality: Toward perceptually convincing computed-mediated environments”, Simula Lab, Oslo, May 15, 2009.
- [T25] “This is your brain on Shared Reality: Toward perceptually convincing computed-mediated environments”, Ambient Intelligence Group, CITEC, Bielefeld University, May 6, 2009.
- [T26] “Distributed and Multimodal Interaction in Virtual and Augmented Reality Environments”, McGill University, School of Physical and Occupational Therapy, November 25, 2008.
- [T27] “Shared Reality: Effective Interaction for (Demanding) Distributed Tasks”, University of Victoria, September 16, 2008.
- [T28] “Bidirectional video communication for real-time applications”, Institut für Telematik, University of Lübeck, Germany, May 15, 2008.
- [T29] “Shared Reality: Effective Interaction for (Demanding) Distributed Tasks”, Aalborg University, Esbjerg, Denmark, May 14, 2008.
- [T30] “Distributed Multimodal Interaction”, Bang & Olufsen, Struer, Denmark, May 13, 2008.

- [T31] “Distributed Musical Practice and Performance”, Biology and Music Lecture, I Medici di McGill, April 28, 2008.
- [T32] “Shared Reality: Effective Interaction for (Demanding) Distributed Tasks”, Arts, Media and Engineering, Arizona State University, February 29, 2008
- [T33] “From Videoconferencing to Shared Reality” Department of Electrical and Computer Engineering, University of British Columbia, October 4, 2007.
- [T34] “Engaging Technolog(ies) for Effective Interaction” Department of Computer Science, Hebrew University of Jerusalem, April 19, 2005.
- [T35] “Engaging Technolog(ies) for Effective Interaction” Intelligence, Agents, Multimedia Group, University of Southampton, UK, March 7, 2005.
- [T36] “From Videoconferencing to Shared Reality” l’Institut de Recherche et Coordination Acoustique/Musique (IRCAM), Paris, November 25, 2004.
- [T37] “From Videoconferencing to Shared Reality” Taiyuan University, Taiyuan, China, April 18, 2004.
- [T38] “From Videoconferencing to Shared Reality” Tsinghua University, Beijing, China, April 14, 2004.
- [T39] “From Videoconferencing to Shared Reality” Beijing University, Beijing, China, April 14, 2004.
- [T40] “From Videoconferencing to Shared Reality” Beihang University, Beijing, China, April 12, 2004.
- [T41] “From Videoconferencing to Shared Reality” Advanced Telecommunications Research (ATR), Nara, Japan, April 9, 2004.
- [T42] “From Videoconferencing to Shared Reality” Dept. of Industrial Engineering, Musashi Institute of Technology, April 5, 2004.
- [T43] “High-fidelity telepresence” Graphics and Geometric Computing Seminar Series, Technion – Israel Institute of Technology, January 1, 2003.
- [T44] “The Virtual Studio” Royal Conservatory of Music, Toronto, February 25, 2002.
- [T45] “Building a Shared Reality” Department of Computer Science, University of Toronto, February 25, 2002.
- [T46] “Distributed Concerts and Shared Reality: Just how much streamed data and computation do we need to support effective interaction?” Department of Computer Science, Clarkson University, November 1, 2001.
- [T47] “Robotics and Design” Round Table Panel, Centre Design UQAM, February 9, 2000.
- [T48] “The Shared Reality Environment” Department of Electrical and Computer Engineering, Ecole Polytechnique, Montreal, May 28, 1999.

Invited Talks in Scholarly Conferences and Workshops

- [T49] Speaker in “Next Gen Health Powered By The Open Grid And Edge AI”, IEEE Future Networks Forum, Montreal, October 14, 2022.
- [T50] “Touch and feel when it isn’t real: Integrating haptics into the XR experience”, InterDigital Scientific Seminar series, December 4, 2020.
- [T51] “Taking Haptics Out of the Lab and Into the Wild”, Introduction to Haptics for Next Generation XR. International Conference on Intelligent Robots and Systems Tutorial Session, October 29, 2020.
- [T52] “Assistive Technology Research in the Shared Reality Lab”, Conférence scientifique du CRIR-Institut Nazareth et Louis-Braille, September 25, 2019.
- [T53] “Learning from sparse feedback: Adapting an environmental awareness app to visually impaired user preferences”, ACM-SIGCHI sponsored summer school on Intelligent User Interfaces in the Era of IoT and Smart Environments, Haifa, Israel, October 3, 2018.
- [T54] Speaker in “AR/VR panel”, IEEE Multimedia Signal Processing Workshop, Montreal, September 23, 2016.
- [T55] “Immersive multimedia and mobile interaction: Applications to new media, gaming, medicine, and beyond” Keynote speaker, Entertainment Technology Summit, Concordia University, Montreal, September 17, 2016.
- [T56] “Leveraging video in public safety scenarios”, Ninth Canadian Public Safety Interoperability Workshop (CITIG 9), Toronto, December 1, 2015.
- [T57] “Future Cities (2040) – Mind: Human and Machine”, Institute for the Public Life of Arts and Ideas, Symposium on Future Cities, March 13, 2015.
- [T58] “UltraVideo and the Quest for Minimal Latency”, International Workshop on High Quality Dynamic cross-continental Networked Artistic interaction, World Opera Association, Struer, Denmark, August 29, 2013.
- [T59] “Assisting the blind and treating amblyopia: Two more things you can do with your smartphone”, 15e Symposium scientifique sur l’incapacité visuelle et la réadaptation (presented with J. Blum). University of Montreal, February 12, 2013.
- [T60] “Revolutions in human-device interaction: How new paradigms impact user experience”, International Conference on Consumer Electronics, Consumer Electronics Society, Las Vegas, January 12, 2013.
- [T61] “Around the World in 80 ms.” Panel presentation in Workshop of the Audio Engineering Society Convention, San Francisco, November 5, 2010.
- [T62] “UltraVideo and Virtual Presence: A Video Perspective.” Presentation on Teaching in Distributed Performance, Tromsø, Norway, October 15, 2010.

- [T63] “Future Interfaces for Audio.” Panel presentation in Workshop of the Audio Engineering Society Convention, New York, October 10, 2009.
- [T64] “World Opera Technologies and Tests”, Danish Sound Technology Network, Aalborg University, June 8, 2009.
- [T65] “The Montreal World Opera Experiments”. Presentation at the World Opera Symposium, Struer, Denmark, May 12, 2009.
- [T66] “Audio-Visual-Haptic-Tactile: Putting them all together for an engaging immersive experience”. Panel presentation in Workshop of the Audio Engineering Society Convention, Munich, Germany, May 10, 2009.
- [T67] “New Technologies for Audio over IP”. Panel presentation in Workshop of the Audio Engineering Society Convention, Munich, Germany, May 10, 2009.
- [T68] “A Platform to Create and Support Ocean Science Virtual Organizations (Oceans 2.0)” and “HSVO Health Services Virtual Organization”, RISQ 2008 Colloquium, Montreal, November 14, 2008.
- [T69] “The Future of VC: Music Teaching and High Fidelity Video”, Elevate 2008: Reaching New Heights in Educational Video-conferencing, Banff, August 27–28, 2008.
- [T70] “Creating an immersive video space”, International Symposium on The World Opera: When the Opera stage becomes worldwide, Tromsø, Norway, May 9, 2008.
- [T71] “Multimodal Streaming and Distributed Audio Interaction”, High Quality Audio over Networks (ANET II) Summit, Banff Centre, April 12, 2008.
- [T72] “Music and Games: How Fun Applications Stimulate Core Technologies”, Canadian University Software Engineering Conference, January 19, 2008.
- [T73] “From Teleoperation to Teleimmersion: Design Challenges for Distributed Interaction”, Canadian University Software Engineering Conference, January 19, 2007.
- [T74] “CANARIE sur UCLP et ROADM, deux technologies qui changent le monde des télécoms”, Round Table panel, RISQ Annual Conference, Quebec City, October 16, 2006.
- [T75] “La recherche sur en ultra-videoconference”, Panel on “Vitrine technopédagogique sur la vidéoconférence”, RISQ Annual Conference, Quebec City, October 16, 2006.
- [T76] “Broadband transmission of multimodal content at the Centre for Interdisciplinary Research in Music Media and Technology (CIRMMT)”, RISQ-CA*net4 Advanced Networking Day, Montreal, October 24, 2005.
- [T77] “Low-Latency Ultra-Videoconferencing and Shared Reality” Interfaces Montreal, Rencontre du Génie numérique et des Affaires. Montreal, October 11, 2005.
- [T78] “Shared Spaces” Asia-Pacific Advanced Networks (APAN) Conference, Taipei Aug. 22–27, 2005.

- [T79] “Engaging Technolog(ies) for Effective Interaction” Keynote speaker, World Conference on Educational Multimedia, Hypermedia and Telecommunications, Montreal, June 29, 2005.
- [T80] “Broadband Distance Education in 2007: Views from the Demand Side” Invited Panelist. World Conference on Educational Multimedia, Hypermedia and Telecommunications, Montreal, June 29, 2005.
- [T81] “Ultra-Videoconferencing and Intelligent Classrooms” Keynote speaker, Canadian Higher Education and Information Technology Conference, Montreal, June 28, 2005.
- [T82] “From Videoconferencing to Shared Reality” Bell University Laboratories’ Annual Conference, Toronto, November 3, 2004.
- [T83] “History of Internet Audio Experiments at McGill” High Quality Audio over Networks (ANET) Summit, Banff Centre, August 20–22, 2004.
- [T84] “Advanced Video Applications: Developments in Extreme Video” Southeastern Universities Research Association Video Development Initiative (SURA/ViDe) 6th Annual Digital Video Workshop. Indianapolis, March 24, 2004.
- [T85] “The Democratic Revolutions – Peer to Peer Meets Open Source: Design, Philosophy, Engineering” Intimate Technologies/Dangerous Zones. Banff New Media Institute, Banff Centre, April 27, 2002.
- [T86] “The Development of Ultra VC Applications and Technology” Southeastern Universities Research Association Video Development Initiative (SURA/ViDe) 4th Annual Digital Video Workshop. University of Alabama at Birmingham, April 25, 2002.
- [T87] “High quality wide-screen SDI video and multichannel audio over CA*net3” CANARIE’s 7th Advanced Networks Workshop, Toronto, November 28, 2001.
- [T88] “Low-latency comes to videoconferencing: The Frères Jacques duet at a distance” RISQ 2001 Conference, Montreal, November 5, 2001.
- [T89] Advanced Networking and the Arts: Innovations in Outreach, Collaboration, and Performance. Panel Discussion at Internet Global Summit INET 2001 Conference, Stockholm, June 6, 2001.
- [T90] “The McGill–Calgary Advanced Learnware Network” CANARIE’s 6th Advanced Networks Workshop, Montreal, November 29, 2000.
- [T91] “Networks and Music Instruction” Panel Discussion with Pinchas Zukerman and Wieslaw Woszczyk, CANARIE’s 6th Advanced Networks Workshop, Montreal, November 29, 2000.
- [T92] “Tools for Distributed VR” Canadian Working Group on Virtualized Reality Systems, Montreal, November 28, 2000.
- [T93] “Evolution of the Intelligent Classroom” Multicultural Perspectives on the use of Technology in Education. Montreal, October 2, 2000.

