IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

In re *Inter Partes* Review of:)
U.S. Patent No. 10,917,737)
Issued: February 9, 2021)
Application No.: 16/558,088)
Filing Date: August 31, 2019)



For: **Defining a Zone with a HPED and Providing Binaural Sound in the Zone**

DECLARATION OF DR. GREGORY F. WELCH IN SUPPORT OF PETITION FOR *INTER PARTES* REVIEW OF U.S. PATENT NO. 10,917,737

TABLE OF CONTENTS

I. Introduction And Qualifications 1

II. Summary Of Materials Reviewed And Considered 6

III. Legal Understandings 15

IV. The '737 Patent 19

V. Level Of Ordinary Skill In The Art And Perspective Applied In This Declaration 22

VI. Claim Construction 24

VII. State of the Art 24

A. Brief History 25

B. Wearable Electronic Devices (WEDs) and Head-Mounted Displays (HMDs) 35

C. Handheld Controllers 38

D. Tracking WEDs/HMDs and Controllers 48

E. Sound Localization and Binaural Sound 60

F. Designating Sound Sources 67

G. Safety and Chaperone Systems 82

VIII. Petition Grounds and Prior Art Combinations 92

IX. The Prior Art Relied On In The Petition 92

A. Overview Of Pedrotti (Ex.1005) 93

B. Overview Of Jang (Ex.1006) 99

C. Overview Of Begault (Ex.1007) 105

D. Overview Of McCulloch (Ex.1008) 110

E. Overview Of Flaks (Ex.1009) 116

X. Ground 1: Claims 1-20 Are Unpatentable Over Pedrotti In View Of Jang, And Further In View Of Begault 120

A. Reasons Persons Of Ordinary Skill In The Art Would Combine Pedrotti And Jang 120

B. Reasons Persons Of Ordinary Skill In The Art Would Combine Pedrotti, Jang, and Begault.....125

C. Independent Claim 1 132

1. 1[pre]: "A method executed by one or more electronic devices, the method comprising:".....132

2. 1[a]: "tracking, with a wearable electronic device (WED) worn on a head of a user, movement of a handheld portable electronic device (HPED) held in a hand of the user such that the movement of the HPED defines a size and a shape of a three-dimensional (3D) zone that extends from a physical floor and around the user;" 133

3. 1[b]: "designating, with the HPED held in the hand of the user, a sound localization point (SLP) in empty space in the zone above the physical floor from where binaural sound originates to the user;".....139

4. 1[c]: "tracking, with the WED worn on the head of the user, the HPED held in the hand of the user such that the HPED provides a location to the WED of the SLP in empty space in the zone above the physical floor from where the binaural sound originates to the user;".....160

5. 1[d]: "processing, by a processor, sound with head-related transfer functions (HRTFs) to generate the binaural sound that externally localizes to the user at the location of the SLP in empty space in the zone above the physical floor; and".....166

6. 1[e]: "displaying, with the WED worn on the head of the user a virtual image at the location of the SLP in empty space in the zone above the physical floor from where the binaural sound originates to the user.".....170

Ex. 1143-003

Meta Platforms, Inc.
Exhibit 1003
Page 003

D. Dependent Claims 2-7 175

1. Claim 2 175

a. 2[a]: "The method of claim 1, wherein the binaural sound is a voice of a virtual reality (VR) character that talks to the user while the user plays a VR game," 175

b. 2[b]: "and the voice externally localizes to the user at the VR character that is at the location of the SLP in empty space in the zone above the physical floor." 183

2. Claim 3 184

a. 3[a]: "The method of claim 1 further comprising: tracking, with the WED worn on the head of the user, the HPED held in the hand of the user as the HPED moves in a trajectory having a shape of an arc;" 184

b. 3[b]: "processing, by the processor and with the HRTFs, the sound to generate SLPs of the binaural sound that moves through the empty space along the trajectory having the shape of the arc; and" 185

c. 3[c]: "displaying, with the WED worn on the head of the user, virtual images that follow the trajectory having the shape of the arc that shows the user the trajectory of the SLPs of the binaural sound moving through the empty space." 186

3. Claim 4 187

a. 4[a]: "The method of claim 1 further comprising: determining, with the WED worn on the head of the user, when a location of the user conflicts with a boundary of the zone; and" 187

Ex. 1143-004

Meta Platforms, Inc.
Exhibit 1003
Page 004

b. 4[b]: "displaying, with the WED, the boundary of the zone to alert the user that the location of the user conflicts with the boundary of the zone." 189

4. Claim 5 191

a. 5[a]: "The method of claim 1 further comprising: displaying, with the WED worn on the head of the user, a virtual image of the zone as lines that extends from the physical floor and around the user," 191

b. 5[b]: "wherein the zone has a customized shape drawn by user with the HPED, and the WED stores coordinate locations of the customized shape." 193

5. Claim 6 195

a. 6[a]: "The method of claim 1 further comprising: displaying, with the WED, a virtual monitor in a field of view (FOV) of the user;" 195

b. 6[b]: "processing, by the processor, the sound with the HRTFs to generate the binaural sound that originates from the virtual monitor; and" 202

c. 6[c]: "tracking, with the WED, head movements of the user to maintain the binaural sound originating from the virtual monitor as the head of the user moves." 203

6. Claim 7: "The method of claim 1, wherein the zone has a shape of a cylinder that extends from the physical floor and around the user, and the WED displays the cylinder to the user." 206

E. Independent Claim 8 208

1. 8[pre]: "A method executed by one or more electronic devices, the method comprising:" 208

Ex. 1143-005

Meta Platforms, Inc.
Exhibit 1003
Page 005

2. 8[a]: "tracking, with a wearable electronic device (WED) worn on a head of a user, a handheld portable electronic device (HPED) that moves to define a shape of a zone that extends from a physical floor and around the user holding the HPED in a hand;" 208

3. 8[b]: "designating, with the HPED held in the hand of the user, a sound localization point (SLP) for binaural sound at a location in empty space in the zone above the physical floor where the HPED is pointed;".....208

4. 8[c]: "tracking, with the WED worn on the head of the user, the HPED and where the HPED is pointed to provide the WED with the location in empty space in the zone above the physical floor that includes the SLP for the binaural sound;" 210

5. 8[d]: "processing, by a processor, sound with head-related transfer functions (HRTFs) to produce the binaural sound that originates at the SLP at the location in empty space in the zone above the physical floor; and" 210

6. 8[e]: "displaying, with the WED worn on the head of the user, a virtual image at the location in empty space in the zone above the physical floor from where the binaural sound originates at the SLP to the user."....211

F. Dependent Claims 9-13 211

1. Claim 9: "The method of claim 8 further comprising: providing a voice as the binaural sound that externally localizes at the virtual image at the location in empty space in the zone above the physical floor, wherein the voice originates from a character in a virtual reality (VR) game that the user plays." 212

2. Claim 10: "The method of claim 8 further comprising: displaying, with the WED, a boundary of the zone with virtual lines to alert the user when the user conflicts with the boundary of the zone while the user plays a virtual reality (VR) game."....212

3. Claim 11: "The method of claim 8 further comprising: displaying the zone as a customized three-dimensional (3D) shape drawn by the user with the HPED held in the hand of the user." 213

4. Claim 12: "The method of claim 8 further comprising: tracking, with the WED, a location where the HPED is pointed as the HPED moves the SLP and the virtual image from one location where the HPED is pointed to another location where the HPED is pointed." 213

5. Claim 13: "The method of claim 8 further comprising: improving performance of the processor processing the sound by storing the HRTFs in a cache memory in the WED, wherein the processor is a digital signal processor (DSP) located in the WED." 214

G. Independent Claim 14 220

1. 14[pre]: "An electronic system, comprising:" 220

2. 14[a]: "a portable electronic device (PED) that moves to define a boundary of a three-dimensional (3D) zone extending from a physical floor on which a user holding the PED stands and around the user and that designates a sound localization point (SLP) in empty space inside the 3D zone; and" 220

3. 14[b]: "a wearable electronic device (WED) that is worn on a head of the user, tracks movement of the PED to determine the boundary of the 3D zone that extends from the physical floor and around the user," 221

4. 14[c]: "includes a processor that processes sound with head-related transfer functions (HRTFs) so sound externally localizes as binaural sound to the user at the SLP in empty space inside the 3D zone defined by movement of the PED, and" 221

Ex. 1143-007

Meta Platforms, Inc.
Exhibit 1003
Page 007

5. 14[d]: "displays a virtual image at the SLP in empty space inside the 3D zone, and displays a 3D virtual image that shows the boundary of the 3D zone that extends from the physical floor and around the user." 221

H. Dependent Claims 15-20 222

1. Claim 15: "The electronic system of claim 14, wherein the 3D zone has a customized size and shape defined by movement of the PED while held in a hand of the user."..... 223

2. Claim 16 223

a. 16[a]: "The electronic system of claim 14, wherein the WED tracks the PED to determine when the PED is at the boundary of the 3D zone, and"..... 223

b. 16[b]: "the WED automatically displays the 3D virtual image that shows the boundary of the 3D zone to alert the user that the PED is at the boundary of the 3D zone."..... 225

3. Claim 17 226

a. 17[a]: "The electronic system of claim 14, wherein the WED tracks the user to determine when the user is at the boundary of the 3D zone, and"..... 226

b. 17[b]: "the WED automatically displays the 3D virtual image that shows the boundary of the 3D zone to alert the user that the user is at the boundary of the 3D zone."..... 226

4. Claim 18 227

a. 18[a]: "The electronic system of claim 14, wherein the WED determines a location of the user," 227

b. 18[b]: "stores the 3D zone for the location, and"..... 227

c. 18[c]: "displays the 3D virtual image that shows the boundary of the 3D zone in response to determining that the user is at the location." 228

Ex. 1143-008

Meta Platforms, Inc.
Exhibit 1003
Page 008

5. Claim 19 230

a. 19[a]: "The electronic system of claim 14, wherein the WED includes one or more sensors that track a light source in the PED to determine a location of the PED as the PED moves to define the boundary of the 3D zone," 230

b. 19[b]: "the WED displays a virtual monitor at the SLP in empty space inside the 3D zone, and" 234

c. 19[c]: "the binaural sound continues originates to the user at the virtual monitor as the head of the user rotates to different orientations with respect to the virtual monitor." 234

6. Claim 20: "The electronic system of claim 14, wherein the WED displays the 3D virtual image that shows the boundary of the 3D zone as lines to enable the user to determine the boundary of the 3D zone." 234

XI. Ground 2: Claims 1-20 Are Unpatentable Over McCulloch In View Of Pedrotti, And Further In View Of Flaks 235

A. Reasons Persons Of Ordinary Skill In The Art Would Combine McCulloch and Pedrotti 235

B. Reasons Persons Of Ordinary Skill In The Art Would Combine McCulloch, Pedrotti, And Flaks 245

C. Independent Claim 1 247

1. 1[pre]: "A method executed by one or more electronic devices, the method comprising:" 247

2. 1[a]: "tracking, with a wearable electronic device (WED) worn on a head of a user, movement of a handheld portable electronic device (HPED) held in a hand of the user such that the movement of the HPED defines a size and a shape of a three-dimensional (3D) zone that extends from a physical floor and around the user;" 247

Ex. 1143-009

Meta Platforms, Inc.
Exhibit 1003
Page 009

3. 1[b]: "designating, with the HPED held in the hand of the user, a sound localization point (SLP) in empty space in the zone above the physical floor from where binaural sound originates to the user;".....257

4. 1[c]: "tracking, with the WED worn on the head of the user, the HPED held in the hand of the user such that the HPED provides a location to the WED of the SLP in empty space in the zone above the physical floor from where the binaural sound originates to the user;".....264

5. 1[d]: "processing, by a processor, sound with head-related transfer functions (HRTFs) to generate the binaural sound that externally localizes to the user at the location of the SLP in empty space in the zone above the physical floor; and".....267

6. 1[e]: "displaying, with the WED worn on the head of the user a virtual image at the location of the SLP in empty space in the zone above the physical floor from where the binaural sound originates to the user."".....270

D. Dependent Claims 2-7.....273

1. Claim 2.....274

a. 2[a]: "The method of claim 1, wherein the binaural sound is a voice of a virtual reality (VR) character that talks to the user while the user plays a VR game,".....274

b. 2[b]: "and the voice externally localizes to the user at the VR character that is at the location of the SLP in empty space in the zone above the physical floor."".....278

2. Claim 3.....279

Ex. 1143-010

Meta Platforms, Inc.
Exhibit 1003
Page 010

a. 3[a]: "The method of claim 1 further comprising: tracking, with the WED worn on the head of the user, the HPED held in the hand of the user as the HPED moves in a trajectory having a shape of an arc;".....279

b. 3[b]: "processing, by the processor and with the HRTFs, the sound to generate SLPs of the binaural sound that moves through the empty space along the trajectory having the shape of the arc; and".....280

c. 3[c]: "displaying, with the WED worn on the head of the user, virtual images that follow the trajectory having the shape of the arc that shows the user the trajectory of the SLPs of the binaural sound moving through the empty space."....281

3. Claim 4.....282

a. 4[a]: "The method of claim 1 further comprising: determining, with the WED worn on the head of the user, when a location of the user conflicts with a boundary of the zone; and".....282

b. 4[b]: "displaying, with the WED, the boundary of the zone to alert the user that the location of the user conflicts with the boundary of the zone."....284

4. Claim 5.....284

a. 5[a]: "The method of claim 1 further comprising: displaying, with the WED worn on the head of the user, a virtual image of the zone as lines that extends from the physical floor and around the user,".....284

b. 5[b]: "wherein the zone has a customized shape drawn by user with the HPED, and the WED stores coordinate locations of the customized shape."....285

5. Claim 6.....287

a. 6[a]: "The method of claim 1 further comprising: displaying, with the WED, a virtual monitor in a field of view (FOV) of the user;" 287

b. 6[b]: "processing, by the processor, the sound with the HRTFs to generate the binaural sound that originates from the virtual monitor; and".....288

c. 6[c]: "tracking, with the WED, head movements of the user to maintain the binaural sound originating from the virtual monitor as the head of the user moves." 289

6. Claim 7: "The method of claim 1, wherein the zone has a shape of a cylinder that extends from the physical floor and around the user, and the WED displays the cylinder to the user." 290

E. Independent Claim 8 291

1. 8[pre]: "A method executed by one or more electronic devices, the method comprising:".....291

2. 8[a]: "tracking, with a wearable electronic device (WED) worn on a head of a user, a handheld portable electronic device (HPED) that moves to define a shape of a zone that extends from a physical floor and around the user holding the HPED in a hand;" 291

3. 8[b]: "designating, with the HPED held in the hand of the user, a sound localization point (SLP) for binaural sound at a location in empty space in the zone above the physical floor where the HPED is pointed;".....291

4. 8[c]: "tracking, with the WED worn on the head of the user, the HPED and where the HPED is pointed to provide the WED with the location in empty space in the zone above the physical floor that includes the SLP for the binaural sound;" 292

Ex. 1143-012

Meta Platforms, Inc.
Exhibit 1003
Page 012

5. 8[d]: "processing, by a processor, sound with head-related transfer functions (HRTFs) to produce the binaural sound that originates at the SLP at the location in empty space in the zone above the physical floor; and" 293

6. 8[e]: "displaying, with the WED worn on the head of the user, a virtual image at the location in empty space in the zone above the physical floor from where the binaural sound originates at the SLP to the user." 294

F. Dependent Claims 9-13 294

1. Claim 9: "The method of claim 8 further comprising: providing a voice as the binaural sound that externally localizes at the virtual image at the location in empty space in the zone above the physical floor, wherein the voice originates from a character in a virtual reality (VR) game that the user plays." 295

2. Claim 10: "The method of claim 8 further comprising: displaying, with the WED, a boundary of the zone with virtual lines to alert the user when the user conflicts with the boundary of the zone while the user plays a virtual reality (VR) game." 295

3. Claim 11: "The method of claim 8 further comprising: displaying the zone as a customized three-dimensional (3D) shape drawn by the user with the HPED held in the hand of the user." 296

4. Claim 12: "The method of claim 8 further comprising: tracking, with the WED, a location where the HPED is pointed as the HPED moves the SLP and the virtual image from one location where the HPED is pointed to another location where the HPED is pointed." 296

5. Claim 13: "The method of claim 8 further comprising: improving performance of the processor processing the sound by storing the HRTFs in a cache memory in the WED, wherein the processor is a digital signal processor (DSP) located in the WED." 297

Ex. 1143-013

Meta Platforms, Inc.
Exhibit 1003
Page 013

G. Independent Claim 14 299

1. 14[pre]: "An electronic system, comprising:" 299

2. 14[a]: "a portable electronic device (PED) that moves to define a boundary of a three-dimensional (3D) zone extending from a physical floor on which a user holding the PED stands and around the user and that designates a sound localization point (SLP) in empty space inside the 3D zone; and" 300

3. 14[b]: "a wearable electronic device (WED) that is worn on a head of the user, tracks movement of the PED to determine the boundary of the 3D zone that extends from the physical floor and around the user," 300

4. 14[c]: "includes a processor that processes sound with head-related transfer functions (HRTFs) so sound externally localizes as binaural sound to the user at the SLP in empty space inside the 3D zone defined by movement of the PED, and" 301

5. 14[d]: "displays a virtual image at the SLP in empty space inside the 3D zone, and displays a 3D virtual image that shows the boundary of the 3D zone that extends from the physical floor and around the user." 301

H. Dependent Claims 15-20 302

1. Claim 15: "The electronic system of claim 14, wherein the 3D zone has a customized size and shape defined by movement of the PED while held in a hand of the user." 302

2. Claim 16 303

a. 16[a]: "The electronic system of claim 14, wherein the WED tracks the PED to determine when the PED is at the boundary of the 3D zone, and" 303

Ex. 1143-014

Meta Platforms, Inc.
Exhibit 1003
Page 014

b. 16[b]: "the WED automatically displays the 3D virtual image that shows the boundary of the 3D zone to alert the user that the PED is at the boundary of the 3D zone."....304

3. Claim 17....305

a. 17[a]: "The electronic system of claim 14, wherein the WED tracks the user to determine when the user is at the boundary of the 3D zone, and"....305

b. 17[b]: "the WED automatically displays the 3D virtual image that shows the boundary of the 3D zone to alert the user that the user is at the boundary of the 3D zone."....305

4. Claim 18....306

a. 18[a]: "The electronic system of claim 14, wherein the WED determines a location of the user,"....306

b. 18[b]: "stores the 3D zone for the location, and"....307

c. 18[c]: "displays the 3D virtual image that shows the boundary of the 3D zone in response to determining that the user is at the location."....308

5. Claim 19....309

a. 19[a]: "The electronic system of claim 14, wherein the WED includes one or more sensors that track a light source in the PED to determine a location of the PED as the PED moves to define the boundary of the 3D zone,"....309

b. 19[b]: "the WED displays a virtual monitor at the SLP in empty space inside the 3D zone, and"....310

c. 19[c]: "the binaural sound continues originates to the user at the virtual monitor as the head of the user rotates to different orientations with respect to the virtual monitor."....310

Ex. 1143-015

Meta Platforms, Inc.
Exhibit 1003
Page 015

6. Claim 20: "The electronic system of claim 14, wherein the WED displays the 3D virtual image that shows the boundary of the 3D zone as lines to enable the user to determine the boundary of the 3D zone." 310

XII. Conclusion 312

I. Introduction And Qualifications

1. I, Gregory F. Welch, submit this declaration on behalf of Meta Platforms, Inc. and Meta Platforms Technologies, LLC (collectively, "Meta" or "Petitioners") to provide my opinion concerning the validity of the claims 1-20 of U.S. Patent No. 10,917,737 ("the '737 patent," Ex.1001), in support of the Petition for *Inter Partes* Review of the '737 patent.

2. I am more than eighteen years of age, and I am a citizen of the United States, currently residing in the state of Florida.

3. In formulating my opinions, I have relied upon my knowledge, training, and experience in the relevant art. My qualifications, along with a more detailed summary of my background and publications, are stated more fully in my *curriculum vitae*, which has been provided as Exhibit 1004. Here, I provide a brief summary of my qualifications.

4. I earned a Bachelor of Science degree, with *Highest Distinction*, in electrical engineering technology from Purdue University in 1986. I earned a Master of Science degree in computer science from the University of North Carolina at Chapel Hill in 1995. I earned a Ph.D. in computer science from the University of North Carolina at Chapel Hill in 1997. My doctoral dissertation is titled "SCAAT: Incremental Tracking with Incomplete Information," which discusses the single-constraint-at-a-time tracking as implemented in tracking or navigation systems.

5. I have extensive research and industry experience with, among other things, all fundamental areas of extended reality (XR), including both Virtual Reality (VR) and Augmented Reality (AR), and in applications of XR such as for training, education, and entertainment.

6. From 1987 to 1990, I was employed by NASA at the Jet Propulsion Laboratory (California Institute of Technology). I worked on the Voyager Spacecraft Project on the Sequence Team under the Flight Command and Data Management Section. I was responsible for programming and maintaining simulators and other software associated with the Voyager spacecraft (Voyager 1 and Voyager 2), assembling "sequences" of instructions to carry out scientific experiments on the spacecraft, overseeing the upload of instructions, and analyzing spacecraft telemetry to ensure successful execution of the experiments. I worked on this before, during, and after the Voyager 2 encounter with the planet Neptune.

7. From 1990 to 1992, I was employed by Northrop Defense Systems Division. My position was Senior Engineer for Airborne Electronic Countermeasures of the Digital Systems Group. During my time there, I was responsible for developing, integrating, and maintain software for electronic radar countermeasures systems. In particular, I worked on the Receiver-Transmitter Compatibility Feature, which was responsible for ensuring the independence of radar sensing and "jamming."

8. From 1996 to 2011, I was a Research Professor in the Department of Computer Science at the University of North Carolina at Chapel Hill. Within that time period I also held a position in Applied & Materials Sciences. From 1996 to 1998 I served as the UNC Site Coordinator for the National Science Foundation (NSF) Graphics and Visualization Center, a center comprised of the University of North Carolina at Chapel Hill, Brown University, the California Institute of Technology, Cornell University, and the University of Utah. I also served on the board of directors of HiBall Tracker Inc. (Chapel Hill, NC) from approximately 1999-2009.

9. Since 2011 through the present, I have been employed by the University of Central Florida. In various years, I have served as faculty for the Interactive Computing Experiences Research Cluster; the Modeling & Simulation Graduate Program; and the Graduate Certificate in Mixed Reality Engineering. I am currently a Professor and the AdventHealth Endowed Chair in Healthcare Simulation with appointments in the College of Nursing, the Department of Computer Science (College of Engineering and Computer Science), and the Institute for Simulation & Training (School of Modeling, Simulation, and Training).

10. I have taught courses on software engineering and programming, virtual worlds and 3D computer modeling and animation, and computer animation. Other tutorials and short courses I have presented include courses on an introduction

to virtual reality, tracking, and the Kalman filter. I have also advised both undergraduate and graduate students in various areas relating to augmented and virtual reality, including displays of such environments and tracking within such environments.

11. Virtual reality (VR) and Augmented Reality (AR) have been my primary areas of research in general since the early 1990s, with human motion tracking being a particular focus, including as the subject of my PhD research. I have co-developed many systems and methods for tracking and motion capture. For example, the HiBall Tracking System that I co-developed in the 1990s was the fastest (with lowest latency), most accurate, and widest area tracking system ever developed. *See e.g.*, G. Welch, G. Bishop, L. Vicci, S. Brumback, K. Keller, and D. Colucci. The HiBall Tracker: High-Performance Wide-Area Tracking for Virtual and Augmented Environments. In Proceedings of the ACM Symposium on Virtual Reality Software and Technology (VRST), pages 1–11. Association of Computing Machinery, ACM Press, Addison-Wesley Publishing Company, December 1999. *See also e.g.,* G. Welch, G. Bishop, L. Vicci, S. Brumback, K. Keller, and D. Colucci. High-Performance Wide-Area Optical Tracking: The HiBall Tracking System. Presence: Teleoperators and Virtual Environments, 10(1):1–21, 2001. I have also developed novel methods for tracking heads, hands, and devices relative to each other. G. Welch, T. Wang, G. Bishop, and G. Bruder. A Novel Approach

for Cooperative Motion Capture (COMOCAP). In G. Bruder, S. Cobb, and S. Yoshimoto, editors, ICAT-EGVE 2018 - International Conference on Artificial Reality and Telexistence and Eurographics Symposium on Virtual Environments, Limassol, Cyprus, November 7–9 2018. The Eurographics Association. I am also the first named inventor on a related patent, U.S. Patent No. 11,042,028, and a first named or co-inventor 21 other patents. I have written surveys and book chapters on tracking. *See*, *e.g.*, G. Welch and E. Foxlin. Motion Tracking: No Silver Bullet, But a Respectable Arsenal. IEEE Computer Graphics and Applications, 22(6):24–38, 2002; G. Welch and L. Davis (Ex.1135, Welch, "*No Silver Bullet*"). Tracking for Training in Virtual Environments: Estimating the Pose of People and Devices for Simulation and Assessment. In J. Cohn, D. Nicholson, and D. Schmorrow, editors, The PSI Handbook of Virtual Environments for Training and Education: Developments for the Military and Beyond, Chapter 30. Praeger Security International, November 30, 2008.

12. I have been an independent consultant on human-computer interaction, virtual and augmented reality, position and motion estimation, sensor fusion, handheld devices, and related technology.

13. As an inventor, I have been awarded 22 domestic patents, with several others in prosecution. The subject matter of these patents primarily include virtual telepresence, virtual and augmented reality displays, pose data and tracking.

14. I also have authored or contributed to over 200 publications, posters, and presentations. Over the course of my academic and professional career, I have received a number of awards and research grants. I am a Fellow of the Institute of Electrical and Electronics Engineers (IEEE), a Fellow of the National Academy of Inventors (NAI), and have been designated an Association for Computing Machinery (ACM) SIGGRAPH Pioneer. Among other honors I have received, at the 15th IEEE International Symposium on Mixed and Augmented Reality (ISMAR 2016), I received the Long Lasting Impact Paper Award for a pair of 1998 papers on "Spatial Augmented Reality" (SAR), with co-authors Professor Ramesh Raskar, Professor Henry Fuchs, and Deepak Bandyopadhyay. At the 25th IEEE Conference on Virtual Reality and 3D User Interfaces (VR 2018), I received the VR Technical Achievement Award for "contributions to human motion tracking and to mixed reality applications in medicine and training." During the 28th IEEE Virtual Reality Conference (VR 2022), I was inducted into the inaugural class of the IEEE Visualization and Graphics Technical Committee's (VGTC) Virtual Reality Academy.

II. Summary Of Materials Reviewed And Considered

15. All of the opinions contained in this Declaration are based on the documents I reviewed and my knowledge and professional judgment. In forming

the opinions expressed in this Declaration, while drawing on my experience, I reviewed the following documents:

Ex.	Description
1001	U.S. Patent No. 10,917,737 ("'737 patent")
1005	U.S. Patent No. 9,851,786 ("Pedrotti")
1006	U.S. Patent No. 8,520,872 ("Jang")
1007	Durand R. Begault, *3-D Sound for Virtual Reality and Multimedia*, NASA/TM-2000-209606 (Aug. 2000) ("Begault")
1008	U.S. Patent No. 9,041,622 ("McCulloch")
1009	U.S. Patent No. 8,767,968 ("Flaks")
1012	International Patent Publication No. WO 2016/064435 ("Fei")
1013	U.S. Patent No. 8,884,984 ("Flaks 984")
1014	U.S. Patent No. 5,900,849 ("Gallery")
1015	U.S. Patent Application Publication No. 2007/0173265 ("Gum")
1016	U.S. Patent No. 2,955,156 ("Heilig")
1017	U.S. Patent No. 9,544,706 ("Hirst")
1018	U.S. Patent No. 10,095,031 ("Katz")
1019	U.S. Patent No. 7,330,197 ("Kobayashi")
1020	U.S. Patent No. 9,884,248 ("Koseki")
1021	U.S. Patent Application Publication No. 2015/0119130 ("Lovitt")
1022	U.S. Provisional Patent Application No. 62/289085 ("Mangiat")
1023	U.S. Provisional Patent Application No. 62/309882 ("Marks")
1024	U.S. Provisional Patent Application No. 62/340110 ("Martin")
1025	U.S. Patent Application Publication No. 2015/0302652 ("Miller 652")
1026	U.S. Patent No. 10,509,466 ("Miller 466")
1027	U.S. Patent Application No. 13/288350 ("Mount 350")
1028	U.S. Patent Application Publication No. 2013/0141421 ("Mount 421")
1029	U.S. Patent No. 9,703,369 ("Mullen")