- [T94] “The Brave New World of Ubiquitous Bandwidth” Internet Global Summit INET 2000 Conference, Yokohama, July 20, 2000.
- [T95] “Multichannel Audio over the Internet: The Next Phase” RISQ 2000 Conference, May 31, 2000.
- [T96] “Multichannel Audio over the Internet” CANARIE’s 5th Advanced Networks Workshop, Toronto, November 29, 1999.
- [T97] “When Telemedicine feels like Regular Medicine” Communications and Information Technology Ontario (CITO) Healthcare for the Future: Telemedicine, February 18, 1999.

MEDIA EXPOSURE

- [M1] Ami-Télé, Ça me regarde, February 8, 2018
- [M2] Forbes, March 9, 2017
- [M3] Discovery Channel, Daily Planet, Mar. 7, 2017
- [M4] Télé-Québec, Electrons Libre, Jan. 17, 2017
- [M5] ACB Radio, Mainstream, Nov. 18, 2016
- [M6] CBC Radio, Tech Column, Aug. 8, 2016
- [M7] CJAD Radio, Tech Talk, Aug. 6, 2016
- [M8] Mobile Syrup, Aug. 4, 2016
- [M9] CBC News, Aug. 4, 2016
- [M10] Betakit, Aug. 3, 2016
- [M11] Accessible Media Inc., Live from Studio 5, Aug. 2, 2016
- [M12] La Presse, Jul. 31, 2016
- [M13] CTV News, Jul. 29, 2016
- [M14] Stevivor, Mar. 2015
- [M15] Venture Beat, Mar. 3, 2015
- [M16] Club Social (TV5), Feb. 4, 2011
- [M17] Global TV (National), Jan. 29, 2009
- [M18] Global TV (Montreal), Jan. 27, 2009
- [M19] CBC Radio, As it Happens, Jan. 27, 2009
- [M20] National Post, Jan. 27, 2009
- [M21] Montreal Gazette, Jan. 27, 2009
- [M22] Montreal Gazette, Feb. 20, 2009
- [M23] Inside Higher Education, Sept. 3, 2008
- [M24] CBC Radio (Daybreak), Sept. 3, 2008

- [M25] CJAD radio, Sept. 2, 2008
- [M26] Cabling Networking Systems, Jan. 2006
- [M27] McGill Reporter, Nov. 24, 2005
- [M28] CTV Quebec, Global News, Dec. 23, 2002
- [M29] New York Times, Technology Section, Dec. 19, 2002
- [M30] Discovery Channel, Daily Planet, Oct. 30, 2002
- [M31] CFCF (CTV Quebec) Global News, June 19, 2002
- [M32] National Post, June 15, 2002
- [M33] CBC Television, The National, May 3, 2002
- [M34] McGill Reporter, Learning the Strings, April 11, 2002
- [M35] Ottawa Citizen, March 29, 2002
- [M36] Montreal Gazette, March 27, 2002
- [M37] Globe & Mail, Dec. 1, 2001
- [M38] Canal Z, La Revanche des Nerdz, Nov. 13, 2001
- [M39] Montreal Gazette, Nov. 10, 2001
- [M40] CJAD Radio, The World Today, July 31, 2001
- [M41] McGill Reporter, April 5, 2001
- [M42] Globe & Mail Report on Business, Oct. 28, 2000
- [M43] TQS Double Clic!, Oct. 7, 2000
- [M44] McGill Reporter, Sept. 21, 2000
- [M45] UPath.com, Vol 40, 2000
- [M46] CBC (Montreal) Home Run, Aug. 22, 2000
- [M47] Montreal Gazette, Aug. 22, 2000
- [M48] CFCF (CTV Quebec) Pulse News, Aug. 21, 2000
- [M49] CBC Radio The Arts Report, July 20, 2000
- [M50] Elle Quebec, June 2000
- [M51] Journal Le Monde des Affaires, May 2000
- [M52] Canal Z, Technofolie, May 3, 2000
- [M53] TQS Double Click, April 29, 2000
- [M54] McGill Reporter, April 6, 2000
- [M55] Briefing Digital, April 2000
- [M56] Interface: La Revue de la Recherche, Vol. 21, No. 2, March-April 2000
- [M57] American Society of Mechanical Engineers, Mechanical Advantage, Vol 9, No 3, March 2000
- [M58] Canal Z, La Revanche des Nerdz, Feb. 2000

- [M59] CFCF (CTV Quebec) Pulse News, Feb. 29, 2000
- [M60] Canal Vox: CityMag, Jan. 15, 2000
- [M61] Montreal Mirror, Jan. 6, 2000
- [M62] Plan Mega: La revue du genie québécois, Ordre des ingenieurs du Québec. Vol 1, Jan. 2000
- [M63] Radio Corporation of Singapore: Science and Technology Watch, Dec. 1999
- [M64] Radio Canada (CBC French) Les Annees lumiere, Nov. 28, 1999
- [M65] Financial Times Life/Technology, Nov. 25, 1999
- [M66] CBC Radio: As it Happens, Nov. 22, 1999
- [M67] Journal de Montreal, Nov. 19, 1999
- [M68] Le Devoir, Nov. 18, 1999
- [M69] TVA CyberClub, Nov. 13, 1999
- [M70] La Presse, Sept. 26, 1999
- [M71] CJAD Radio, April 11, 1999
- [M72] Montreal Mirror, April 8, 1999
- [M73] McGill Reporter, Jan. 14, 1999
- [M74] High-Tech Shower International, Nov. 26, 1997
- [M75] CBC Newsworld "Futureworld", Oct. 5, 1996
- [M76] Discovery Channel, Sept. 18, 1996
- [M77] Toronto Star, Sept. 15, 1996
- [M78] University of Toronto Varsity, Sept. 3, 1996
- [M79] TV Ontario "Studio Two", June 26, 1995

RESEARCH SUPERVISION

RESEARCH PROFESSIONALS

Name	Period	Project title	Present Position
Singh, Jaydeep	Sep 2021–	web developer, IMAGE project	
Novack, Kaylee	Sep 2021–Apr 2022	medical doctor researcher on Avatar Therapy project	
Kuo, Cyan	Aug 2021–	Usability Research Lead, IMAGE project	
Patil, Gandharv	Jun 2021–Mar 2022	ML Research Lead, IMAGE project	
Grond, Florian	Apr 2021–	Audio Research Lead, IMAGE project	
Eichhorn, Alexander	Feb 2013 – Aug 2013	research associate under GRAND	CTO of Kidtsunami
Bouchard, Mathieu	Jan 2011 – Nov 2018	research assistant under MSG project	
Chen, Guangyi	Jan 2010 – Jul 2010	research associate under Canarie NEP	
Vincent, Coralie	Oct 2010 – Mar 2011	research assistant	CNRS, France
Dansereau, Don	Jun 2009 – Jan 2010	research associate under FRQNT grant	Senior Lecturer, University of Sydney
To, Long	Jan 2009 – Sep 2011	research associate under NSERC I2I	Software engineer, Abcam
Blum, Jeff	Oct 2008 – Aug 2013	research assistant under MSG project	

Continued on next page

Name	Period	Project title	Present Position
Olmos, Adriana	Sep 2008 – July 2012	user interface engineer under Canarie NEP	Interaction designer, Google/YouTube
Sun, Haijian	Sep 2008 – Oct 2010	computer engineer under Canarie NEP	programmer, Des- jardins
Soukhodolski, I.	Oct 2005 – Dec 2007	web services programmer under Ca- narie IIP	Owner, W4 Tech- nology
Kiewe, Howard	Oct 2005 – Dec 2007	user interface developer under Canarie IIP	consultant
Spackman, S.	2000–2006	research associate on Canarie and VRQ projects	Google, Mountain View
Sarikaya, Deniz	2003–2004	research assistant on VRQ projects	deceased
Soucy, Gilbert	1999	research associate on CFI project	Imaging Specialist, 36pix Inc., Mon- treal

POST-DOCTORAL FELLOWS

Name	Period	Project title	Present Position
Sullivan, John	Sep 2021–Apr 2022	Multimodal Rendering for the IMAGE Project	post-doctoral fellow, Université Paris-Saclay
Jyoti, Vishav	Mar 2021–Feb 2022	Mixed-Reality Platform for Simulation and Synthesis of Multi-Modal Hallucinations	
Talhan, Aishwari	Jan 2021–Dec 2022	Wearable Haptics	Research Scientist, New York
Yoo, Yongjae	Mar 2020–Jul 2022	Wearable Haptics and Haptics Lead, IMAGE project	Assistant Professor, Hanyang University ERICA, South Korea
Weill – Duflos, A.	Jan 2018 – Jan 2021	Wearable Haptics	Director of Research and Product Integration, Haply Robotics
Arnold, Andre	Oct 2017 – Dec 2017	Wearable Haptics	Product Manager – AI Nuvoola
Panëels, S.	Jan 2011 – Jan 2012	Natural Interactive Walking and In-Situ Audio Services	Researcher, Commissariat à l'énergie atomique et aux énergies alternatives (CEA)
Pelletier, S.	Nov 2009 – Jun 2011	Real-time Image-based Rendering (Canarie NEP, 2009-2010)	
		Parallax Barrier Display rendering software optimization (NSERC ENGAGE, 2011)	Game Programmer, Behaviour Interactive
Otis, Martin	Jan 2010 – Dec 2010	Natural Interactive Walking (FRQNT Scholarship)	Assoc. Professor, U. Québec à Chicoutimi

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Name	Period	Project title	Present Position
Millet, G.	Nov 2009 – Mar 2012	Natural Interactive Walking	Patent Examiner, EPO, The Hague
Bouillot, Nicolas	Sep 2007 – Dec 2011	Mobile Audio Interaction (NSERC New Media Initiative, 2007-2009)	
		Open Orchestra (Canarie NEP-2 Project)	Research Engineer, Société des arts technologiques
Darolti, Cristina	Jan – Dec 2009	Real-time Image-based Rendering (Canarie NEP)	Patent Examiner, EPO, The Hague
Wang, Guangyu	Sep 2007 – Mar 2011	Neurosurgical Visualization and Virtual Presence (NSERC Strategic and NCE)	Facebook, Mountain View
Wang, Yan	2002–2003	Channel and spatial view allocation for videoconferencing (VRQ)	V.P. Marketing, AMH Canada

PH.D. STUDENTS

Name	Period	Thesis title	Present Position
Conan, Corentin*	Sep 2022– present	Advanced Airspace Usability	
Astles, Samantha*	Sep 2022– present	Advanced Airspace Usability	
Shen, Lichao*	Oct 2021– present	Social telepresence	
Regimbal, J.* ^{◇‡}	Sep 2021– present	Audio-haptic authoring for information rich content delivery	
Fortin, P.* [◇]	Sep 2016 – Sep 2021	Methods and Interfaces for Closed-Loop Smartphone Communications	Asst. Professor, U. Québec à Chicoutimi
Blum, Jeff* ^{†g}	Sep 2013– present	Implicit Communication for Enriched Human Interaction	
Erfani-Joorabchi, M.*	Jan 2013 – Jan 2015		iOS Software Engineer, Google
Anlauff, Jan*	Jan 2011– present	Sensor-Actor Wearables	
Tordini, F.	Jan 2011 – Feb 2018	Auditory salience modeling for continuous processes sonification	Technology Transfer Manager, Innovation and Partnerships, McGill University
Ghourchian, N.* [†]	Jan 2010 – Apr 2011	Affective Evaluation	transferred to another group
El-Shimy, D. [†]	Jan 2009 – Nov 2014	Reactive Environment for Network Music Performance	Senior UX Research Manager, Miro
Benovoy, M. [†]	Oct 2007 – Aug 2010	Biosignals analysis	transferred to another group

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Name	Period	Thesis title	Present Position
Visell, Yon	Sep 2005 – Mar 2011	Walking on virtual ground: physics, perception, and interface design	Assistant Professor (ECE), UC Santa Barbara
Qi, Zhi	Jan 2004 – Dec 2008	Towards dynamic mosaic generation with robustness to parallax effects	Associate Professor (School of Electronic Science & Engineering), Southeast University, China
Pelletier, S. ^p	Jan 2003 – Oct 2009	Acceleration methods for image super-resolution	Game Programmer, Behaviour Interactive
Yin, Jianfeng	Sep 2000 – Aug 2008	Toward an Alternative Approach to Multi-Camera Scene Reconstruction	Software engineer, Geomagical Labs
Sun, Wei	2002–2006	Multi-camera Object Segmentation in Dynamically Textured Scenes Using Disparity Contours	Apple Inc., Cupertino
Cayouette, F. [†]	2003–2006	human tracking (withdrew from program)	Programmer, Behaviour Interactive, Montreal
Arseneau, S.	2000–2006	Representing Junctions through Asymmetric Tensor Diffusion	Chief Engineer for R&D, Laser Shot, Houston

* McGill Engineering Doctoral Award recipient

† NSERC PGS D Scholarship recipient

‡ NSERC CGS D Scholarship recipient

◊ FRQNT Scholarship recipient

^g Graphics Animation and New Media (GRAND) Scholarship recipient

^p Precarn Scholarship

ADDITIONAL PH.D. SUPERVISORY SERVICE

I co-supervised a portion of the thesis work of the following students:

- Liu, X., (Nov 2013-Dec 2015), visiting student from University of Electronic Science and Technology, China

- Xie, M., (Sep 2012-Mar 2014), visiting student from Beijing University of Aeronautics and Astronautics, China
- Grond, F. (Jul-Dec 2010), visiting student from Bielefeld University, Germany
- Zambon, S.. (Jul-Oct 2010), visiting student from Verona University, Italy
- Cirio, G. (Jun-Aug 2010), visiting student from INRIA-IRISA, France
- Rizutti, C. (Sep-Oct 2008), visiting student from Università della Calabria, Italy
- Bossi, E. (Sep-Oct 2008), visiting student from Università della Calabria, Italy
- Pellerin, R. (Jun-Sep 2008), visiting student from Conservatoire Nationale des Arts et Métiers, France
- Cupellini, E. (Jul-Aug 2007), visiting student from Università della Calabria, Italy
- Usher, J. (2003-2004), Ph.D. student, Faculty of Music, McGill University
- Mohammadi, M. (Feb-Aug 2004). visiting student from Sharif University, Iran

I served as external reviewer or examiner of the following theses:

- Mauricio Fontana de Vargas, School of Information Studies, McGill University (2022)
- Richard Olayniyan, Department of Computer Science, McGill University (2021)
- Xavier de Tingu, Université Rennes, France (2020)
- Damien Brun, Le Mans Université, France (2020)
- Cheryl Savery, Queen's University (2014)
- Alexandre Plouznikoff, École Polytechnique de Montréal (2009)
- Xiaoyong Sun, School of Information Technology and Engineering, University of Ottawa (2007)
- Nicolas Bouillot, Conservatoire Nationale des Arts et Métiers, France (2006)
- Harold Okai-Tetty, Computer Science, Rhodes University, South Africa (2006)

I served on the supervisory and/or examination committees of the following students:

- Department of Electrical and Computer Engineering: Edouard Antoniou, Oliver Astley, Carmen Au, Marc Boulé, Wei Chu, Olivier St-Martin Cormier, Vincent Levesque, Muhua Li, Rui Ma, Dante De Nigris Moreno, Jun Ouyang, Jerome Pasquero, Andrew Phan, Ala Qumsieh, Harkirat Sahambi, Wei Sun, Yick Kei Wong, Dingrong Yi, Olivier St-Martin Cormier, Karl Fayad, Shalaleh Rismeni, Lixiao Zhu
- School of Information Studies: Xiaofeng (Allan) Yong
- Faculty of Music: Jason Corey, Cory McKay, Caroline Medeiros, Sean Olive, Dale Stammen, Vanessa Yarmechuk, Mark Zadel
- Grad. School of Library and Information Studies: Charles-Antoine Julien
- Department of Educational Psychology and Counselling: Adam Finkelstein
- Department of Mechanical Engineering: Zahir Albadawi
- School of Computer Science: Paul Haroun, Wisam Al Abed

MASTERS STUDENTS

Name	Period	Thesis title	Present Position
Bazin, Romain	Sep 2022–	TBD	
Quadros, Venissa Carol	Sep 2022–	TBD	
Aubet, Antoine	Sep 2022–	TBD	
Liu, Yujing	Sep 2021–	Graphical rendering strategies for avatar therapy	
Wilson, É.	Sep 2021–	Lightfield rendering techniques for XR musical interaction	
Duarte, Nathan [◊]	Sep 2021–	Wearable sensor deployment for pandemic mitigation	
Henry, Max	Sep 2021–	Spatial-aware audio rendering for immersive telepresence	
Lewis-Lane, Jonathan	Sep 2021–	Wearable haptic feedback for real-time training tasks	
Akut, Rohan	Jan 2021–	Active learning for image labelling	
Gannavarapu, S.	Sep 2020–	Haptic rendering and perception	
Isran, Rayan	Sep 2020–	Haptic rendering and perception	
Kirby, Linnea	Sep 2020–	Multimodal feedback to guide body-movement	
Knappe, Sabrina	Sep 2020 – Dec 2022–	Towards a User Interface for Audio-Haptic Exploration of Internet Graphics by People who are Blind and Partially Sighted	Ph.D. student (see above)
Regimbal, J.	Sep 2020 – Aug 2021	Haptic effects authoring in artistic and utilitarian contexts	(fast-tracked to Ph.D. program)

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Name	Period	Thesis title	Present Position
Ducher, Clara [‡]	Sep 2019 – Sep 2021	GAN-based interaction paradigms for photorealistic avatar creation	Pipeline Technical Director, Double Negative
Marino, David	Sep 2019 – Nov 2021	Implicitly Conveying Emotion While Teleconferencing	R&D Scientist, Hitachi Energy, Montreal
Lee, Hyejin	Sep 2019 – Apr 2022	Generating Convincing Simulation of Internalized Voices for Human-avatar Interaction	
Li, Yaxuan	Sep 2019 – May 2022	Towards Context-aware Automatic Multimodal Haptic Effect Generation for Home Theatre Environments	
Bouanane, Y.	Jan 2019 – Dec 2020	EchoDepth: Using a depth camera and sonification for blind navigation	Entrepreneur, sktch.io
Demers, Marc	Sep 2018 – Mar 2021	A Data-Driven Strategy for Evaluating Tacton Perceptual Similarity	Data Scientist, Maxen Technologies
Vyas, Preeti	Sep 2017 – Apr 2020	Foot-based Haptic Interfaces for Numeric Information Delivery and Dance Learning	Ph.D. student, UBC
Sulmont, E.	Sep 2017 – Dec 2018	Improved Learning of Machine Learning by Non-Majors	Curriculum Manager, DataCamp
Patil, Gandharv	Jan 2017 – Dec 2019	Min-Max Inverse Reinforcement Learning for learning bi-modal dialogue policies	
Girgis, Roger	Sep 2016 – Apr 2019	Assessing the Use of Deep Learning in Assisting Visually Impaired People with Outdoor Exploration	Ph.D. student, MILA
Kim, Taeyong	Sep 2016 – Aug 2019	Exploration of foot based interaction for menu control and virtual reality applications	HRI Researcher, Hyundai Robotics