1030	U.S. Patent No. 9,767,618 ("Najaf-Zadeh")
1031	U.S. Patent No. 9,037,468 ("Osman")
1032	U.S. Patent No. 10,162,177 ("Pedrotti 177")
1033	U.S. Patent No. 9,674,507 ("Pirchheim")
1034	U.S. Patent No. 9,367,811 ("Ramachandran")
1035	U.S. Patent No. 10,070,239 ("Romigh")
1036	U.S. Patent Application Publication No. 2016/0124502 ("Sawyer")
1037	U.S. Patent No. 9,301,069 ("Seligmann")
1038	U.S. Patent No. 9,787,846 ("Srinivasan")
1040	U.S. Patent No. 10,114,465 ("Wan")
1041	U.S. Patent No. 8,419,545 ("Yen")
1042	U.S. Patent Application Publication No. 2012/0183161 ("Agevik")
1043	U.S. Patent Application Publication No. 2017/0115488 ("Ambrus")
1044	U.S. Patent No. 7,710,654 ("Ashkenazi")
1045	U.S. Patent Application Publication No. 2016/0292924 ("Balanchandreswaran")
1046	V.R. Algazi et al., *The CIPIC HRTF Database*, IEEE Workshop on Applications of Signal Processing to Audio and Acoustics 99-102 (2001) ("Algazi")
1047	ASME International, *The Link Flight Trainer, A Historic Mechanical Engineering Landmark* (June 2000)
1048	Mark Billinghurst et al., *A Wearable Spatial Conferencing Space*, IEEE (1998) ("Billinghurst 1998")
1049	Mark Billinghurst et al., *A Survey of Augmented Reality*, 8 Foundations and Trends in Human-Computer Interactions 73-272 (2015) ("Billinghurst 2015")
1050	Douglas S. Brungart, *Near-Field Virtual Audio Displays*, IMAGE 2000 Conf., Scottsdale, Ariz., July 10-14, 2000 ("Brungart")
1051	Anil Çamci et al., *Interactive Virtual Soundscapes: A Research Report*, ICMC 2015, Sept. 25-Oct. 1, 2015 ("Çamci")
1052	Michael Cohen, *Integrating Graphic and Audio Windows*, 1 Presence

	468-81 (Fall 1992) ("Cohen 1992")
1053	Michael Cohen, *Throwing, Pitching and Catching Sound: Audio Windowing Models and Modes*, 39 Int. J. Man – Machine Studies 269-304 (1993) ("Cohen 1993")
1054	John David N. Dionisio et al., *3D Virtual Worlds and the Metaverse: Current Status and Future Possibilities*, 45 ACM Computing Surveys 34 (June 2013)
1055	Steve DiPaola & David Collins, *A 3D Virtual Environment for Social Telepresence*, W. Comput. Graphics Symp., Mar. 24-27, 2002
1056	Kai-Uwe Doerr et al., *Evaluation of a Low-Cost 3D Sound System for Immersive Virtual Reality Training Systems*, 13 IEEE Transactions on Visualization & Comput. Graphics 204-12 (2007)
1057	Thomas Erickson et al., *Synchronous Interaction Among Hundreds: An Evaluation of a Conference in an Avatar-based Virtual Environment*, CHI 2001 Session: Meetings & Interaction Spaces, May 7-12, 2011 ("Erickson")
1058	Oli Welsch, *Oculus Touch Is the Gold Standard in VR Control*, (June 24, 2015) https://www.eurogamer.net/oculus-touch-is-the-gold-standard-in-vr-control
1059	Foster, Cornell Univ. (SP2012), Lecture 25 Memory and Locality, https://www.cs.cornell.edu/courses/cs3110/2012sp/lectures/lec25-locality/lec25.html ("Foster")
1060	Nathan Martz, *Spatial Audio Comes to the Cardboard SDK*, Google Developers Blog (Jan. 13, 2016) https://developers.googleblog.com/2016/01/spatial-audio-comes-to-cardboard-sdk.html
1061	John L. Hennessy & David A. Patterson, *Computer Architecture, A Quantitative Approach* (5th ed. 2012) ("Hennessy") (excerpts)
1062	M.P. Hollier et al., *Spatial Audio Technology for Telepresence*, 15 BT Tech. J. 33-41 (Oct. 1997)
1063	Jason Jerald, *The VR Book: Perception and Interaction Design for Virtual Reality* (2015) ("The VR Book")
1064	Jiménez, TAMU Lecture 7: Caches, https://people.engr.tamu.edu/djimenez/taco/utsa-www/cs5513-fall07/lecture7.html (last visited Apr. 18, 2023)

1065	Are you Talking to Me? | Job Simulator Wikia |Fandom, https://jobsimulator.fandom.com/wiki/Are_You_Talking_to_Me%3F (last visited Apr. 4, 2023)
1066	Dean F. Kocian, *A Visually-Coupled Airborne Systems Simulator (VCASS) – An Approach to Visual Simulation*, Report No. AMRL-TR-77-31 (1977)
1067	Julian Löhr, *OpenAL-MOB With OpenFrameworks on Android* (Dec. 18, 2014), https://www.julianloehr.de/tag/ndk
1068	Bruce D. Lucas & Takeo Kanade, *An Iterative Image Registration Technique with an Application to Stereo Vision*, Proc 7th Intl Joint Conf on Artificial Intelligence (IJCAI) 674-79 (Aug. 24-28, 1981)
1069	David McGrath, *Huron – A Digital Audio Convolution Workstation*, 5th Australian Regional Convention 1-7 (Apr. 26-28, 1995) ("McGrath")
1070	Timoni West, *UX Pointers for VR Design* (Nov. 10, 2015), https://medium.com/@timoni/ux-pointers-for-vr-design-dd52b718e19
1071	Todd Holmdahl, *BUILD 2015: A Closer Look at the Microsoft HoloLens Hardware*, Microsoft Blog (Apr. 30, 2015) https://blogs.windows.com/devices/2015/04/30/build-2015-a-closer-look-at-the-microsoft-hololens-hardware/ ("Microsoft, *BUILD 2015*")
1072	Microsoft, Overview, *Spatial Audio*, Microsoft (Dec. 1, 2015)
1073	NSA, *Virtual Reality*, DOCID: 3929132 (1992)
1074	Xueni Pan et al., *Virtual Character Personality Influences Participant Attitudes and Behavior – An Interview with a Virtual Human Character about Her Social Anxiety*, 2 Frontiers in Robots & AI Article 1 (Feb. 2015)
1075	Tony Parisi, *Learning Virtual Reality: Developing Immersive Experiences and Applications for Desktop, Web and Mobile* (2016) ("Parisi")
1076	Randy Pausch et al., *Disney's Aladdin: First Steps Toward Storytelling in Virtual Reality*, ACM 193-205 (1996) ("Pausch")
1077	Tabitha C. Peck et al., *An Evaluation of Navigational Ability Comparing Redirected Free Exploration with Distractors to Walking-in-Place and Joystick Locomotion Interfaces*, Proc IEEE Virtual Real

	Conf. 55-62 (Mar. 19, 2011) ("Peck")
1078	Glenn Chapman, *Google Glass Available in US as of April 15*, Phys.Org (Apr. 10, 2014) https://phys.org/news/2014-04-google-glass-april.html
1079	Lars Klint, *Holographic Programming: A HoloLens How-To in a Mixed Reality World*, PluralSight (May 2016)
1080	Spanner Spencer, *Sixense Picks Up CES Awards for Virtual Reality Controller* (Jan. 13, 2015) http://www.pocketgamer.biz/news/60642/sixense-picks-up-ces-awards-for-virtual-reality-controller
1081	Qualcomm, *What's So Special About the Digital Signal Processor?*, Qualcomm OnQ Blog (Dec. 5, 2013)
1082	Francisco Cheng, *Mobile Processors 101: Why Smartphones are Smarter with an All-In-One Processor*, Qualcomm OnQ Blog (June 12, 2013)
1083	RAF Museum, *Flight Simulation and Synthetic Trainers*, https://www.rafmuseum.org.uk/research/online-exhibitions/taking-flight/historical-periods/flight-simulation-and-synthetic-trainers/ (last visited Apr. 4, 2023)
1084	VisiSonics Corp., *Manual for VisiSonics' RealSpace3D Audio Unity Plugin* (Nov. 17, 2015)
1085	Paul James, *Watch Halo Played on Microsoft HoloLens in Augmented Reality*, RoadtoVR (Dec. 7, 2015), https://www.roadtovr.com/watch-halo-played-on-microsoft-hololens-in-augmented-reality/
1086	Paul James, *Samsung Gear VR Gets Positional Tracking Via Sixense STEM, Announced at SFVR (Video)*, RoadtoVR (Nov. 8, 2014), https://www.roadtovr.com/samsunng-gear-vr-gets-positional-tracking-via-stem-demod-sfvr-video/
1087	Warren Robinett & Richard Holloway, *The Visual Display Transformation for Virtual Reality*, 4 Presence 1-23 (1995)
1088	Eric E. Sabelman & Roger Lam, *The Real-Life Dangers of Augmented Reality*, North American, Spectrum.ieee.org (July 2015) ("Sabelman")
1089	*Using the Oculus Rift with Second Life*, Linden Labs Blog (May 21, 2014), http://community.secondlife.com/blogs/entry/1275-using-the-oculus-rift-with-second-life/

1090	Jianbo Shi and Carlo Tomasi, *Good Features to Track*, IEEE Conf. on Comput. Vision & Pattern Recognition (CVPR94) (June 1994) ("Shi")
1091	M. Slater et al., *Acting in Virtual Reality*, ACM 103-10 (2000) ("Slater")
1092	*Characteristics of Flight Simulator Visual Systems*, NASA Technical Memorandum 81278 (Irving C. Statler ed., 1981)
1093	Ivan E. Sutherland, *A Head-Mounted Three Dimensional Display*, Fall Joint Comput. Conf. 757-764 (1968) ("Sutherland 1968")
1094	Frederic Lardinois, *HoloLens Hands-On: How We Built An App For Microsoft's Augmented Reality Headset*, TechCrunch (May 2015)
1095	Stuart Dredge, *Virtual World Second life to Be Reincarnated, with Oculus Rift*, The Guardian (June 24, 2014) https://www.theguardian.com/technology/2014/jun/24/second-life-oculus-rift-virtual-world
1096	Unity Manual: Audio Spatializer SDK (2020), https://docs.unity.cn/530/Documentation/Manual/AudioSpatializerSDK.html
1097	Ian Hamilton, *In a Cartoon World, Holojam Shows Participants a Slice of Space-Time*, Upload VR (Aug. 4, 2015), https://www.uploadvr.com/holojam-shows-participants-slice-space-time/
1098	Joe Durbin, *Google Cardboard Now Offers Spatial Audio*, UploadVR (Jan. 15, 2016)
1099	Dean Takahashi, *Second Life Creator Linden Lab Starts Testing Its Virtual-Reality World: Project Sansar*, Venture Beat (Aug. 18, 2015), https://venturebeat.com/games/linden-lab-starts-testing-its-virtual-reality-world-projet-sansar/
1100	Dean Takahashi, *Unreal Engine's Latest Innovation Is About Building Games While Inside Virtual Reality*, Venture Beat (Feb. 4, 2016), https://venturebeat.com/games/epic-games-lets-you-design-your-game-inside-vr-with-new-edition-of-unreal-engine-editor
1101	Dean Takahashi, *Final Approach Is an HTC Vive VR Game that Turns You into a Kid Playing with Toy Airplanes*, Venture Beat (Jan. 29, 2016), https://venturebeat.com/games/final-approach-is-an-htc-vive-vr-game-that-turns-you-into-a-kid-playing-with-toys

1102	Dean Takahashi, *Valve's Virtual Reality Apps with the HTC Vive Headset Won't Make You Seasick*, Venture Beat (May 2, 2015), https://venturebeat.com/games/valves-virtual-reality-apps-with-the-htc-vive-headset-wont-make-you-seasick/
1103	Greg Welch et al., *High Performance Wide-Area Optical Tracking: The HiBall Tracking System*, 10 Presence: Teleoperators and Virtual Environments 1-22 (Feb. 2001) ("Welch 2001")
1104	Elizabeth M. Wenzel et al., *A Virtual Display System for Conveying Three-Dimensional Acoustic Information*, Proc. Hum. Factors Soc'y – 32nd Ann. Meeting (1988) ("Wenzel 1988a")
1105	Elizabeth M. Wenzel et al., *Development of a Three-Dimensional Auditory Display System*, 20 SIGCHI Bull. 52-57 (Oct. 1988) ("Wenzel 1988b")
1106	Elizabeth M. Wenzel et al., *Localization with Non-Individualized Virtual Acoustic Display Cues*, ACM (1991) ("Wenzel 1991")
1107	Zhiying Zhou, *An Experimental Study on the Role of Software Synthesized 3D Sound in Augmented Reality Environments*, 16 Interacting with Computers 989-1016 (2004) ("Zhou")
1108	Wikipedia, *Job Simulator* https://en.wikipedia.com/wiki/Job_Simulator
1109	Cardboard Unity (2015), https://github.com/jkammerl/cardboard-unity/blob/master/Cardboard/Editor/CardboardAudioSourceEditor.cs
1110	Aurale R. DeRuyck & Jack Kuipers, *An Electromagnetic Position Sensor*, Report No. AFAL-TR-73-281 (Nov. 30, 1973)
1111	Dmitry N. Zotkin et al., *Rendering Localized Spatial Audio in a Virtual Auditory Space*, 6 IEEE Transactions on Multimedia 553-64 (Aug. 2004) ("Zotkin")
1112	Ronald T. Azuma, *A Survey of Augmented Reality*, 6 Presence 355-85 (1997)
1113	Gary Bishop & Henry Fuchs, *The Self-Tracker: A Smart Optical Sensor on Silicon*, 1984 Conf. on Advanced Rsch. in VLSI 65-73 (Jan. 23, 1984) ("Bishop")
1114	Mark R. Mine, *Working in a Virtual World: Interaction Techniques Used in the Chapel Hill Immersive Modeling Program*, TR96-029,

	Univ. N.C. (August 1, 1996) ("Mine 1996")
1115	Mark R. Mine, *ISAAC: A Meta-CAD System for Virtual Environments*, 29 Computer-Aided Design 547-53 (1997) ("Mine ISAAC 1997")
1116	Mark Raymond Mine, *Exploiting Proprioception in Virtual-Environment Interaction* (1997) (Ph.D. dissertation, Univ. N.C.) ("Mine Exploiting Proprioception 1997")
1117	Adrienne Vincent-Phoenix, *Step into the DISH – A Visit to Imagineering's Digital Immersive Showroom*, MousePlanet (June 5, 2012), https://mouseplanet.com/9994/Step_into_the_DISH_a_visit_to_Imaginerrings_Digital_Immersive_Showroom
1118	Ian Hamilton, *How They Did It: Cars Land's Virtual Reality*, Orange Cnty. Reg., June 25, 2012, https://www.ocregister.com/2012/06/25/how-they-did-it-cars-lands-virtual-reality/
1119	Gregory F. Welch, *Hybrid Self-Tracker: An Inertial/Optical Hybrid Three-Dimensional Tracking System* (1995) (dissertation proposal Univ. N.C.) ("Welch 1995")
1120	Steven M. Kaplan, *Wiley Electrical and Electronics Engineering Dictionary* 71 (2004)
1121	Plaintiff's Infringement Contentions, Exhibit 16, *Eight Khz, LLC v. Meta Platforms, Inc*., No. 6:22-cv-00575 (W.D. Tex. Mar. 3, 2023)
1122	Amended Complaint for Patent Infringement and Demand for Jury Trial, *Eight Khz, LLC v. Meta Platforms, Inc*., No. 6:22-cv-00575-ADA, (W.D. Tex. Oct. 10, 2022)
1123	Mark Billinghurst et al., *The MagicBook – Moving Seamlessly Between Reality and Virtuality*, IEEE Computer Graphics and Applications, 6-8 (2001) ("Billinghurst 2001")
1124	Jaka Sodnik &Sašo Tomažič, *Spatial Auditory Human-Computer Interfaces*, Springer Briefs Comput. Sci. (2015) ("Sodnik")
1125	U.S. Patent No. 9,392,212 ("Ross")
1131	U.S. Patent No. 5,173,944 ("Begault 944")
1132	U.S. Patent No. 5,438, 623 ("Begault 623")
1133	Karl-Petter Akesson & Kristian Simsarian, *Reality Portals*, ACM

	(1999)
1134	Mark Mine, *Towards Virtual Reality for the Masses: 10 Years of Research at Disney's VR Studio*, Eurographics Ass'n (2003) ("Mine 2003")
1135	Greg Welch & Eric Foxlin, *Motion Tracking: No Silver Bullet, but a Respectable Arsenal*, IEEE Computer Graphics and Applications 24-28 (2002) ("Welch, *No Silver Bullet*")
1137	Dave Smith, *Three-Dimensional Audio Makes Virtual Reality So Much Better It's Crazy*, BUSINESS INSIDER (Apr. 3, 2015, 1:06PM), https://www.businessinsider.com/virtual-reality-the-importance-of-3d-positional-audio-2015-4
1138	Mona Lalwani, *Surrounded by Sound: How 3D Audio Hacks Your Brain*, THE VERGE (Feb. 12, 2015, 10:30AM), https://www.theverge.com/2015/2/12/8021733/3d-audio-3dio-binaural-immersive-vr-sound-times-square-new-york
1139	Ben Kuchera, *Google Cardboard Adds 'Inexpensive' Spatial Audio to Its SDK*, POLYGON (Jan. 13, 2016, 12:00PM EST)
1140	Sutherland, *Sketchpad: A Man-Machine Graphical Communication System*, Thesis, Massachusetts Institute of Technology (1963) ("Sutherland 1963")

16. My opinions are additionally guided by my appreciation of how a person of ordinary skill in the art would have understood the claims of the '737 patent at the time of the alleged invention, which I have been asked to assume is June 10, 2016.

III. Legal Understandings

17. I am not an attorney. However, I have been informed by counsel of certain legal standards and have applied those standards, described below, in formulating my opinions.

18. I understand that the claims of a patent define the limits of the patentee's exclusive rights. I understand that to determine the scope of the claimed invention, courts may construe claim terms, the meaning of which the parties may dispute. I understand that claim terms should generally be given their ordinary and customary meaning as understood by a person of ordinary skill in the art at the time of filing of the patent application.

19. I understand that claims must be construed in light of and consistent with the intrinsic evidence. In this context, I understand that intrinsic evidence includes the claims themselves, the written disclosure in the specification, and the patent's prosecution history, including prior art that was considered by the United States Patent and Trademark Office. I understand that the specification is always highly relevant to the claim construction analysis and often is the single best guide to the meaning of a disputed term. I understand that extrinsic evidence may also be considered when construing claims and may include, for example, technical dictionaries, technical publications and books, treatises, and expert testimony, though the intrinsic record will be more persuasive as to the meaning of a particular term.

20. I understand that a prior art reference can render a patent claim obvious to a person of ordinary skill in the art if the differences between the subject matter set forth in the patent claim and the prior art are such that the subject matter of the

claim would have been obvious at the time the claimed invention was made. In analyzing obviousness, I understand that it is important to consider the scope of the claims, the level of skill of a person of ordinary skill in the relevant art, the scope and content of the prior art, the differences between the prior art and the claims, and so-called 'secondary considerations' of non-obviousness.

21. I understand that the claimed subject matter is obvious when a person of ordinary skill in the art would have been motivated to combine pre-existing elements and that combination yields no more than what a person of ordinary skill in the art would have expected. I also understand that in assessing whether a claim is obvious, one must consider whether the claimed improvement is more than the predictable use of prior art elements according to their established functions. I understand that there need not be a precise teaching in the prior art directed to the specific subject matter of a claim because one can take account of the inferences and creative steps that a person of ordinary skill in the art would employ.

22. I understand that obviousness cannot be based on the hindsight combination of components selectively culled from the prior art. I understand that in an obviousness analysis, neither the motivation nor the avowed purpose of inventors controls the inquiry. Any need or problem known in the field at the time of the invention and addressed by the patent can provide a reason for combining elements. For example, I understand that it is important to consider whether there

existed at the time of the invention a known problem for which there was an obvious solution encompassed by the patent's claims. I understand that known techniques can have obvious uses beyond their primary purposes, and that in many cases a person of ordinary skill in the art can fit the teachings of multiple pieces of prior art together.

23. I understand that certain issues relating to validity must be judged from the perspective of a person of ordinary skill in the art. I further understand that factors that may be considered in determining the level of skill of a person of ordinary skill in the art include, but are not limited to, (1) the type of problems encountered in the art; (2) prior art solutions to those problems; (3) rapidity with which innovations are made; (4) sophistication of the technology; and (5) the educational level of active workers in the field.

24. I have been informed and understand that a person of ordinary skill in the art is a hypothetical person who is presumed to be aware of all pertinent prior art, thinks along conventional wisdom in the art, and is a person of ordinary creativity. Importantly, this hypothetical person is of ordinary skill in the art to which the claimed subject matter pertains.

25. I understand that, when there is a reason to solve a problem and there are a finite number of identified, predictable solutions, a person of ordinary skill in the art has good reason to pursue the known options within his or her technical grasp.

I further understand that, if this leads to the anticipated success, it is likely the product not of innovation but of ordinary skill and common sense, which bears on whether the claim would have been obvious.

26. I understand that secondary considerations of nonobviousness can include, for example, evidence of commercial success of the invention, evidence of a long-felt need that was solved by an invention, evidence that others copied an invention, or evidence that an invention achieved an unexpected result. I further understand that such evidence must have a nexus, or causal relationship to the elements of a claim, in order to be relevant.

IV. The ’737 Patent

27. The ’737 patent is entitled “Defining a Zone with a HPED and Providing Binaural Sound in the Zone.” ’737 patent (Ex.1001) at Title. I understand that the ’737 patent is assigned to Eight kHz LLC (“8K”).

28. The ’737 patent is directed to assigning sounds “to different zones or different sound localization points (SLPs)”—i.e., “location[s] where a listener localizes sound”—“so sounds localize as binaural sound into the assigned zone or to the assigned SLP.” ’737 patent (Ex.1001) at Title, 1:22-27 (Summary), 66:23-24 (defining SLP as quoted). For example, “[t]elephony software applications are assigned to zone A; a voice of an intelligent personal assistant (IPA) of the listener

is assigned to zone B; and music and/or musical instruments are assigned to zone C." '737 patent (Ex.1001) at 11:12-17.

29. The '737 patent explains that "[t]hese designations assist the listener in organizing different sounds and software applications and reduces confusion that can occur when different sounds from different software applications externally localize to varied locations, overlapping locations, or locations that are not known in advance to the listener." '737 patent (Ex.1001) at 11:33-38.

30. The '737 patent's Figures 13A-13E "provide example configurations or shapes of zones in 3D space" where SLPs can be designated. '737 patent (Ex.1001) at 46:17-19. For example, Figure 13A "shows a sphere or spherical configuration" where the user's head is located at origin 1310A and the area around the user "can be divided into a plurality of SLPs and/or zones," such as the "two [] zones [] shown at 1320A and 1322A":

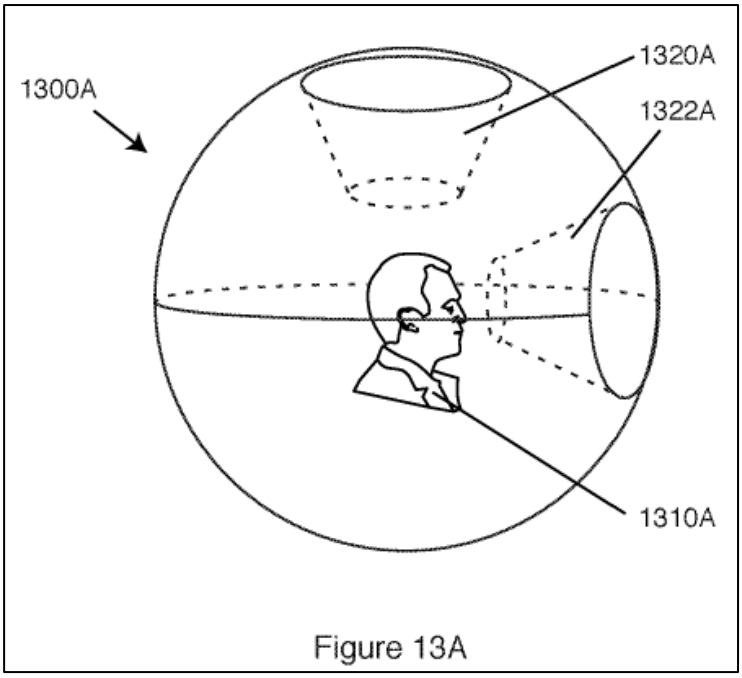


Figure 13A

'737 patent (Ex.1001) at 46:30-38, Fig. 13A.

31. As another example, Figure 13C shows a user's head located at origin 1300C with zones 1320C, 1322C, and 1324C:

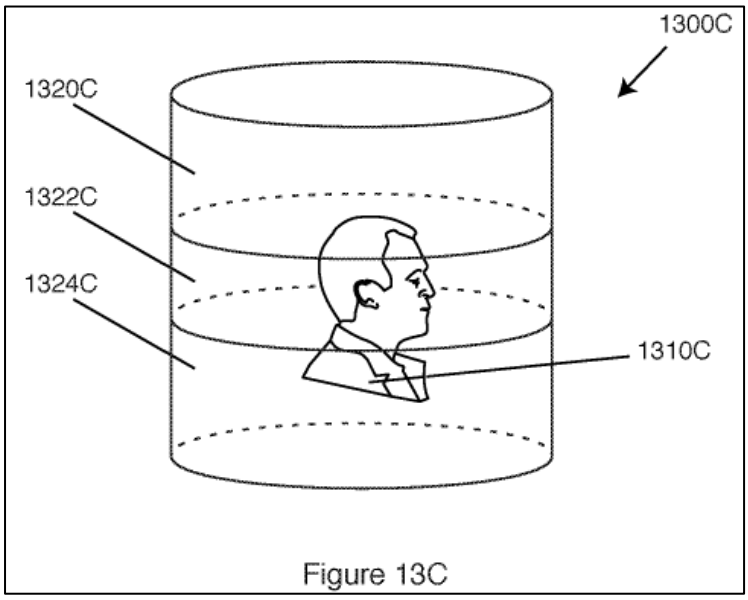


Figure 13C

'737 patent (Ex.1001) at 47:1-18, Fig. 13C.

32. As another example, Figure 13E shows a user's head located at an origin 1310E surrounded by "a cube-shaped zone 1320E," "a cube-shaped zone 1322E," "a curved planar zone 1324E," "a planar zone 1326E," and "a planar zone 1328E":

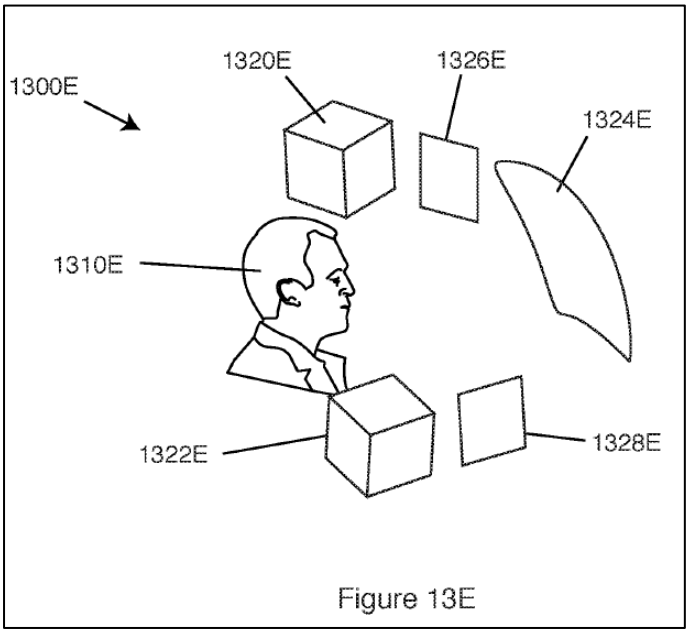


Figure 13E

'737 patent (Ex.1001) at 47:29-40, Fig. 13E.

33. The '737 patent provides that binaural sound externally localizes to designated SLPs in such zones when "a digital signal processor (DSP) or other processor convolves and/or processes the sound." '737 patent (Ex.1001) at 24:1-4; *see also* '737 patent (Ex.1001) at 39:3-45, 39:46-63, 40:7-30.

V. Level Of Ordinary Skill In The Art And Perspective Applied In This Declaration

34. I understand that certain issues relating to validity must be judged from the perspective of a person of ordinary skill in the relevant art.

35. With respect to the ’737 patent, a person of ordinary skill in the art at the time of the earliest claimed priority date, June 10, 2016, would have been familiar with the development and implementation of virtual and/or augmented reality systems, and underlying technology used therein.

36. A person of ordinary skill in the art would have had a bachelor’s degree in computer science/engineering, or a related field, and at least two years of industry experience or academic research experience in virtual/augmented reality, including visual and audio modeling and rendering. In my view, more education can supplement relevant experience and vice versa.

37. At the time of the earliest claimed priority date for the ’737 patent (June 10, 2016), I met the qualifications to be a person of ordinary skill in the art.

38. I also believe that I have a sufficient level of knowledge, experience, and education to provide expert opinions in the field of the ’737 patent.

39. While my own level of skill exceeded that of the ordinary level of skill as of June 2016, I am well-acquainted with the actual performance and capabilities of a person of ordinary skill in the art as defined above. For example, during the relevant timeframe, I was supervising and evaluating the performance of such individuals, such as my graduate students who were performing research in this area. Furthermore, my participation in professional organizations and in workshops and

events exposes me to the state of the industry and the level of experience of individuals who, like I did, had at least the ordinary level of skill.