Continued on next page

Name	Period	Thesis title	Present Position
Alirezaee, P.	Sep 2016 – Dec 2019	Multimodal approaches to improved hospital alarms	Product Designer, Unity Technologies
Diaz, Manfred	Sep 2016 – Aug 2017	Interactive and Uncertainty-Aware Imitation Learning	
Ahmer, Z.	Jan 2016 – Jan 2019	Automated musical accompaniment to children's stories	
Yin, G.	Sep 2015 – Oct 2018-	Augmented Reality Tools for Workplace Safety	Software Engineer, Kooltra
Fortin, P.	Sep 2015 – Aug 2016	Physiological Perception of Tickling Sensation	(fast-tracked to Ph.D. program)
Horodniczy, D. [†]	Sep 2014 – Dec 2016	Characterization and Application of a Variable-Friction Foot Device	Software Developer, Philips Innovative Imaging Technologies
Vuibert, Vanessa	Sep 2013 – Aug 2015	Efficient and Accurate Performance with Unconstrained Mid-air Interaction	Software Developer, Guavus
Hieda, Naoto	Sep 2012 – Aug 2015	Digital Video Projection for Interactive Entertainment	Visiting Researcher, Pola Art Foundation Fellow, Concordia University
Viswanathan, R.	Jan 2010 – Dec 2012	Testing the Two-Stream Hypothesis in an Immersive Virtual Environment	Developer, MontrealTel
Knight, Trevor	Jan 2010 – Sep 2011	Music Visualization for Open Orchestra (CIRMMT Student Award)	Software Developer, Noteloop Systems
Li, Weizhong	Sep 2008 – May 2009	(recommended alternative supervision)	
Ip, Jessica	Sep 2008 – Mar 2011	Augmented Reality for Interactive Play in a Virtual and Physical Environment	iOS developer, Shopify, Toronto

Continued on next page

Name	Period	Thesis title	Present Position
Namit, Gaurav	May 2008 – Oct 2009	(withdrew in 2009 to pursue social entrepreneurship venture)	
El-Shimy, D.	Sep 2007 – Dec 2008	Gestural interaction for complex tasks	(fast-tracked to Ph.D. program)
Law, A.	Sep 2007 – Sep 2010	A Vibrotactile Floor for Enabling Interaction through Virtual Walking Spaces	Data Systems Engineer, AECOM, Vancouver
Benovoy, M.	Sep 2006 – Oct 2007	Biosignals analysis and its application in a performance setting	(fast-tracked to Ph.D. program)
Audet, Samuel [†]	2005-2007	Shadow Removal from Multi-Projector Displays via Three-Dimensional Modeling and Object Tracking	Deeplearning4j (Skymind), Tokyo, Japan
Wozniowski, M.	2003-2006	A framework for interactive three-dimensional sound and spatial audio processing in a virtual environment	research engineer, Société des arts technologiques, Montreal
Rudzicz, Frank*	2004-2006	CLAVIUS: Understanding Language Understanding in Multimodal Interaction	Professor, University of Toronto
Rioux, Francois [†]	2003-2005	Software Framework for Parsing and Interpreting Gestures in a Multimodal Virtual Reality Context	Ph.D., Laval; Software Architect, Thales Canada
Chan, Siu-Chi	2002-2005	Hand and Fingertip Tracking for Gesture Recognition	Technical Staff, AMD Toronto
Hilario, Nadia*	2002-2005	Occlusion Detecion in Front Projection Environments	Software Developer, Stingray Digital
Perez, Michael	2002-2005	Multimodal Human-Computer Interaction for a Public Kiosk System	User Interface Designer, Nuance
Sud, Daniel	2002-2005	Design of a Multi-Projector Display System	Senior Producer, Lucky Hammers

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Name	Period	Thesis title	Present Position
Boussemart, Y.	2002-2005	Design and Implementation of Framework for Immersive Environments in a Shared Context	Chief Design Officer, Quantum-Black, UK
Pelletier, S.	2001-2003	High-Resolution Video Synthesis from Mixed-Resolution Video Based on the Estimate-and-Correct Method	(see above)
Gu, Jinhua	2000-2002	A distributed software architecture for the Shared Reality Environment.	VP, Radian Asset Assurance Inc., NY
Yao, Jie	2000-2002	Human Arm Gesture Detection and Recognition in a Classroom Environment.	Ph.D. student, Concordia University
Zhang, Yuan	2000-2002	An efficient coding method for spatial data: the rotating, hierarchical, overlapping representation.	Ph.D. student, University of Delaware
Doutriaux, S.	1998-1999	(withdrew in 1999 to launch start-up company)	
Arseneau, S.	1998-2000	Robust Image Segmentation Towards an Action Recognition Algorithm.	(see above)
Xu, Aoxiang	1998-2000	A High-Performance Audiovisual Communication System.	QNX Software Systems, Ottawa

* FRQNT Graduate Scholarship recipient

† NSERC PGS M Scholar recipient

‡ McGill nominee for Northeastern Association of Graduate Schools Distinguished Thesis Award

◊ McCall MacBain Scholar

ADDITIONAL MASTERS SUPERVISORY SERVICE

I co-supervised a portion of the thesis work of the following students:

- Dever, Ani (Sep 2017-Feb 2018), visiting student from Polytechnic University of Turin, Italy
- Gallo, Nicola (Sep 2015-Feb 2016), visiting student from Polytechnic University of Turin, Italy
- Roy, Louise (Jul-Dec 2015), visiting student from Ensimag, Grenoble, France
- Glessner, David (Feb-Jun 2012). visiting student from Ensimag, Grenoble, France
- Penin, O. (Jul-Aug 2011). visiting student from Paris-Sud 11, France

- Mabire, N. (Apr-Sep 2010). visiting student from Supélec, Metz, France
- Brulé, M. (Feb.-Aug 2009). visiting student from Université de Louis Pasteur, Strasbourg, France
- Anlauff, J. (Dec 2008-Mar 2009). visiting student from Bielefeld University, Germany
- Delattre, G. (Apr-Aug 2007). visiting student from Université Paris VI, France

I served on the supervisory and/or examination committees of the following students:

- Zhonghao Zhao (M. Eng. project), Electrical and Computer Engineering, McGill University
- Anne-Marie Burns, Faculty of Music, McGill University
- Frank Riggi, Electrical and Computer Engineering, McGill University
- Eric Benzacar, Electrical and Computer Engineering, McGill University
- Oles Protsiym, Faculty of Music, McGill University

FUNDING

INDIVIDUAL RESEARCH GRANTS AND CONTRACTS

Date	Source	Amount	Title/Description
2023	MEDTEQ/ NSERC	\$531,000	<i>Improving Intelligibility of Speech in Noisy Environments.</i> MEDTEQ Partenar-IA funding approved pending successful review of NSERC Alliance grant
2023	MEDTEQ/ HBHL	\$282,188	<i>Haptic devices for conveying non-textual visual information on the internet for individuals with vision loss.</i> MEDTEQ Partenar-IA funding through the Ministère de l'Économie, de l'Innovation et de l'Énergie
2022	HBHL	\$50,000	<i>Extending Internet Multimodal Access to Graphical Exploration.</i> CFREF Healthy Brains, Healthy Lives Neuro Commercialization Ignite Grant
2022	Meta	\$30,000	Unrestricted gift
2021	Mitacs	\$13,333	<i>Analyse et recherche d'optimisation d'un processus d'adaptation de contenu issu de la numérisation 3D à un contenu photo-réaliste et interactif.</i> Mitacs Accelerate – Intern: Chen, Hongjun
2021- 2022	ISED	\$608,594	<i>Enabling Access to Graphical Image Content Published via the Internet for People Who Are Blind, Deaf-Blind or Visually Impaired.</i> Innovation, Science and Economic Development Canada (ISED), Accessible Technology Program (Total project budget of \$765,787)
2019- 2021	NSERC/ MEDTEQ	\$374,366	<i>Mixed-Reality Platform for Simulation and Synthesis of Multi-Modal Hallucinations with Applications to Schizophrenia Treatment.</i> Collaborative Research and Development Grant with Industrial Partners, iMD Research and IA Précision Santé Mentale
2019	NSERC	\$25,000	<i>360 degree imaging for navigation assistance for the visually impaired.</i> Engage Grants Program with Industrial Partner, ImmerVision.
2019	Mitacs	\$15,000	<i>Advanced sensor control implementations for energy optimization in commercial buildings using machine learning and data visualisation applied to building automation systems.</i> Mitacs Accelerate – Intern: Demers, Marc
2019	Mitacs	\$6,000	<i>Facilitating Human Interaction with a Robotic Exercise Coach using Smart Objects.</i> Mitacs Globalink – Intern: Vyas, Preeti

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Date	Source	Amount	Title/Description
2018	Mitacs	\$6,000	<i>Mobile Remote Implicit Communication.</i> Mitacs Globalink: Intern: Blum, Jeff
2018	NSERC	\$25,000	<i>Educational wine recommendations from initially sparse data.</i> Engage Grants Program with Industrial Partner, Wineout Inc.
2017-2018	McGill	\$7500	<i>Physiological confirmation of stimulus reception.</i> Faculty of Engineering TechAccelR Grant
2017-2020	NSERC	\$631,650	<i>Wearable Haptics.</i> Collaborative Research and Development Grant with InterDigital Corporation
2017-2018	CIRA	\$44,500	<i>Intelligent Agent for the Visually Impaired: Vision-based scene description and contextual awareness for Autour.</i> Canadian Internet Registry Authority .CA Community Investment Program
2017-2022	NSERC	\$ 222,000	<i>Multimodal Influences on Perception and Action in Computer-Mediated Environments.</i> Discovery grant.
2017-2018	MSP	\$177,673	<i>Social Media Monitoring Architecture.</i> Research Contract with Ministère de la Sécurité publique
2015	CIRA	\$53,878	<i>What's Around Me? Conveying Environmental Awareness to the Visually Impaired Community.</i> Canadian Internet Registry Authority .CA Community Investment Program
2014-2015	Mitacs	\$15,000	<i>Effect of Mobile Technologies in Emergency Response.</i> Mitacs Accelerate – Intern: Erfani-Joorabchi, Minoo
2014	NSERC	\$25,000	<i>Haptic user experience delivered through the shoes.</i> Engage Grants Program with Industrial Partner, InterDigital Canada
2013-2014	NSERC	\$137,474	<i>3D immersive projection infrastructure with full-body motion capture and analysis.</i> Research Tools and Instruments Grants
2012-2013	Mozilla	\$50,000	<i>Real-Time Emergency Response.</i> Mozilla Ignite Development Challenge (in partnership with the National Science Foundation)
2012-2017	NSERC	\$210,000	<i>Improved Shared Reality for Multi-Party, Multimodal Simulation and Interaction.</i> Discovery grant.
2012	Toyota	\$30,000	<i>Haptic interaction with an augmented steering wheel.</i> Toyota Infotechnology Centre
2011	HP	\$60,950	<i>Capturing attention via spatialized audio cues.</i> HP Labs Innovation Research Program (IRP)
2011	NSERC	\$25,000	<i>Improved Parallax Barrier Autostereoscopic Display Software.</i> Engage Grants Program with Industrial Partner, Holoptick Technologies Inc.