40. In forming and expressing my opinions in this declaration, I have applied the perspective of a person of ordinary skill in the art, as of June 2016. Unless otherwise stated, my opinions refer to the knowledge of one of ordinary skill in the art at the relevant time.

VI. Claim Construction

41. In my analysis, I have applied the plain and ordinary meanings of the claim terms in the ’737 patent, as a person of ordinary skill in the art would have understood them in the context of that patent in approximately June 2016. In particular, I have been asked to assume that the term “processing, by a digital signal processor (DSP) …” has its plain and ordinary meaning. However, my analysis does not depend on any particular or precise construction of a term, because I did not find that to be necessary to provide my opinions regarding the relationship between the prior art and the claims of the ’737 patent. The opinions that I provide in this declaration would remain true under any reasonable construction of the claim terms in the ’737 patent.

VII. State of the Art

42. In this section, I provide overviews of technologies and prior art pertinent to the ’737 patent and to the state of the art as of the ’737 patent’s earliest

possible priority date of June 10, 2016. In later sections, I address in detail how the prior art discloses and renders obvious the recitations of each limitation in the challenged claims, and the challenged claims as a whole.

43. The prior art references described below and discussions of what was known to a person of ordinary skill in the art provide a general description of the state of the art at the time of the invention, provide additional motivation to modify the primary references evaluated in the grounds of invalidity with the knowledge of a person of ordinary skill in the art or other references cited herein, and provide support for why a person of ordinary skill in the art would have had a reasonable expectation of success in combining the teachings of the references. The additional prior art references identified in this section are exemplary in nature and are included to provide factual support for my opinions.

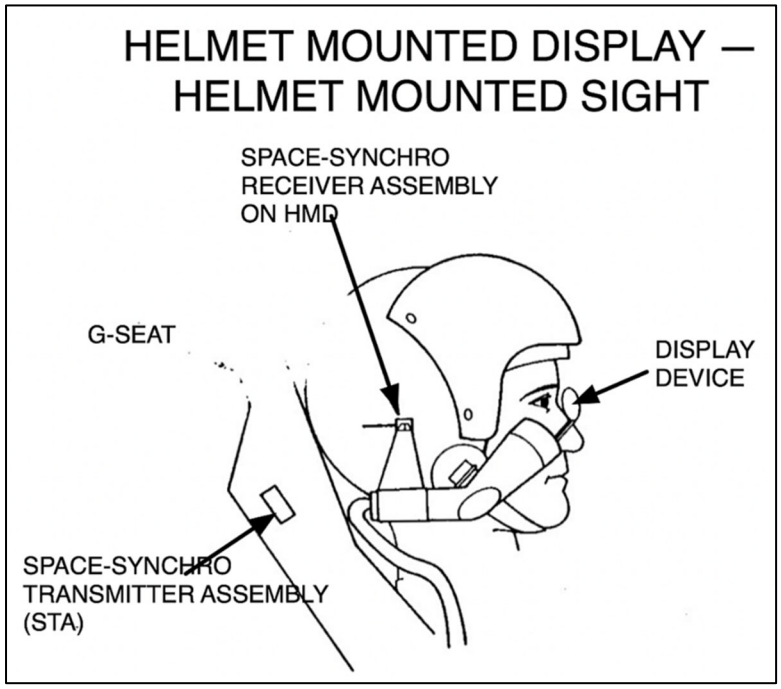
A. Brief History

44. Virtual environments generated by a computer have been around for many decades, long before June 2016. What began as targeted, virtual simulations have grown into more comprehensive virtual "experiences," with the common goal of complete immersivity driving these developments through the 2000s. A brief chronology of these developments is described in this section.

45. Some of the earliest examples of regularly used systems for 3D human-computer interaction for visual simulation were flight simulators.

46. The earliest example of a flight simulator is an electromechanical pilot trainer developed by Edwin Link in 1929. ASME, *The Link Flight Trainer* (June 10, 2000) (Ex.1047) at 2-3. Real-time simulators with digital displays became available in the 1950s to 1960s, when realistic imagery of scenery could be coupled with the motion systems of those simulators. Royal Air Force Museum, *Flight Simulation and Synthetic Trainers* (Ex.1083) at 1-2; Statler, *Characteristics of Flight Simulator Systems* (1981) (Ex.1092) at 64-65 (describing flight simulators that upgraded their CRT displays to digital displays).

47. Looking more narrowly at systems with interactive graphics, around 1966 the Air Force Aerospace Medical Research Laboratory (AFAMRL) began work on the Visually Coupled Airborne System Simulator (VCASS), shown below, one of at least two visually coupled systems being pursued by AFAMRL:



Kocian, *A Visually-Coupled Airborne System Simulator* (1977) (Ex.1066) at Fig. 2.

48. This work gave rise to the development of the Space Synchro (SPASYN) magnetic head-tracking technique by Polhemus Navigation Services, and the Isotrak tracking system, introduced by Polhemus in 1979, which would become the primary means for head tracking in VR for years, which I further discuss in Section VII.D. DeRuyck, *An Electromagnetic Position Sensor* (1973) (Ex.1110) at 9-11, 17-20, Fig. 3.

49. Systems for what we would today call mixed reality (MR), Augmented Reality (AR), and Virtual Reality (VR) also existed for decades before June 2016.

50. A seminal example of such work is that of Ivan Sutherland and his students at the University of Utah in the 1960s, including Sutherland's "head-mounted three dimensional display" paper, which is among the most well-known in the field:

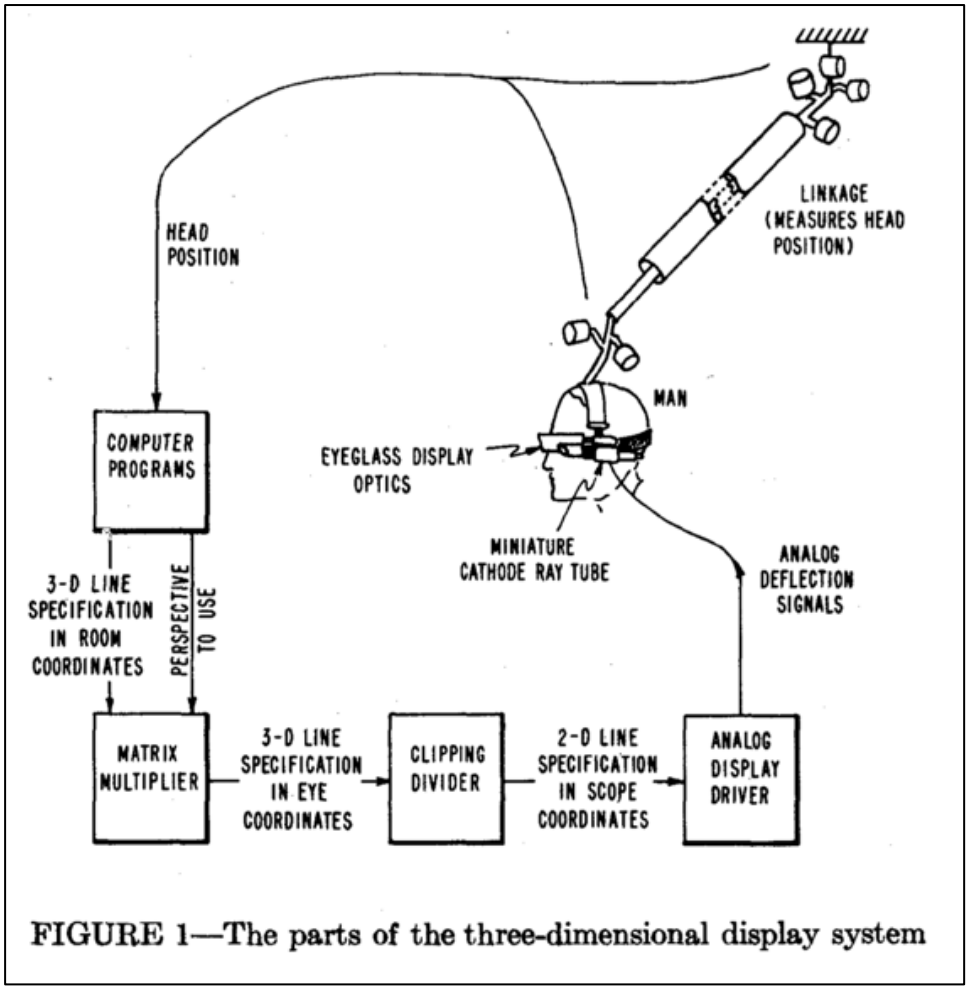


FIGURE 1—The parts of the three-dimensional display system

Sutherland, *A Head-Mounted Three Dimensional Display* (1968) ("Sutherland") (Ex.1093) at Fig. 1 (Sutherland's three-dimensional display system); *see also* Sutherland at Figs. 2-4 (photographs of Sutherland's prototype system, showing for example a custom graphics computer, a head tracking system, and a head-mounted display):

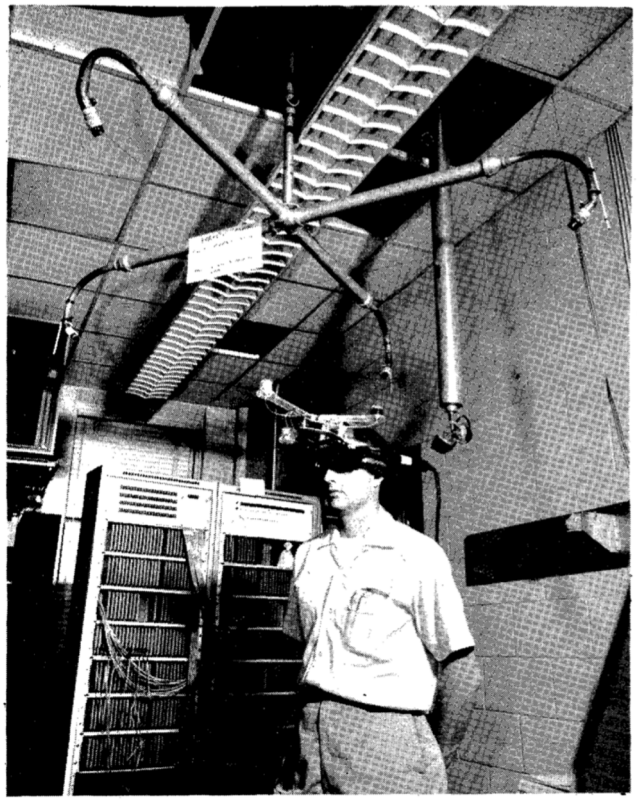


FIGURE 3—The mechanical head position sensor in use



FIGURE 4—The ultrasonic head position sensor in use

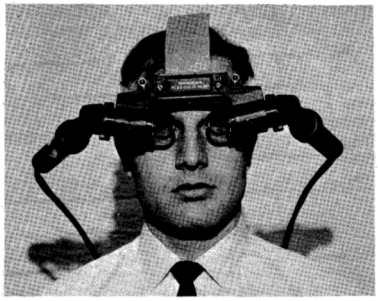


FIGURE 2—The head-mounted display optics with miniature CRT's

51. Sutherland's work offers one of the earliest examples of AR and VR wearable electronic devices for displaying AR and VR environments to users, for tracking users' positions and orientations (the "pose") in a coordinate system corresponding to real, physical space, mathematically transforming pose estimates into a coordinate system corresponding to virtual space, rendering the virtual environment, and displaying it in a head-worn device—i.e., a head-mounted display (or "HMD").

52. Over the years, the systems and methods associated with each of those component areas have steadily evolved into more sophisticated, higher performance,

and more robust versions. *See* Jerald, THE VR BOOK (2015) ("Jerald, THE VR BOOK") (Ex.1063) at Chpt. 2 (providing a general history of VR). In parallel, researchers around the world have been developing sophisticated user interfaces (UI) for navigating virtual environments and interacting with virtual objects and entities.

53. For example, "tracking systems" have evolved from versions requiring relatively significant infrastructure on and around the user, to systems that can estimate a user's pose using only devices worn on the user, and trackable devices with several degrees of freedom. *See* Jerald, THE VR BOOK (Ex.1063) at 307-08 (explaining that six degrees of freedom, or "6DoF" or "6 DoF," systems, for example, "measure full 3D translation (up/down, left/right, forward/backward) and rotation (roll, pitch, and yaw)"), 308 ("VR hand tracking should have a minimum of 6 DoF"). As one example, by the early 1980s, the "Self-Tracker," prototyped at the University of North Carolina, Chapel Hill, provided "[t]racking with an outward view," which "offers the possibility of operating in many different environments, ordinary rooms with ordinary room lights, with little or no overhead of setup." *See* Bishop, *The Self-Tracker: A Smart Optical Sensor on Silicon* (1984) ("Bishop") (Ex.1113) at 67.

54. Similarly, computer graphics systems have evolved from room-sized racks of computers and specialized graphics computers to personal computers with

specialized graphics processors, to battery-operated systems that reside entirely on the user.

55. Driven primarily by the advent of the smartphone—in particular the Apple iPhone in 2007—AR and VR systems became self-contained within single head-worn units that included computers, wireless networking, motion tracking, graphics rendering, and high-resolution displays. Several such examples are discussed below, and in Section VII.B.

56. The gaming industry also fueled significant advances in such features, as well as other technologies that enabled truly immersive and interactive AR and VR experiences.

57. For example, in 2015, Microsoft unveiled its HoloLens HMD and invited developers to create AR applications for it. TechCrunch, *HoloLens Hands-On: How We Built An App For Microsoft's Augmented Reality Headset* (May 1, 2015) (Ex.1094) at 1 ("Microsoft gave developers … a chance to spend some quality time with HoloLens by building our own 'holographic application' using the Unity engine and Visual Studio."). HoloLens was a "self-contained, untethered headset" that rendered "virtual objects into the users view of the real world":



RoadtoVR, *Watch Halo Played on Microsoft HoloLens in Augmented Reality* (Dec. 7, 2015) (Ex.1085) at 1-2.