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Date	Source	Amount	Title/Description
2010-2011	Google	\$50,000	<i>A Spatialized Audio Map System for Mobile Blind Users.</i> Google Faculty Research Awards.
2010-2011	Honda	\$30,000	<i>Facial Expression Recognition for Machines.</i> Honda Research Institute.
2010	UVic	\$8,000	<i>NEPTUNE Pleora streamer.</i> University of Victoria software license
2008-2012	MDEIE	\$367,195	<i>Natural Interactive Walking.</i> Support for International Research and Innovation Initiatives, Ministère du Développement économique, de l'Innovation et de l'Exportation; for Canadian participation in EU FP-7 program with partners in France, Italy, and Denmark.
2007-2010	MDEIE	\$15,000	<i>Un environnement virtual pour la création de musique et de son à partir de systèmes chaotiques.</i> Support for International Research and Innovation Initiatives, Ministère du Développement économique, de l'Innovation et de l'Exportation.
2006-2009	NSERC	\$317,785	<i>A pervasive multi-user augmented space for mobile immersive interaction with sound and music.</i> (additional funding for artist collaborator received from Canada Council for the Arts) New Media Initiative STPGP 337999-06.
2006-2011	NSERC	\$100,000	<i>Enhanced video for shared reality environments.</i> Discovery grant.
2004-2006	NSERC	\$136,600	<i>Soundscape performance works via interactive environment for immersive audiovisual scene generation.</i> (additional funding for artist collaborator received from Canada Council for the Arts) New Media Initiative NMIPJ 307934-04.
2002-2006	NSERC	\$100,000	<i>Shared Reality Interaction over High Bandwidth Connectivity.</i> Discovery grant.
2000	LUB	\$100,000	<i>Distributed Visualization Environment.</i> Laboratoire universitaire Bell Equipment Grant.
1999-2000	Petro-Canada	\$20,500	<i>Interactive Web Tools for Critique of Presentation Skills and Evaluation of Student Learning.</i> Young Innovator Award.
1999-2002	FCAR	\$45,000	<i>Augmenting an Electronic Classroom for Improved Instructor-Student Interaction.</i> New Researchers Award.
1999	FCAR	\$15,700	<i>Augmenting an Electronic Classroom for Improved Instructor-Student Interaction.</i> Equipment Grant.
1999	AES	\$25,000	<i>Multichannel audio over Internet.</i> Audio Engineering Society.

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Date	Source	Amount	Title/Description
1999	OSC	\$15,000	<i>Timespace Exhibit</i> . Ontario Science Center contract.
1999	MFM	\$10,000	<i>Intelligent Classroom tools</i> . McGill Faculty of Management.
1998- 2002	NSERC	\$76,000	<i>Reactive Hospital Environment</i> . Discovery research grant.
1998	FGSR	\$20,000	McGill Graduate Studies and Research Development Fund

TEAM RESEARCH GRANTS AND CONTRACTS

(Percentages refer to my portion.)

Date	Source	Amount	Title/Description
2023	Mitacs	\$150,000 (75%)	<i>Avatar Care Provider for Seniors Residences</i> Mitacs Accelerate (with K. Moffatt)
2022-2025	CRIAQ	\$800,000 (25%)	[†] NSERC Alliance with Consortium for Aerospace Research and Innovation of Québec (CRIAQ) <i>ADvanced Airspace Usability (ADAIR)</i> (with P. Doyon-Poulin (Poltechnique), Joon Chung (Ryerson), and 6 aerospace industrial partners)
2020-2021	CIRMMT	\$1,500	*Agile Seed Funding for <i>Conveying paralinguistic cues and context while teleconferencing</i> (with students David Marino, Max Henry and Pascal Fortin)
2017-2018	SSHRC	\$199,680 (10%)	[†] <i>Real time impact signalling and collective goods</i> Partnership Development Grant (with R. Janda and 6 co-investigators)
2016-2017	NAKFI	\$100,000 (20%)	<i>Empathy Mirror</i> National Academies Keck Futures Initiative Art and Science, Engineering and Medicine Grant (with B. Korgel and 3 co-applicants)
2015-2018	FRQNT	\$182,880 (25%)	[†] <i>Étude des modèles d'interactivité humain-robot en réalité mixte afin de réduire l'apparition des troubles musculo-squelettiques en utilisant une cellule de travail hybride</i> Recherche en équipes (with M. Otis and 6 co-applicants)
2014	Mozilla	\$20,000 (90%)	* <i>Augmented Reality Tools for Improved Training of First Responders</i> Mozilla Gigabit Community Fund (with R. Dearden)
2011	CIRMMT	\$10,000 (90%)	* <i>Acoustic Sculptures</i> CIRMMT Strategic Innovation Fund Award (with A. Olmos and 3 others)
2010-2011	NSERC	\$49,815 (90%)	* <i>Novel Portable Treatment Device for Lazy Eye</i> Idea to Innovation (I2I) Booster (Phase Ib) (with R. Hess)
2009-2011	MSG	\$200,000 (80%)	* <i>Location-Based Spatialized Audio Interaction for the Blind and Visually Impaired</i> Programme Appui au passage à la société de l'information (Support for the transition to an information society program), Ministère des Services gouvernementaux (MSG) (with M. Wozniowski and Z. Settel)
2010-2014	CHRP	\$327,000 (?%)	<i>Computational and statistical tools for image guided neurosurgery of brain tumors</i> NSERC Collaborative Health Research Projects (with L. Collins and 7 others)

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Date	Source	Amount	Title/Description
2009-2010	CCSIP	\$48,000 (4%)	<i>*Digitally Merged Environments</i> California-Canada Strategic Initiatives Program (with S. Brown, UCSD and 20 co-applicants)
2009-2011	Canarie	\$927,648 (40%)	<i>†Open Orchestra</i> Network-Enabled Platforms 2 (with J. Roston and W. Woszczyk)
2010-2014	NCE	\$23,000,000 (2%)	<i>†GRAND: Graphics, Animation and New Media</i> Networks of Centres of Excellence (With K. Booth and 49 others)
2009	DND	\$47,500	<i>†Video-Based Facial Recognition–Algorithm and Demonstration</i> Department of National Defence Contract (with M. Levine)
2008-2009	NSERC	\$120,250 (90%)	<i>*Novel Portable Treatment Device for Lazy Eye</i> Idea to Innovation (I2I) (with R. Hess)
2008-2010	Canarie	\$1,397,758 (7%)	<i>NEPTUNE: A Platform to Create and Support Ocean Science Virtual Organizations</i> Network-Enabled Platforms (with B. Pirenne and J. Roston)
2008-2010	Canarie	\$2,000,000 (18%)	<i>Health Services Virtual Organization</i> Network-Enabled Platforms (with R. Ellaway and 8 others)
2008-2010	NSERC	\$196,000 (50%)	<i>*3-D Visualization and gestural interaction with multimodal neurological data</i> Strategic Projects (with 5 others)
2006-2009	FRQNT	\$146,550 (50%)	<i>*Unités agenceables: Réseau d’Environnements Immersifs pour Collaboration à Distance</i> Recherche en équipes (with X.-W. Sha)
2005-2006	Canarie	\$825,000 (50%)	<i>Undersea Window–High Definition Video Online</i> Intelligent Infrastructure Program. (with J. Roston)
2005-2006	SAT	\$1,276,000 (1%)	<i>TOT2: Nouveau Territoires de la Création-Diffusion en Réseau</i> Heritage Canada New Media Research. (M. Savoie, PI)
2004-2006	Canarie	\$568,971 (33%)	<i>Shared Spaces – High Definition Ultra-Videoconferencing</i> Advanced Applications Program. (with J. Roston)
2003-2004	SAT	\$792,082 (1%)	<i>TOT1: Nouveau Territoires de la Création-Diffusion en Réseau</i> Heritage Canada New Media Research. (M. Savoie, PI)
2002-2005	IRIS	\$573,000 (25%)	<i>*Parallel Distributed Camera Arrays for Intelligent Environments</i> (with J. Clark, S. Fels, R. Vertegaal)
2002-2005	VRQ	\$2,180,000 (20%)	<i>Real-time Communication Of High-res. Multi-sensory Content via Broadband Networks.</i> Valorisation-Recherche Quebec (with W. Woszczyk and others)
2001-2002	Canarie	\$391,000 (30%)	<i>Remote Video Sign-Language Interpreting.</i> Advanced Networking Apps. Services & Technologies. (with J. Roston and others)

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Date	Source	Amount	Title/Description
2000-2002	Canarie	\$808,000 (35%)	<i>McGill Advanced Learnware Project.</i> Advanced Networking Applications Services and Technologies. (with B. Pennycook)
2000-2003	LUB	\$150,000 (50%)	<i>*Distributed Shared Visualization Environment.</i> Laboratoire universitaire Bell. (with B. Ozell)
2000-2001	Royal Bank	\$2,000 (80%)	<i>*Improving Teaching through an Interactive Critiquing System.</i> Teaching Improvement Fund Award. (with R. Harris and J. Blatter)
1999-2002	CFI	\$400,000 (50%)	<i>†The Shared Reality Environment.</i> New Opportunities Award. (with J. Clark)
1999-2000	Royal Bank	\$10,000 (80%)	<i>*Interactive Web Tools for Critique of Presentation Skills and Evaluation of Student Learning.</i> TIF (with R. Harris)

*Indicates grants on which I am project leader. †Grant on which I am co-investigator.