58. The HoloLens processed head-related transfer functions (or "HRTFs"), which I discuss more below in Section VII.E, to generate "spatial sound so you can hear holograms even when they're behind you." Microsoft, *BUILD 2015: A Closer Look at the Microsoft HoloLens Hardware* (Apr. 30, 2015) ("Microsoft, *BUILD 2015*" Ex.1071) at 4 ("Using a scientific model that characterizes how the human ear receives sound from a specific physical location, HoloLens can synthesize a binaural sound so that you perceive it to come from a specific location in the physical space around you."); Pluralsight, *Holographic Programming: A HoloLens How-To in a Mixed Reality World* (May 27, 2016), *available at* https://www.pluralsight.com/blog/software-development/holographic-programming-hololens (Ex.1079) ("[Y]ou can design sound[s] that indicate direction and proximity to the user, so they will turn towards the sound and interact with the object it is coming from. HoloLens is using Head Related Transfer Function (HRTF), which simulates how human ears hear sound. Four individual speakers

create 3D sound that simulates your 3D holographic world"); Microsoft, *Spatial Audio* (Dec. 1, 2015) (Ex.1072) at 1-2 (discussing Microsoft's work on spatial sound, HRTFs, and specifically "convert[ing] spatial audio research projects to shippable code in various Microsoft products" including "the audio engine in HoloLens"). An inertial measurement unit (IMU) "coupled with head tracking cameras … enable[d] HoloLens to understand where your head is and how it's moving." Microsoft, *BUILD* 2015 (Ex.1071) at 4.

59. Other popular systems available before June 2016 included Samsung's Gear VR (below on left) and Google Cardboard (below on right), both of which ran on a smartphone:





Parisi, LEARNING VIRTUAL REALITY (Nov. 2015) ("Parisi") (Ex.1075) at 19 ("Through a partnership with Samsung, Oculus technology has been incorporated into the Gear VR, a revolutionary headset … with new head-tracking technology, placed in a custom headset that houses a mobile phone with a high-resolution display."), 20 ("In 2014 Google introduced Cardboard VR, which allows users to experience virtual reality using pretty much any mobile phone.").

60. Around late 2014, Samsung Gear VR also enlisted Sixense to advance the positional tracking for its controllers. *See* RoadtoVR, *Samsung Gear VR Gets Positional Tracking Via Sixense STEM* (Nov. 8, 2014) (Ex.1086) at 1; Pocket Gamer, *Sixense picks up CES awards for virtual reality controller* (Jan. 13, 2015) (Ex.1080) at 3 ("very positive responses to [Sixense] demos on Samsung Gear VR").

61. All of these AR and VR systems would have been well-known to persons of ordinary skill in the art. *See* Parisi (Ex.1075) at 141-47 (compiling list of headsets, input devices, software development kits ("SDKs"), other related AR and VR technology, and "noteworthy companies" in its appendix); *see also* Parisi (Ex.1075) at 1 (identifying Unity3D and Unreal as game engines that "have become tools of choice for native VR development").

62. Companies were also pursuing the development of AR and VR software and game engines before June 2016, including the development of tools that people could use to create AR and VR games and other applications.

63. For example, Unity and Unreal were freely available, full-featured VR game engines that were well known before June 2016. *See* Parisi (Ex.1075) at 1 (recognizing "Unity3D and Unreal game engines" as "tools of choice for native VR development").

64. The core components of the Unity and Unreal game engines included a modeling system to create and position virtual objects (including visual components

and sound sources) throughout a three-dimensional virtual scene, a rendering engine for generating 3D graphics, an audio engine for processing sounds, a physics engine that simulated real-world physics, and a user interface (UI) system that allowed users to navigate and interact with virtual environments. And with these pre-built tools, developers could design immersive virtual environments and intuitive ways to interact with them. *See* Parisi (Ex.1075) at 1.

65. Moreover, even before consumer-level AR and VR devices were released, the technologies underlying those devices were extensively described in industry publications, patent applications and publications, and patents, as the following subsections show.

B. Wearable Electronic Devices (WEDs) and Head-Mounted Displays (HMDs)

66. Many variants of head-mounted displays (HMDs), which are wearable electronic devices (WEDs), were well known before June 2016.

67. "Head-mounted displays (HMDs) are the most common visual interface to virtual environments." NSA, *Virtual Reality* (Dec. 1, 2011) ("NSA, *Virtual Reality*") (Ex.1073) at 25. HMDs are also sometimes referred to with other names, such as a head-worn display or a heads-up display, and sometimes provide specificity as to the type of HMD, such as "glasses" or "goggles."

68. The image below depicts some of the many different types of HMDs that were known to persons of ordinary skill in the art before June 2016:

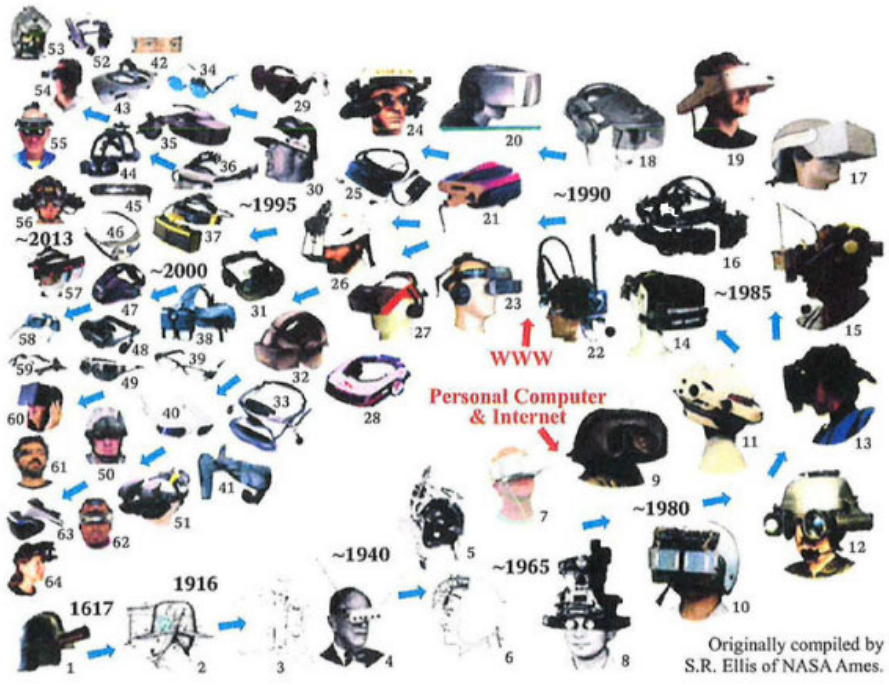
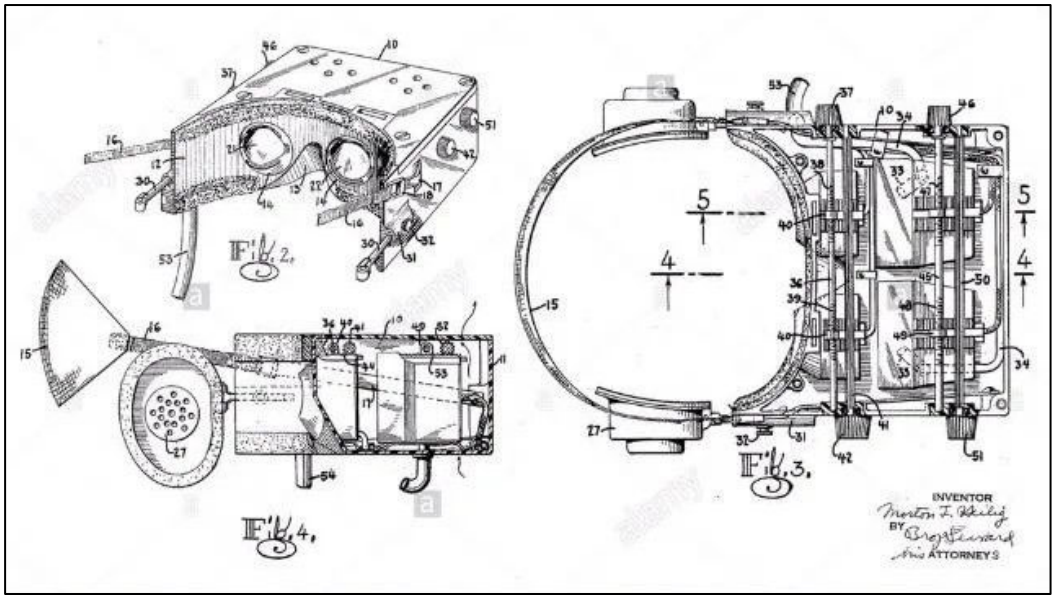


Figure 2.1 **Some head-mounted displays and viewers over time.** (Originally compiled from Ellis (2014))

Jerald, THE VR BOOK (Ex.1063) at Fig. 2.1 (discussing various types of HMDs).

69. HMDs have existed since at least the 1960s, as shown by, for example, the VCASS flight simulator system shown in Figure 2 of Kocian, or the HMD of the Sutherland system shown in Figure 2 of Sutherland, both reproduced in Section VII.A above.

70. Another example of an early HMD comes from a 1960 patent, which taught use of stereo displays to create 3D peripheral images, and stereo and binaural sound played through adjustable earphones:



U.S. Patent No. 2,955,156 ("Heilig") (Ex.1016) at 3:18-21 ("By the independent feeding of right and left eyes with images taken by separate film or TV cameras equipped with wide angle lenses, a truly three dimensional peripheral image is created."), 1:37-40 ("Another object is to provide ear phones which are so designed that the outer ear is completely free and untouched, thus allowing the ear phones to operate fully as sound focusing organs."), 3:14-17, ("the spectator is given a complete sensation of reality, i.e., moving three dimensional images, which may be in color, with 100% peripheral vision, binaural sound, scents and air breezes"), 3:22-25 ("By providing independent ear phones, which are fed separately from sounds recorded by independent microphone systems, excellent stereophonic or binaural sound 1."), Figs. 2-4. I discuss sound localization and binaural sound in further detail in Section VII.E.

71. As I explain further in Sections VII.D and VII.E, many AR and VR systems as of June 2016 comprised head-worn systems that included far more than just displays. They typically included substantial processing units capable of head and hand (controller) tracking and the rendering of view-dependent stereo images and spatialized sound. *See, e.g.*, Jerald, THE VR BOOK (Ex.1063) at 32 ("Position and orientation tracking of HMDs is essential for VR because the display and earphones move with the head.").

C. Handheld Controllers

72. Handheld controllers were commonly known and used as input devices in AR and VR systems before June 2016, and when tracked, were used to allow the user to point at, select, and manipulate virtual objects in virtual environments.

73. "Virtual reality is an attempt to provide an interactive, immersive interface to a synthetic, computer-generated world," and it "provides direct manipulation and control of synthetic objects as well as providing the user with the illusion of immersion." NSA, *Virtual Reality* (Ex.1073) at 46.

74. To enhance user interaction, AR and VR systems commonly used handheld controllers with motion tracking to allow users to interact with virtual objects.

75. "Tracked hand-held controllers [we]re typically 6DoF devices (known as 'wands' in the VR research community where they ha[d] been used for decades."

Jerald, THE VR BOOK (Ex.1063) at 314, 308 ("VR hand tracking should have a minimum of 6 DoF"); Billinghurst, *A Survey of Augmented Reality* (Mar. 2015) ("Billinghurst 2015") (Ex.1049) at 167-69 (describing 6DoF "wand type pointing devices" and "joysticks" that allow users to "point at or manipulate virtual objects"). Such tracked handheld controllers were "easy to use for many 3D tasks due to their natural, direct mapping to hand motion." Jerald, THE VR BOOK (Ex.1063) at 314-15.

76. Tracked handheld controllers, like those shown below, "enhance[] presence through physical touch," "facilitate communication with the virtual world," and "make spatial relationships seem more concrete to the user":



Figure 27.3 **The Sixense STEM (left) and Oculus Touch (right) tracked hand-held controllers.** (Image courtesy of Sixense)

Jerald, THE VR BOOK (EX.1063) at 315 (describing, in 2015, "integrated analog sticks (as on the Sixense STEM and Oculus Touch controllers as shown in Figure 27.3)"), Fig. 27.3.

77. It was well known that handheld controllers were used to allow a user to select and manipulate virtual objects, and to interact with a virtual environment

and virtual characters. Typical controller gestures included pointing or moving the controller to the virtual object, then pressing a button on the controller to select or grab the object, and moving the controller to manipulate (e.g., move, throw, or aim) the object. U.S. Patent No. 8,419,545 ("Yen") (Ex.1041) at 19:67-11:5 (user waves motion controller to cause avatar to wave virtual object); U.S. Patent No. 9,703,369 ("Mullen") (Ex.1029) at 11:18-26 (handheld controller acts as a pointer using a "virtual laser [that] emanates out of [the] controller."), 9:16-24 (user points motion controller to aim virtual gun at virtual objects), 14:26-15:6 (user presses button on motion controller to grab virtual objects and moves motion controller to move them); U.S. Patent No. 10,162,177 ("Pedrotti") (Ex.1032) at 9:26-40 (user grabs virtual weapon by reaching for it with motion controller and "pressing a button on the controller," and then moves the virtual weapon by moving the controller); Mine, *Exploiting Proprioception in Virtual-Environment Interaction* (1997) ("Mine Exploiting Proprioception 1997") (Ex.1116) at 70-71 (describing "[o]bject selection/manipulation where "[u]sers select and manipulate objects with their dominant hand" and "[t]he default form of manipulation is unconstrained 6DoF manipulation"). These are forms of "direct manipulation," which include "pushing an object, and selection via hand pointing." Jerald, THE VR BOOK (Ex.1063) at 299. As "different tasks may require different interaction techniques," some techniques may require a sequence of operations, e.g., "a specific manipulation technique only

occurs after a specific selection technique"—that is, the user first selects an object with the controller and then moves that object using the controller. Jerald, THE VR BOOK (Ex.1063) at 300; Mine, *ISAAC: A Meta-CAD System For Virtual Environments* (1997) ("Mine ISAAC 1997") (Ex.1115) at 548 ("To select an object, the user points the laser beam at a desired object and clicks on a button on the input device").

78. With handheld controllers, pointing "is one of the most fundamental and often-used patterns for selection." Jerald, THE VR BOOK (Ex.1063) at 327, 328 ("When hand tracking is available, hand pointing with a ray extending from the hand or finger is the most common method of selection."); Ross (Ex.1125) at 22:17-29 ("user may use a pointer (a physical pointer such as a mouse and/or other pointer and/or a virtual pointer displayed in the virtual space)," and "a controller (e.g., a pointer)" to control "fields of view, [and] view boundaries"), 14:44-52 ("the user may use a pointer"), 7:51-62 (describing authoring capabilities that use pointing). Pointing offers advantages, such as not requiring the user to travel to be close to the object to be selected, as would be required for hand selection. Jerald, THE VR BOOK (Ex.1063) at 325-27 ("The Pointing Pattern is typically better than the Hand Selection Pattern unless realistic interaction is required."), 347 (referencing paper that "found pointing to take less time and to be more preferred by users"). Pointing can be used to select objects by having the user point to an object to select, and then

applying a direct hand manipulation (e.g., selection via a user-controller trigger). Jerald, THE VR BOOK (Ex.1063) at 327.