CENTRE RESEARCH GRANTS

Date	Source	Amount	Title/Description
2022-2026	IILS	\$400,000	FRQNT International Institute on Learning Systems, funded jointly by CNRS (France) and FRQNT (Quebec), Pablo Piantanida, PI, \$100,000 per annum
2019-2025	FRQNT	\$2,160,000	Regroupement Stratégique pour <i>Systèmes cyberphysiques et intelligence machine matérialisée (REPARTI)</i> . (with C. Gosselin and 49 others) \$480,000 per annum.
2015	CFI	\$4,366,723	Innovation Fund: <i>Live Expression “in situ”: Musical and Audiovisual Performance and Reception</i> (with M. Wanderley and 9 others)
2014-2020	FRQSC/ FRQNT	\$1,800,000	Regroupement Stratégique: <i>Centre Interdisciplinaire de Recherche en Musique, Médias et Technologie</i> . (with M. Wanderley and 23 others)
2013-2019	FRQNT	\$2,160,000	Regroupement Stratégique pour <i>l’Étude des Environnements PARTagés Intelligents répartis (REPARTI)</i> . (with D. Laurendeau and 34 others) \$359,943 per annum.
2008-2014	FRQSC/ FRQNT	\$1,800,000	Regroupement Stratégique: <i>Centre Interdisciplinaire de Recherche en Musique, Médias et Technologie</i> . (with S. McAdams and 23 others)
2007-2009	NSERC	\$57,630	Major Resources Support: <i>Centre for Interdisciplinary Research in Music Media and Technology (CIRMMT)</i> . (with S. McAdams and 8 others)
2006-2013	FRQNT	\$1,530,000	Regroupement Stratégique pour <i>l’Étude des Environnements PARTagés Intelligents répartis (REPARTI)</i> . (with D. Laurendeau and 23 others) \$100,000 per annum allocated to CIM.
2002-2005	FCAR	\$720,000	Regroupement Stratégique: <i>Réseau Québécois de Recherche en Réalité Artificielle Distribuée (QUERRAnet)</i> . (with F. Ferrie, R. Bergevin, P. Cohen, and others)
2001	CFI	\$6,500,000	Major Facilities Award: <i>Centre for Integrated Research in Music Media and Technology</i> . (with W. Woszczyk and 11 others)
2000-2002	FCAR	\$113,500	Centre de Recherches. (with F. Ferrie and 17 others)
2000	NSERC	\$275,000	<i>Information Systems in Support of Intelligent Machine Research</i> . (with F. Ferrie and 17 others)

TEACHING

COURSES TAUGHT

Course title and number	Description	Semester
ECSE-618 <i>Haptics</i>	Graduate course on haptic information design, co-taught with other instructors across Canada, under the informal designation of HAPTICS 501	Winter 2021–present
ECSE-421 <i>Embedded Systems</i>	Undergraduate course dealing with both the theory and practice of design for embedded systems	2018–present
ECSE-526 <i>Artificial Intelligence</i>	Graduate level course in artificial intelligence with emphasis on machine learning and autonomous agents	1998–present
*ECSE-683 <i>Topics in Vision and Robotics</i>	Graduate level laboratory course for RoboCup projects	Fall 2000 Fall 2002
*ECSE-424/542 <i>Human-Computer Interaction</i> [†]	Undergraduate (424) and graduate (542) course in human-computer interaction with emphasis on new interface paradigms	2000–present
ECSE-487 <i>Computer Architecture Laboratory</i>	Undergraduate laboratory course	1999–2018
ECSE-427 <i>Operating Systems</i>	Undergraduate course (core for Computer Engineering students)	1998
CSC-270 <i>Introduction to Modelling and Optimization</i>	Computer Science undergraduate course, University of Toronto	1993–1994
CEE 1714Y <i>Digital Systems and Computers</i>	Continuing Engineering Education course for the Association of Professional Engineers of Ontario	1993–1994
CSC-228 <i>File Structures and Data Management</i>	Computer Science undergraduate course, University of Toronto	1992–1995

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Course title and number	Description	Semester
COSC-3411	Computer Science undergraduate course,	1992
<i>File Structures and Data Management</i>	York University	

*Indicates new course that I created.

†In 2011, a project from this class placed third in the [Usability Professionals Association International Student Design Competition](#). Note that graduate students have also enrolled in this course under the designation of ECSE-681, *Colloquium in Electrical Engineering* or ECSE-689, *Recent Advances in Electrical Engineering*.

UNDERGRADUATE SUPERVISION

ECE Honors Undergraduate Projects (2 semesters)

Name	Year	Research topic
Bu, Bruce	2020	360° Imaging for Navigation Assistance for the Visually Impaired
Akgul, Ahmet	2017-2018	Haptic Wearables
Bashar, Sharhad	2016-2017	Image-based environment description
Wu, Pei Yuan (Richard)	2016	Mixed-Reality Human-Machine Interaction
Gordon, Adam	2011-12	Virtual Presence
Warraich, Shahjahan	2010-11	Natural Interactive Walking
Lin, Nan	2008	Location sensing for mobile apps
Wang, Letao	2007	Interactive Agent
Charlebois, Pierre-Olivier	2004–2005	Sound Objects in a Soundscape
Myer, Sam	2003	Automated Music Transcription
El-Refaei, Sameh	1998–1999	Shared Reality simulator

ECE Undergraduate Design Projects (2 semesters)

Name	Year	Research topic
Cui, Bowen	2022-2023	Immersive multimodal CAVE experience
El Haddad, Georges	2022-2023	Immersive multimodal CAVE experience
Fazal, Gohar Saqib	2022-2023	Immersive multimodal CAVE experience
Mahajan, Madhav	2022-2023	Immersive multimodal CAVE experience
Pan, Edwin	2022-2023	Touching faces in VR
Gosman, Mircea	2022-2023	Touching faces in VR
Justin, Legrand	2022	Vision-guided Navigation Assistance
Sen, Wang	2022	Vision-guided Navigation Assistance
Chamberland, Noah	2022	Vision-guided Navigation Assistance
Natchev Keanu	2022	Novel digital representation of sign language
Arabian Matthias	2022	Novel digital representation of sign language
Destiné, Maxens	2022	Novel digital representation of sign language
Jarvis, Thomas	2022	Natural Dialog Generation for Mental Health
Kong, Norman	2022	Natural Dialog Generation for Mental Health
MacNaughton, Ben	2021-2022	plots data parsing for IMAGE project
Williams, Aidan	2021-2022	plots data parsing for IMAGE project
Nunez, Matteo	2021-2022	Foot-fluid interaction simulation in mobile VR
Comeau, Francis	2021-2022	Foot-fluid interaction simulation in mobile VR
Gure, Kaan	2021-2022	Foot-fluid interaction simulation in mobile VR
Calin, Haluk	2021-2022	ML-based Navigation Assistance
Cano, Victor	2021-2022	ML-based Navigation Assistance

Continued on next page

Name	Year	Research topic
Das Sharma, Kaustav	2021-2022	ML-based Navigation Assistance
Dufault, Louca	2021-2022	ML-based Navigation Assistance
Simard, Felix	2021	detecting benevolent sexism in text
Watson, Tyler	2021	detecting benevolent sexism in text
Porporino, Anthony	2021	detecting benevolent sexism in text
Bourbeau, Charles	2021	detecting benevolent sexism in text
Ko, Neroli	2020-2021	haptic dance shoes
Zwack, Noah	2020-2021	haptic dance shoes
Zhang, Weijing	2020-2021	haptic dance shoes
Szwimer, Benjamin	2020-2021	visually impaired access to web graphics
Zoltak, Matthew	2020-2021	visually impaired access to web graphics
Itovitch, Ethan	2020-2021	visually impaired access to web graphics
Weiss, Ben	2020-2021	mixed-reality for schizophrenia treatment
Bieber, Nicolas	2020-2021	mixed-reality for schizophrenia treatment
Khan, Marwan	2020-2021	360° imaging for navigation assistance
Johansen, Anthony	2020-2021	360° imaging for navigation assistance
Gurkan, Mert	2020-2021	360° imaging for navigation assistance
Warsi, Osman	2020-2021	360° imaging for navigation assistance
Lague, Ethan	2019-2020	AR firefighter situational awareness tools
Masciotra, Alex	2019-2020	AR firefighter situational awareness tools
Philippon, Thomas	2019-2020	AR firefighter situational awareness tools
Bouchard, Tristan	2019-2020	AR firefighter situational awareness tools
Smith, Babette	2019-2020	AR and 360: camera-mediated future
Smith, Lilith	2019-2020	AR and 360: camera-mediated future
Chen, Jennie	2019-2020	Foot-fluid interaction simulation in mobile VR
Servera, Ryan	2019-2020	Foot-fluid interaction simulation in mobile VR
Wong, Tyrone	2019-2020	Foot-fluid interaction simulation in mobile VR
Bluethner, Lucas	2019-2020	Foot-fluid interaction simulation in mobile VR
Volodina, Yuliya	2019	360° camera scene understanding
Ritch, David	2019	360° camera scene understanding
Lam, Guillaume	2019	360° camera scene understanding
Nasseem, Veronica	2019	360° camera scene understanding
Amjad, Adeeb Ibne	2019	360° camera supported intersection-crossing
Amarouche, Hakim	2019	360° camera supported intersection-crossing
Tang, James	2019	360° camera supported intersection-crossing
Commodari, Stefano	2019	360° camera supported intersection-crossing
Regimbal, Juliette	2019	Haptic Wearables
Radi, Nusaiba	2019	Haptic Wearables
Berman, Isaac	2018	Vision-based crossing assistance
Mashaal, Stuart	2018	Vision-based crossing assistance
Liu, Shi Yu	2018	Vision-based crossing assistance
Legrand, Augustin	2018	Force Feedback for VR and AR
Fournier, Clément	2018	Force Feedback for VR and AR