79. Tracked handheld controllers enabled dynamic gestures, which "consist of one or more tracked points," e.g., "making a gesture with a controller." Jerald, THE VR BOOK (Ex.1063) at 296. Tracked handheld controllers also allowed conveying spatial information related to the gesture. For example, "gestures can manipulate (e.g., push/pull), indicate (e.g., point or draw a path), describe form (e.g., convey size), describe functionality (e.g., twisting motion to describe twisting a screw), or use objects." Jerald, THE VR BOOK (Ex.1063) at 296.

80. Tracked handheld controllers were known to be intuitive and easy to use "due to their natural, direct mapping to hand motion." Jerald, THE VR BOOK (Ex.1063) at 314; *see also* Jerald, THE VR BOOK (Ex.1063) at 314-15 ("[b]ecause the controllers are tracked, they can be visually co-located with the real hands").

81. It was also known that an HMD could display a "visual representation of a tracked hand-held controller" with labels to provide "immediate instruction of what [] buttons do":

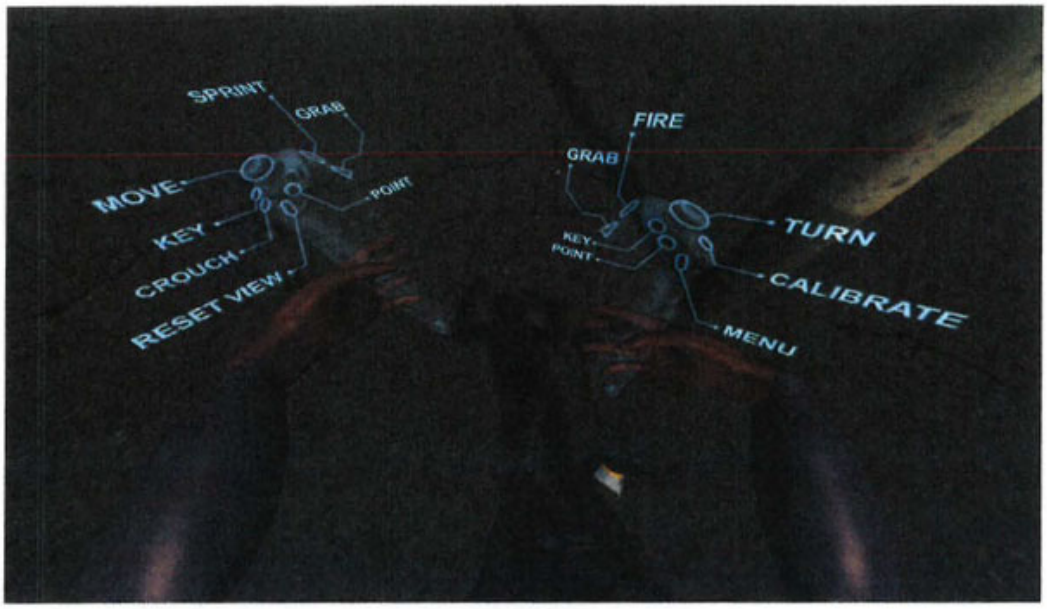


Figure 26.3 **A simple transparent texture in the hand can convey the physical interface.** (Image courtesy of NextGen Interactions)

Jerald, THE VR BOOK (EX.1063) at 315, Fig. 26.3.

82. In AR and VR games and applications, tracked handheld controllers were used as proxies for physical objects that users would use during game play. *See, e.g.*, Medium, *UX Pointers for VR Design* (Nov. 19, 2015) (Ex.1070) at 14 ("In VR, the same physical controllers can be rejiggered to be guns, lightsabers, laser pointers, slingshots, grapplehooks, spray cans, or anything else you might dream up."); U.S. Patent No. 9,884,248 ("Koseki") (Ex.1020) at 27:38-51 ("[A] pointing device may be used depending on the game. A known gun-type controller, a known stick motion controller, or the like may be used as the pointing device …. In such a case, the pointing device may be used as the game controller 1200."); Eurogamer, *Oculus Touch is the Gold Standard in VR Control* (June 24, 2015) (Ex.1058) at 2

("Move and Valve's solution[s] are also very good, and based on the same basic principle - you grip one controller in each hand and both are subject to three-dimensional motion tracking, giving you two virtual hands with which to manipulate objects around you in virtual space.").

83. Pointing and selecting were also commonly used to interact with game elements. *See, e.g.*, VentureBeat, *Final Approach Is An HTC Vive VR Game That Turns You Into A Kid Playing With Toy Airplanes* (Jan. 29, 2016) (Ex.1101) at 4 ("Using the touch control system of the HTC Vive, you can point at aircraft and trace a path. [Y]ou can get them to fly through a series of circles and land."); VentureBeat, *Unreal Engine's Latest Innovation Is About Building Games While Inside Virtual Reality* (Feb. 4, 2016) (Ex.1100) at 3 ("You can [use motion controller to] grab objects and place them in the world or aim at them with a virtual laser pointer and then move them around.").

84. In other games and applications, tracked handheld controllers were used as tools to draw, create, and author. *See, e.g.*, UploadVR, *In a Cartoon World, Holojam Shows Participants a Slice of Space-Time* (Aug. 14, 2015) (Ex.1097) at 2 (participants "will be armed with magic wands allowing them to paint or sculpt an evolving work of art"); Mine, *Working in a Virtual World: Interaction Techniques Used in the Chapel Hill Immersive Modeling Program* (1996) ("Mine 1996") (Ex.1114) at 3 (in the 3-Draw system, "[b]y using a stylus held in the other hand,

one could draw two-dimensional curves on the palette which resulted in curves in three-dimensional space"); Mine 1996 (Ex.1114) at 3 (the THRED system "is a two-handed (6DOF each) computer-aided design system for sketching free-form polygonal surfaces"); Mine 1996 (Ex.1114) at 3 (Holosketch system is a "VR based sketching system that extends the 2D sketch-draw paradigm to 3D" using "a 6DOF wand").

85. The use of a handheld device to draw free-form polygonal objects and geometric "primitives" such as lines, circles, and rectangles in VR traces its roots back to early two-dimensional drawing and computer aided design (CAD) systems. A well-known seminal example is that of Sketchpad, a stylus-based (light pen) system developed by Ivan Sutherland at the MIT Lincoln Labs in the early 1960s:



FIGURE 1.2. TX-2 OPERATING AREA - SKETCHPAD IN USE.
On the display can be seen part of a bridge similar to that of Figure 9.6. The Author is holding the Light pen. The push buttons used to control specific drawing functions are on the box in front of the Author. Part of the bank of toggle switches can be seen behind the Author. The size and position of the part of the total picture seen on the display is obtained through the four black knobs just above the table.

Sutherland, Sketchpad: A Man-Machine Graphical Communication System, Thesis, Massachusetts Institute of Technology (1963) ("Sutherland 1963") (Ex.1140) at Fig. 1.2; *see also* Sutherland 1963 at 13-15, Fig. 1.4 (depicting steps for drawing straight lines and circle arcs and showing examples of how free-form drawing is turned into a line and a circle), and Fig. 1.5 (depicting examples showing the creation of shapes from equal-length line segments).

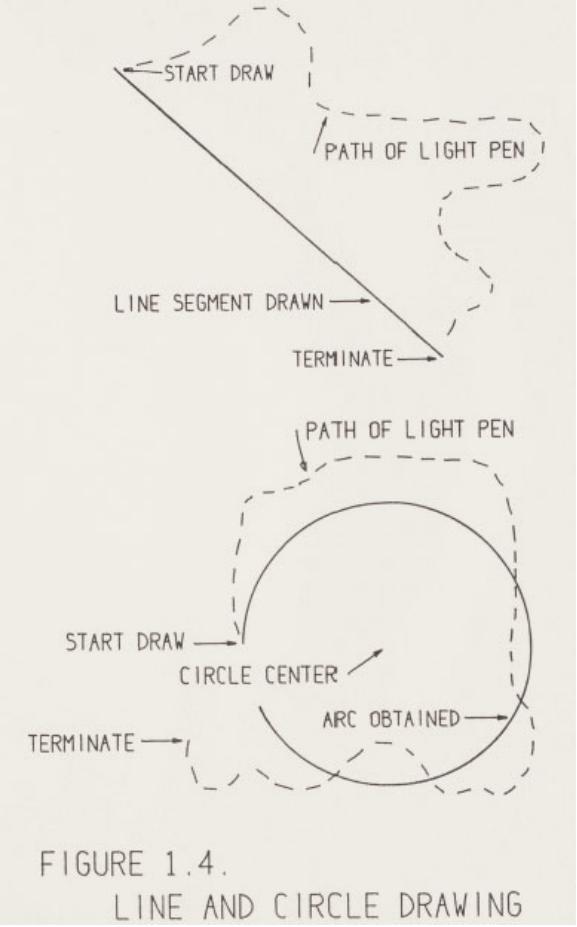


FIGURE 1.4.
LINE AND CIRCLE DRAWING

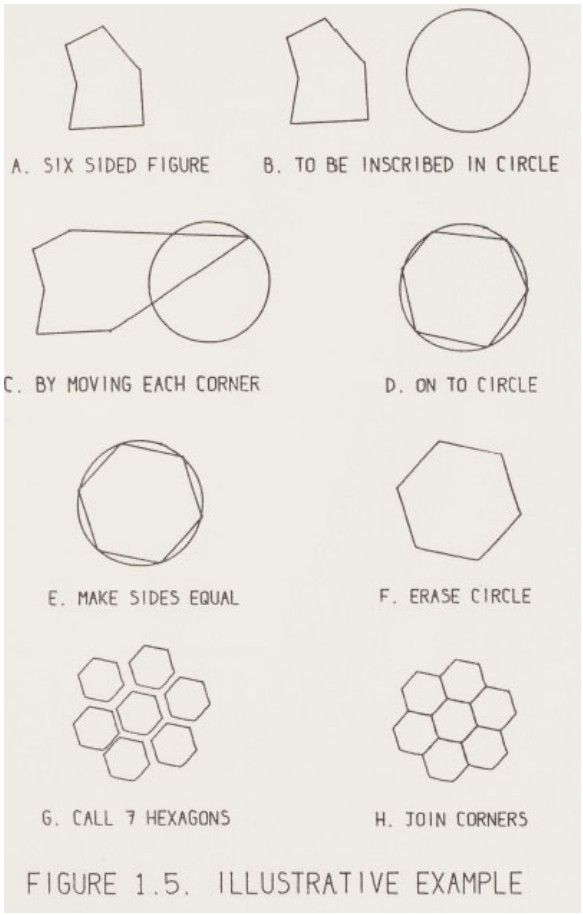


FIGURE 1.5. ILLUSTRATIVE EXAMPLE

86. It was also known before June 2016 that, in association with virtual object selection in three-dimensional virtual environments, feedback could be provided to a user, e.g., haptic, visual, or audio feedback:

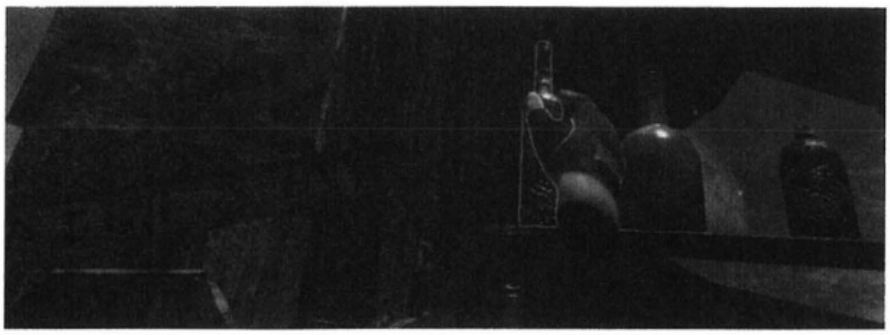


Figure 26.5 **In the game "The Gallery: Six Elements," the bottle is highlighted to show the object can be grabbed.** (Image courtesy of Cloudhead Games)

Jerald, THE VR BOOK (Ex.1063) at 356 (disclosing use of these forms of feedback "to signify touching of objects"), 305 ("Highlighting is visually outlining or changing the color of an object … Highlighting is also used to convey that an object is able to be selected or grabbed when the hand is close even though a collision has not yet occurred,"), Fig. 26.5.

D. Tracking WEDs/HMDs and Controllers

87. As I discuss in several examples in this section, both head tracking (e.g., tracking WEDs and HMDs) and hand tracking (e.g., tracking a peripheral associated with the user's hands) in AR and VR systems were known to persons of ordinary skill in the art before June 2016. Furthermore, by June 2016, HMDs included processors with sufficient processing capacity to perform such tracking.

88. "Concepts such as head tracking [and], hand tracking … are core elements for VR experiences." Jerald, THE VR BOOK (Ex.1063) at 263; *see also* , Welch, *No Silver Bullet* (Ex.1135).

89. To render appropriate imagery of a virtual environment for a user's HMD and play spatialized audio as they move around, the system must estimate head pose. Jerald, THE VR BOOK (Ex.1063) at 99 ("Auditory perception is quite complex and is affected by head pose"), 156 ("[u]se binaural cues with head pose to give a sense of sound location"), 189 ("rendering needs to be tightly coupled to head pose with minimal delay"), 318 ("head tracking must be accurate, precise, fast, and

well calibrated for the virtual world to appear stable"); Begault, *3-D Sound for Virtual Reality and Multimedia*, 133 (2000) ("Begault") (Ex.1007) ("If one of the perceptual requirements is to have virtual sound images remain fixed in virtual space independent of where one's head moves, a six degree-of-freedom tracker system is necessary, consisting of a source, sensor, and a hardware unit housing power supply, electronics, and RS-232 interface to send positional data to a host computer.") (emphasis in original omitted).