Continued on next page

Name	Year	Research topic
Nith, Romain	2018	Force Feedback for VR and AR
Malik, Numan	2017-2018	Variable-Friction Surface Mechanism
Eshaq, Yousef	2017-2018	Variable-Friction Surface Mechanism
Alalawi, Beshr	2017-2018	Variable-Friction Surface Mechanism
Ahmed, Ridwan	2017-2018	Variable-Friction Surface Mechanism
Nichyporuk, Brennan	2017-2018	AI/vision-based Q&A Dialogue
Benseler, Nick	2017-2018	AI/vision-based Q&A Dialogue
Karatzas, Thomas	2017-2018	Wine recommendation engine
Zhilin, Oleg	2017-2018	Wine recommendation engine
Simard-Morissette, Olivier	2017-2018	Wine recommendation engine
Mirfallah Liarestani, N.	2017	Autour
Kim, Yong Beom	2017	Autour
Gibeault-Girard, Gabriel	2017	AR firefighter display
Velastegui, Nicolas	2017	AR firefighter display
V Cama, Carmen Aimee	2017	AR firefighter display
Dermont, Daniel	2016-2017	Haptic shoes
Makriogiorgos, A.	2016-2017	Haptic shoes
Rohlicek, Greg	2015-2016	Mobile telepresence
Carter, Stephen	2015-2016	Mobile telepresence
Zhang, Zhaowei	2015-2016	Haptic shoes
Huynh, Alex	2015-2016	Haptic shoes
Guzman, Juan	2015-2016	Video analytics
Ali, Hassan	2015-2016	Video analytics
Macario, Daniel	2015-2016	Automated event detection
Arané, Yarden	2015-2016	Automated event detection
Leighton, Brett	2015-2016	Automated event detection
Aird, Nicholas	2015-2016	AR firefighter display
Chen, Yuechuan	2015-2016	AR firefighter display
Lei, Simon	2015-2016	AR firefighter display
Mendonca, Justin	2015-2016	Firefighter IPS
Asfour, Justin	2015-2016	Firefighter IPS
Ward, Thomas	2015-2016	Firefighter IPS
Laramée, Alexandre	2015-2016	Firefighter IPS
Sahib, Shivan	2015-2016	Biosignal wearables
Nath, Saptaparna	2015-2016	Biosignal wearables
Bramson, Shawn	2013-2014	Mobile Telepresence
Larose, Andrew	2013-2014	Mobile Telepresence
Dirik, Alize	2013-2014	Mobile Telepresence
Mansour, Rita	2013-2014	Walking Straight
Elkerdi, Ghalia	2013-2014	Walking Straight
Redel, Josh	2012	Augmented Meeting Collaboration
Savchenko, Eugene	2010	3D interaction

ECE Undergraduate Design Projects (1 semester)

Name	Year	Name	Year	Name	Year
Himmelman, Tristan	2009	Glass, Emily	2001	Li, (Shao-Gi) Chris	1999
Ephraim, Theo	2009	Asselin, Ramy	2001	El-Sharif, Osama	1999
Peck, Benjamin†	2008	Sud, Daniel	2001	Nasereddin, Hazem	1999
Mankarios, Daniel	2007	Gapakov, Timofei	2001	Virdi, Gurpratap	1999
Konstantinidis, Alex	2007	Rosenblatt, Avi	2001	Shah, Ali	1999
Pufahl, David	2005	Pekofsky, Gregory	2001	Djihanian, Sylvie	1999
Zhu, Ming-Zhang	2005	Kitisa, Anousack	2000	Moussaoui, Khaled	1999
Chan, Keng Chi	2005	Vial, Thibaut	2000	Dib Youssef	1999
Phan, Andrew	2004	Bernier, Martin	2000	Tam, H.	1999
Saiffee, Ali-Akber	2004	Agha, Khurram Z.	2000	Gagnon, Gabriel	1999
Shield, Robert	2004	Bhattacharya S.	2000	Tjhin, P.	1999
Aubé, Francois	2004	Lavery, William	2000	Luong, Mai	1999
Rudzicz, Frank	2003	Yeung, Jason	2000	Lau, Sau	1999
Sarikaya, Deniz	2002	Liao, Yuan Mei	1999	Tsai, Wanti	1999
Vallianatos, K.	2002	Yee, Amy	1999	Lerner, Sorin*	1999
Hassaine, Sofiane	2002	Pereira, David	1999	Hochstein, Lorin*	1999
Wyse, Marisa	2001	Ciambella, Gary	1999	Pollack, Jonathan	1998
Bancroft, David	2001	Kassouf, Nadim	1999	Nguyen, Bau	1998
		Lee, Garvin	1999		

*Co-supervised with James Clark

†Co-supervised with Paul Kry

Computer Science Undergraduate Projects (1 semesters)

Nejad, Namdar	2022	Utilizing Context to Improve Accessible Representations of Web Graphics
Li, Dailun	2022	Training and Testing an Open-Source French TTS Model

Mechanical Engineering Undergraduate Design Projects (2 semesters)

Sadaqa, Abdel-Rahman	2020-2021	Haptic illusions
Waite, Emilie	2020-2021	Haptic illusions
Shi, Rock	2020-2021	Haptic illusions
Fitz-Gerald, Thomas	2020-2021	Haptic illusions
Pollet, Nathan	2020-2021	Multimodal haptic armrest
Uzan, Emanuel	2020-2021	Multimodal haptic armrest
Ruivo Patricia	2020-2021	Multimodal haptic armrest
Abravanel Tal	2020-2021	Multimodal haptic armrest
Fowo, Clovis	2017-2018	Haptic interface for the feet
Robert, Gabrielle	2015-2016	Variable friction shoe
King, Michael	2013-2014	Variable Friction Foot-Ground Contact

Undergraduate Internships

Name	Year	Research project
Li, Hanzi	2022	(CS Intern) Internet Multimodal Access to Graphical Exploration (IMAGE)
Gutiérrez, Diego Macias	(Mitacs Globalink) Haptic dance shoes	
Cortes, Dafne Peña	(Mitacs Globalink) Internet Multimodal Access to Graphical Exploration (IMAGE)	
Shen, Xing	2022	(ECE Intern) Vision-Guided Navigation Assistance
Dutta, Riana	2022	(NSERC USRA) Internet Multimodal Access to Graphical Exploration (IMAGE)
Pan, Edwin	2022	(SURE Student) Touching Face in VR
Chen, Hongye	2022	(ECE Intern) Internet Multimodal Access to Graphical Exploration (IMAGE)
Behal, Rahul	2021-2022	ML-based Navigation Assistance for the Visually Impaired
Rao Appala, Siddharth	2021	(Mitacs Globalink) Making internet graphics accessible through rich audio and touch
Contreras, Luis F. H.	2021	(Mitacs Globalink) Haptic device for sensory re-education application
Bhayana, Rachit	2021	(NSERC USRA) Conveying Paralinguistic and Non-Verbal Cues in Teleconferencing
Reszetnik, Grace	2021	(NSERC USRA) Avatar therapy for psychosis
Jiang, Cecilia	2021	(NSERC USRA) Avatar therapy for psychosis
Radi, Rakshitha	2021	(ECE Intern) Assistive Technology Project
Marshall, Kenji	2020-21	(ECE Intern) Avatar therapy for psychosis
Pollet, Nathan	2020	(SURE Student) 360° camera imaging
Bu, Bruce	2019	(SURE Student) Haptic Wearables
Chen, Jennie	2019	(SURE Student) Haptic Wearables
Zhang, Yukai	2019	(SURE Student) Haptic Wearables
Ratnakirti, Navneet	2019	(SURE Student) Sweatsponse
Al Taha, Feras	2018-2019	(NSERC USRA) Haptic Wearables
Nunez, Matteo	2018	(SURE Student) Haptic Wearables

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Name	Year	Research project
Huang, Yixiang	2018	(SURE Student) Non-Intrusive Mobile Experience Sampling
Li, Zihang	2018	(Mitacs Globalink) Enhanced Remote Viewing Capabilities from a Camera Array
Kaoubi, Hadir	2018	(Mitacs Globalink) Autour: “What’s around me?”
Ma, Jiantong	2018	Haptic Zoom
Tran, Jessica	2017	Social Media Monitoring
Xing, Emily	2017	Attention Switching Protocols in Family Conversations
Hao, Ju	2017	(Mitacs Globalink research intern) Haptic shoes
Lisus, Daniil	2017	(NSERC USRA) Natural Interactive Walking
Tran, Andrew	2016-2017	Multimodal CAVE integration
Sun, Nan Jin (Kelly)	2016-2017	Multimodal CAVE integration
Liu, Yufei (Kevin)	2016	Flexible graphical display of foot-ground interactions
Kashyap, Sumeha	2016	(Summer Intern from Indian Institute of Technology Guwahati) Walking Straight Project
Hamed-Baghi, Bobak	2016	(SURE Student) Game Interaction for Haptic Shoes
Dubé, Felix	2016	(SURE Student) Haptic Shoes
Yang, Yanzhe	2015	(Mitacs Globalink) Enhanced Remote Viewing Capabilities from a Camera Array
Morency-Trudel, Juan	2015	(NSERC USRA) Spatialized audio for environmental awareness for the visually impaired
Liu, Bei Chen	2015	(SURE Student) Haptic in-sole design and implementation
Liu, Shuxuan (Dennis)	2015	Multimodal CAVE integration
Chaudhary, Yetesh	2014	Communication in Emergency and Crisis Response
Pavlassek, Jana	2014	(NSERC USRA) Natural Interactive Walking
Jiang, Mike	2014	(IAESTE student trainee) Graphics Rendering for Multimodal CAVE
Yin, Guofan	2014	(Mitacs Globalink) Enhanced Remote Viewing Capabilities from a Camera Array
Murgai, Prateek	2014	Acoustic Signal Processing
Sharma, Alok	2013-14	(BITS India Student) rt Emergency Response

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Name	Year	Research project
Gupta, Sakshi	2013	(SURE Student from Indian Institute of Information Technology, Jabalpur) In-Situ Audio Services
Brais, Robert	2013	(NSERC USRA) Natural Interactive Walking
Gourdy, Oriane	2013	(Grenoble INP Student) 3DUI Interaction
Jain, Nehil	2011-12	(BITS India Student) In-Situ Audio Services
Sutcliffe, Andrew	2011	Haptically Augmented Steering Wheel
Greencorn, Dan	2011	Food Analysis Simulation
Redel, Josh	2011	Open Orchestra
Varenne, Dylan	2011	(Polytech Nice-Sophia), In-Situ Audio Services
Tomiyoshi, Marcio	2011	(ELAP Scholarship Student) Open Orchestra
Beniak, Stephane	2010	(NSERC USRA) Natural Interactive Walking
Salenikovich, Stepan	2010	Natural Interactive Walking
Chaw, Gary	2010	Natural Interactive Walking
Redel, Josh	2010	Health Services Virtual Organization
Smith, Severin	2009-11	Natural Interactive Walking
Rajalingham, Rishi	2009	(NSERC USRA) Natural Interactive Walking
Rener, Farid	2009	(SURE Student) Natural Interactive Walking
Bae, Sung	2009	Optical Tracking for Audio Graffiti
Jathal, Kunal	2007	Haptic and auditory perception in human walking
Lin, Nan*	2006	(NSERC USRA) Interactive navigational control of robotic wheelchair
Reiter, Philippe	2005	(VP USRA Student) Distributed Video Rendering
Ariane Chan-You	2003	Region-of-Interest Control in Videoconferencing
Ariane Chan-You	2002	Videoconferencing Data Reduction
Gupta, Greeshma	2000	(NSERC Student) Automated slide converter
Cote, Christian	2000	(NSERC Student) Video transformations
Ayatizadeh, Negah	2000	Network communication daemons
Swartz, Tanya	2000	Speech-based TV-tuner interface
Cohen, Ouri	2000	Classroom 2000 access control
Yeong, Jason Aw	1999	(Work Study) Previously Asked Questions system

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Name	Year	Research project
Agha, Khurram Zubair	1999	(Work Study) URL access tracking
Lim, Weoi Peng	1999	(Work Study) Graffiti board
Agha, Haroon Ali	1999	(Work Study) Classroom 2000 minipres. system
Klinger, Zamir	2000	(NSERC Student) Automated Door Attendant
Hooshangi, Sara	2000	(NSERC Student) Intelligent Classroom
Liao, Yuan Mei	1999	Electronic Classroom control interfaces
Luo, Jiexin	1999	PowerPoint C2000 interface and image libraries
Zhao, Changpeng	1998-99	Seamless PowerPoint upload for Classroom 2000
Lakdawalla, Azeem	1998-99	Real-time conjugate-gradient based head-tracking

*Co-supervised with Joelle Pineau

SERVICE

UNIVERSITY SERVICE

Department Committees

2020-2022	ECE Unit Lab Access Committee
2017-2018	Undergraduate Recruitment Committee, Chair
2017-2020	Search Committee (Software Engineering, Artificial Intelligence)
2017-2018	Tenure Committee
2015-2022	Safety Committee (Chair in 2015-2017)
2014-2016	Grant Application Support Committee
2012-2022	Graduate Committee
2008-2012	Undergraduate Recruitment Committee
2005-2011	Scholarships/Graduate Student Financing Committee
2002	Ad hoc Committee on Computing Infrastructure for ECE/SOCS
2000-2008	College Liaison Committee
2001-2004	Information Technologies & Undergraduate Lab
2000-2002	Curriculum Committee
2000	Software Engineering subcommittee
2000-2007	Undergraduate Student Advisor

Other University Service

2014-2016	Elected Member of Council, McGill Association of University Teachers
2009-2013	Member, CIRMMT Executive Committee
2007-2013	Co-chair, Multimodal Immersive Systems research axis, CIRMMT
2006-2008	Member, CIRMMT Board of Directors
2006	Advisory Committee for Dean of Music
2004	Tomlinson University Science Teaching Project adjudication
2003-2004	Royal Bank Teaching and Learning Innovation Fund adjudication
2003	Groupe de travail sur les normes et standards de la formation en ligne. Conférence des recteurs et des principaux des universités du Québec (CREPUQ), McGill University Representative
2002-2003	SC-IST Workgroup on Research Computing
2000-2003	SC-IST Workgroup on Classroom Design
1999-2004	Engineering Committee on Teaching and Learning
1999	SC-IST McGill Machine Project
1998	Workgroup on Educational Technology

Fundraising Activities

2002	RoboCup demonstration at McCord museum for Dean's Circle
2002	Corporate fundraising for McGill RoboCup team
2001-2002	Intelligent Classroom promotion with the Engineering Class of '50; helped raise \$274,000
2001	Trottier Building research promotion

Other Activities

2007-2010	Promotion of Academic Integrity
2001-2002	Design of new Intelligent Classroom systems for ENGM 304
1999-2002	Maintenance of the Intelligent Classrooms, training other faculty in use of the technology
1999	Curriculum development of three new courses in software engineering

PROFESSIONAL ACTIVITIES**Service to the Community**

2019	Government of Canada, Network of Canadian Experts on Virtual Reality
2018	Consulted by Ordre des ingénieurs du Québec regarding the OIQ's position on AI
2018	Invited Member, Fonds de recherche, Chantier sur l'intersectorialité et la créativité
2018	Co-chair, ACM SIGCHI Demonstrations
2017	External member of academic selection committee, École de technologie supérieure
2016	Organizing Committee, IEEE International Workshop on Multimedia Signal Processing, Special Session on Multimodal Interaction with Digital Information in Smart Cities
2016, 2019	Selection Committee, Bill Buxton HCI Thesis Award
2016	Digital Media Program Review, York University
2016	Critique of TCPS CORE Tutorial on Research Ethics (Secretariat agreed to remove problematic question associated with the Zimbardo study)
2010-2015	Theme Leader, Enabling Technologies, Graphics Animation and New Media (GRAND) Networks of Centres of Excellence
2010-ongoing	Voting Member, IEEE Communication Society Multimedia Communications Technical Committee (IEEE MMTC)
2009	Organizer and Chair, AES Workshop on Network Technologies for Audio over IP
2008	Tenure Portfolio evaluation, York University
2005-2006	Organizer, AES Tutorial and Workshop on Human Factors in Audio
2004	Founder, AES Technical Committee for Human Factors in Audio Systems
2003	Organizer, Workshop on LAN Delivery of Audio for AES
2002-2003	Comité Scientifique de Robofolies, Centre Science de Montreal
2001	Local Events Organizer, Autonomous Agents Conference, Montreal
2001-2009	Chair, AES Technical Committee for Network Audio Systems
2000-2004	Scientific Organizer, RoboCup Junior, Montreal
2000-2001	Organizing Committee, Robofesta International Robot Games Festival, Japan
1999-2000	Member and Webmaster, Canadian Virtualized Reality Working Group
1998	Co-organizer, AAAI Symposium on Intelligent Environments

Editorial Service

2021-ongoing	Associate Editor, IEEE Transactions on Haptics
2021	Senior Program Committee, International Conference on Multimodal Interaction
2021	Guest Editor, IEEE Transactions on Haptics (WHC track)
2020-ongoing	Associate Editor, Frontiers in Virtual Reality
2019	Associate Editor, World Haptics Conference
2019	Guest Editor, Multimodal Technologies and Interaction, Special Issue on Multimodal Medical Alarms
2018-2022	Associate Editor, Program Committee member, Haptics Symposium
2013	Guest Editor, Journal of the Audio Engineering Society, Special Issue on Audio Networking
2008-2022	Associate Editor, Journal of the Audio Engineering Society

Journal Referee

2022	IEEE Multimedia
2021	ACM Transactions on Human-Computer Interaction
2020-21	ACM Transactions on Applied Perception
2020	ACM Interactive, Mobile, Wearable and Ubiquitous Technologies
2019	Frontiers in Neurobotics
2018	Peer J–Journal of Life & Environmental Sciences
2017	Sensor Review
2015	Ambient Intelligence and Smart Environments
2010-20	IEEE Transactions on Haptics
2012	International Journal on Acoustics
2011	BMC Medical Informatics and Decision Making
2011	IEEE Software
2010	IEEE Transactions on Affective Computing
2010	IEEE Transactions on Robotics
2010	IEEE Signal Processing Magazine
2009	IEEE Transactions on Robotics
2008	EURASIP Advances in Signal Processing
2008	EURASIP Image and Video Processing
2008-ongoing	Audio Engineering Society
2007	IEEE Transactions on Systems, Man, and Cybernetics
2006	International Journal of Human-Computer Interaction
2006	Springer Virtual Reality
2005	Elsevier: Computers and Education
2005	Elsevier: Image and Vision Computing
2004, 2019	IEEE Pervasive Computing
2000, 2003	Wiley Journal of Robotic Systems
1999	ACM Transactions on Computer-Human Interaction
1999	IEEE Transactions on Robotics and Automation
1998	IEEE Personal Communications

Conference Review

2020	IEEE Virtual Reality
2018, 2020	ACM SIGCHI User Interface Systems and Techniques
2018	Workshop on Assistive Computer Vision and Robotics
2018	Eurohaptics
2017	International Conference on Auditory Display
2017	Mobile HCI
2017-19	IEEE World Haptics
2016	IEEE International Workshop on Multimedia Signal Processing
2015	ACM Multimedia
2015	INTERACT
2014	ACM SIGGRAPH
2012, 2013	Workshop on Context Based Affect Recognition
2012, 2013	International Society for Presence Research
2012	IEEE Canadian Conference on Electrical and Computer Engineering
2011	AES Conference on Audio Networking
2011	Intelligent Robots and Systems
2011	VRIC Wkshop on Haptics for Telepresence, Teleoperation & Collab. Environments
2009	IEEE Haptics Symposium
2009	International Computer Music Conference
2009	Stereoscopic Displays and Applications
2008-19	ACM SIGCHI Human Factors in Computing
2008	Immersive Medical Telepresence
2006	International Conference on Digital Audio Effects
2006, 2007	IEEE Workshop on Projector-Camera Systems (part of CVPR)
2005-2009	Canadian Conference on Computer and Robot Vision
2004, 2009-14, 2016	Graphics Interface
2003, 2006	Audio Engineering Society
2003	New Interfaces for Musical Expression
2002	RoboCup International Symposium
2002, 2015	IEEE International Conference on Robotics and Automation
2001	ACM UbiComp
2001	IEEE International Conference on Computer Vision

Grant Review

2017	NSERC Strategic Project Grants
2017	Member of Expert Committee, CFI Innovation Fund
2016	L'Agence Nationale de la Recherche (France)
2011	NSERC Collaborative Research and Training Experience Program (CREATE)
2009, 2011	Mathematics of Information Technology and Complex Systems (MITACS)
2009	NSERC Strategic Networks (Site Visit Chair)
2008, 2015, 2017	Peer review, NSERC Collaborative Research and Development Grants
2007-2008	NSERC Industrial Research Chair (Site Visit)
2007-2020	Research Grants Council, Hong Kong
2005	NSERC Steacie Memorial Fellowship
2002, 2005-2008	Panel member, NSERC/Canada Council, New Media Initiative
2001-2017	Peer review, NSERC Discovery Grants
2001, 2008	Peer review, CFI (Canada Foundation for Innovation)

Participation in Academic Fora

2019	San Diego Opera – Opera Hack, July 27-28
2019	Dagstuhl Seminar on Ubiquitous Computing Education, June 2-7
2010	Participant, NSF/CCC Workshop on Ultra-Large Scale Interaction

CONSUMER ADVOCACY

2013	brought successful appeal (2013 QCCA 1670) before Quebec Court of Appeal regarding anti-SLAPP legislation
2013	initiated petition to improve rights of Canadian airline passengers
2010	advocating for reliable public transportation in Montreal
1997-present	created and maintained passenger rights website