90. As a general principle, to track the pose of a user's head with sensors (e.g., cameras or microphones) and sources (e.g., LEDs or speakers), one can either put the sources on the user's moving head and then mount sensors at fixed points in the environment, or the reverse—put the sensors on the user's moving head and mount sources at fixed points in the environment. The former is sometimes referred to as "outside-looking-in" tracking and the latter as "inside-looking-out" tracking:

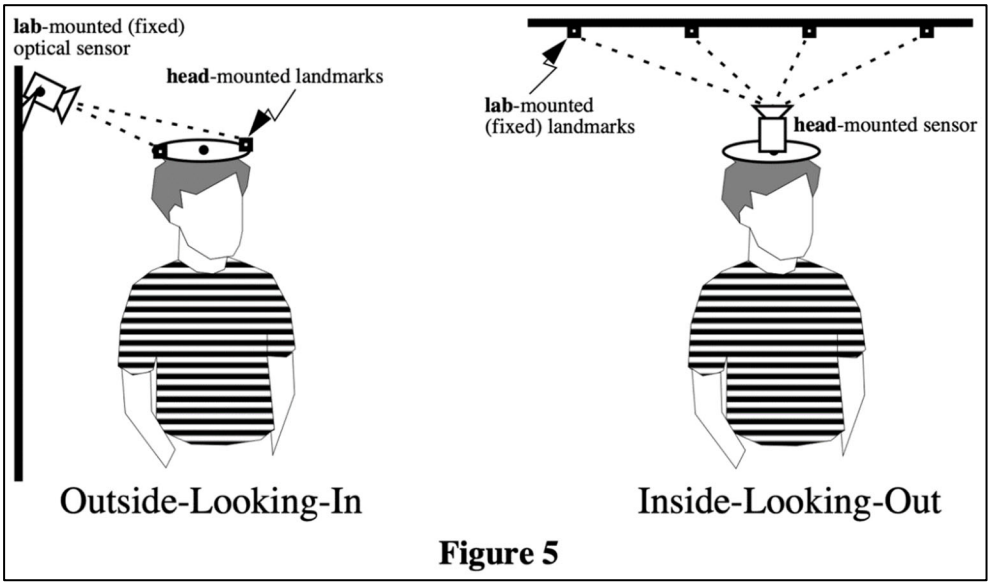


Figure 5

Welch, *High-Performance Wide-Area Optical Tracking: The HiBall Tracking System* (2001) ("Welch 2001") (Ex.1103) at Fig. 5 (describing benefits and design considerations for both configurations). Persons of ordinary skill would be very familiar with these principles and understand that the same principles apply to tracking other parts of a user's body (e.g., hands and feet) and other objects.

91. Research and development aimed at eliminating the need for intentionally added infrastructure (sensors or sources) has been going on for decades, and began at least in the 1980s. *See, e.g.*, Lucas, *An Iterative Image Registration Technique with an Application to Stereo Vision* (1981) (Ex.1068); Shi, *Good Features to Track* (1994) (Ex.1090); Bishop. Since then, tracking has been implemented in a variety of ways, including through the use of magnetic sensors (e.g., electromagnetic compasses), MEMS-based strap-down inertial sensors (e.g., gyros and accelerometers), Global Positioning Systems (GPS), small high-resolution cameras, analog optical sensors (e.g., lateral-effect photo diodes), and a variety electromagnetic sources including optical, magnetic, and acoustic sources such as infrared LEDs, small magnetic coils, and small speakers. *See, e.g.*, U.S. Patent Publication No. 2017/0115488 ("Ambrus") (Ex.1043) at [0075] ("pose and/or movement data may be determined based on sensor information from any combination of sensors mounted on the wearer and/or external to the wearer including … gyroscopes, accelerometers, inertial measurement units (IMUs), GPS

devices, barometers, magnetometers, cameras (e.g., visible light cameras, infrared light cameras, time-of-flight depth cameras, structured light depth cameras, etc.)"), U.S. Patent No. 9,041,622 ("McCulloch") (Ex.1008) at 8:17-22 ("Inside, or mounted to temple 102, are … an inertial sensing unit … a location sensing unit … some examples of which are a GPS transceiver, an infrared (IR) transceiver, or a radio frequency transceiver for processing RFID data."); Begault (Ex.1007) at 133 (describing "electromagnetic sensors," or "optical, mechanical, and acoustic tracking systems"); Jerald, THE VR BOOK (Ex.1063) at 315 ("Hand-held tracked devices typically use inertial, electromagnetic, ultrasonic, or optical (camera) technologies."); Mine Exploiting Proprioception 1997 (Ex.1116) at 68 ("hardware configuration includes an immersive head-mounted display, a magnetic tracking system with three 6 degree-of-freedom (DoF) sensors (one for the head and one for each hand), two separate input devices (one for each hand) and a high speed graphics computer"); U.S. Patent No. 9,392,212 ("Ross" Ex.1125) at 11:4-28 (describing using "one or more of a GPS sensor, a gyroscope, an accelerometer, an altimeter, a compass, a camera based sensor, a magnetic sensor, an optical sensor, an infrared sensor, a motion tracking sensor, an inertial sensor, a CCB sensor, an eye tracking sensor, a facial tracking sensor, a body tracking sensor, and/or other sensors" to "generate output signals conveying information related to any number of different view directions, (e.g., orientation of one or more parts of the user's body," "position

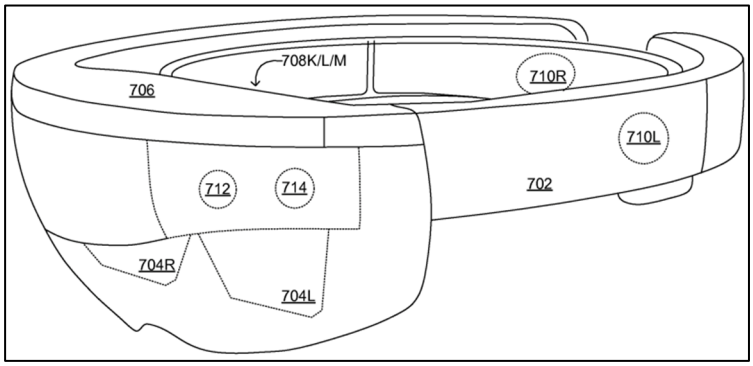
of a user within the virtual space, and/or other directional information)"). Furthermore, it was common to use a "hybrid method of integrating multiple technologies together (sensor fusion) to provide both high precision and accuracy." Jerald, THE VR BOOK (Ex.1063) at 315; Billinghurst 2015 (Ex.1049) at 124-25 (describing early examples of hybrid tracking systems, and explaining that "[h]ybrid tracking systems fuse data from multiple sensors to add additional degrees of freedom, enhance the accuracy of the individual sensors, or overcome weaknesses of certain tracking methods"); Welch, *Hybrid Self-Tracker: An Inertial/Optical Hybrid Three-Dimensional Tracking System* (1995) ("Welch 1995" Ex.1119) at 1, 11 (proposing, for example, a hybrid system including an inertial navigation subsystem and computer vision subsystem). In fact, as Sutherland shows, VR systems used both electro-mechanical linkages and sound waves as early as the 1960s. Sutherland (Ex.1093) at 760-61.

92. While vision-based (using a camera) pose tracking has been possible for at least 30 years, it was the advent of mobile phones with cameras that began to transform the fields of AR and VR, and even more so the advent of "smart" phones with inertial sensors, electromagnetic compasses, cameras, and powerful processors. Certainly by the early 2000s, mobile devices included sensors that provided pose estimation and tracking for users using these technologies. Billinghurst 2015 (Ex.1049) at 124 ("Many mobile devices include cameras, accelerometers and

gyroscopes … which can be combined to provide highly accurate pose estimation") (internal citations omitted).

93. By 2015, the AR and VR industry knew numerous ways of tracking movement of HMDs and peripherals in six degrees of freedom (again, "6DoF"), i.e., tracking movement of the HMD and controllers in three-dimensional space, and having processing take place in the HMD.

94. For example, a 2015 patent publication describes an AR HMD that uses data from IMU sensors 708, color camera 712, and depth camera 714 that projects structured or pulsed infrared light and captures the reflections, to perform 6DoF "position tracking, direction and orientation sensing, and/or motion detection of the user's head":

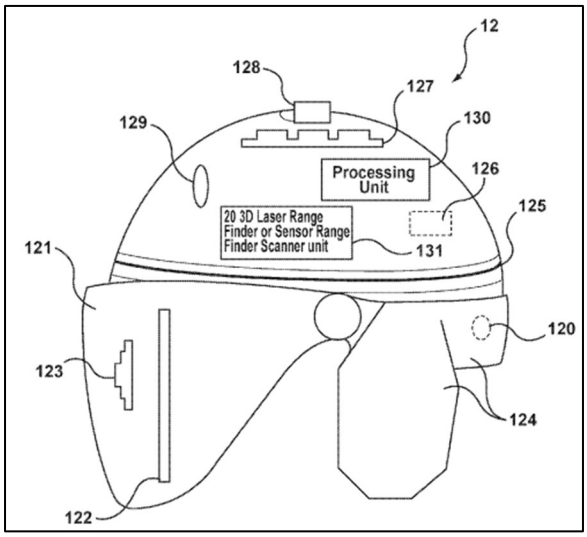


Ambrus (Ex.1043) at [0016] (describing "a combined six degrees of freedom"), [0074]-[0078], Fig. 7.

95. In another 2015 patent, a disclosed HMD was described as capable of at least 6DoF tracking, and did not rely on an external base station for tracking.

McCulloch (Ex.1008) at 7:24-67, 8:17-39, 15:31-38; *see also* Section IX.D (overview of McCulloch).

96. As another example, a 2013 patent application disclosed an HMD comprising "a 9-degree-of-freedom (DOF) inertial measurement unit (IMU) configured to determine the direction, orientation, speed and/or acceleration of the HMD and transmit that information to the processor" and "a local positioning system (LPS) operable to dynamically determine the user's position in 2D or 3D within the physical environment":



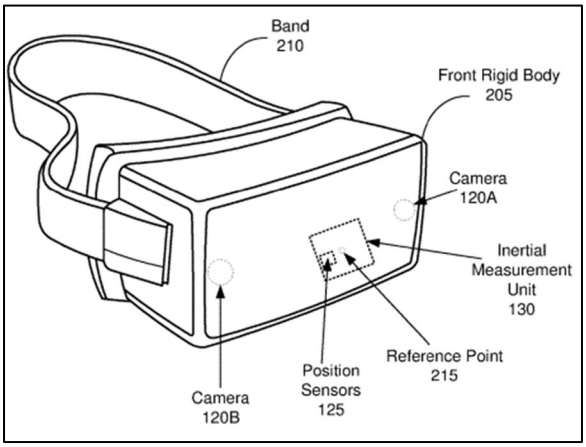
U. S. Patent Publication No. 2016/0292924 ("Balachandreswaran") (Ex.1045) at Fig. 5, [0084] (LPS of this system "invoke[s] one or more ultrasonic, radio frequency (RF), Wi-Fi location, GPS, laser range finding (LRF) or magnetic sensing technologies"), [0101]; *see also* Balachandreswaran (Ex.1045) at [0055] ("Each HMD 12 may not need to delegate any processing tasks … if the console 11 or the

processor embedded on each HMD is … capable of performing the processing required"), [0110] ("all processing tasks may be performed by one or more processors in each individual HMD within a physical environment").

97. As another example, a 2013 patent application disclosed a device (e.g., a wearable device such as an HMD or virtual reality glasses) that "use[d] one or more sensors or application data to gather environmental information" as part of a "context aware localization, mapping, and tracking (CALMT)" module. U.S. Patent No. 9,367,811 ("Ramachandran") (Ex.1034) at 12:18-23 (CALMT "can perform visual mapping, localization, and tracking with the most effective coordinate system for use in indoor scenes."), 2:47-3:2 (describing the device and various sensors in the device), 4:36-44 (similar), Fig. 1.

98. A different 2014 patent application similarly disclosed "systems [that] can process the input of a single camera and continuously build up a three dimensional (3D) model (e.g., a SLAM map) of an environment as the camera moves in Six Degrees of Freedom (6DOF)." U.S. Patent No. 9,674,507 ("Pirchheim") (Ex.1033) at 1:18-29, 3:36-52 (describing the device, which can be a wearable device or augmented reality device, with modules for at least for image processing and 6DOF simultaneous localization and mapping that "may be combined and/or implemented in the processor"), 4:49-64 (discussing 6DOF simultaneous localization and mapping), Fig. 1.

99. As another example, a continuation patent application that references a priority application filed on January 1, 2016 discloses an HMD with tracking technology including "at least two cameras," "one or more sensors," and "an inertial measurement unit":

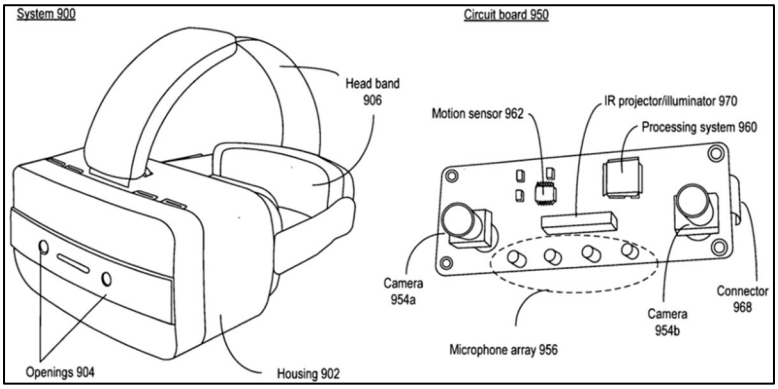


U.S. Patent No. 10,095,031 ("Katz") (Ex.1018) at Fig. 2, 3:41-4:43 (describing the VR headset and how cameras capture image data and combine this information with other sensor data).

100. As another example, a patent application filed on January 15, 2016 disclosed an HMD that also used tracking technology involving a combination of cameras and sensors. *See* U.S. Patent No. 10,114,465 ("Wan") (Ex.1040) at 2:41-45 ("Example VR functions include, but are not limited to, 6 degree-of-freedom (6DoF) head tracking, finger/hand tracking, environmental (or depth) sensing, pass-through of images for display via or in the V-HMD, tracking a VR controller or other device held by a user, etc."), 6:65-7:9 ("The 6DoF processor 316 provides

determined 6DoF tracking data 332 the VR function portion 330 for further processing"), Fig. 6A.

101. As another example, a 2014 patent application disclosed an HMD with an IR projector that "project[ed] certain patterns … onto one or more surfaces of the physical environment" for "efficient and robust tracking" of the HMD's location and orientation:



International Patent Publication No. WO 2016/064435 ("Fei") (Ex.1012) at [044]-[045], [088], Figs. 9A-9B.

102. Additionally, as I discussed in Section VII.C and further showed through a number of the examples identified above, it was well known to pair tracked handheld controllers as input devices to WEDs or HMDs or to track finger or hand movements directly using WEDs or HMDs. *See, e.g.*, McCulloch (Ex.1008) at 4:25-31 ("real controller device may be "a handheld inertial motion unit (IMU)"), 7:4-23 (describing that the real controller device communicates with the display device system); Pedrotti (Ex.1005) at 7:52-54 ("the physical controllers may also have

magnetic trackers located within them, similar to the tracker in the headset"); Sawyer (Ex.1036) at [0025] ("The HMD and the optional sensors provide sensory input to a controller, which in turn provides sensory feedback to the HMD or another output device."); Wan (Ex.1040) at 7:19-20 ("data [from the image processing portion] can be provided to a finger/hand tracker 334 in the VR tracking portion").

103. Systems capable of tracking WEDs/HMDs and controllers also necessarily used coordinate systems (also called "coordinate spaces" or "coordinate frames") to track and display virtual objects, which were updated with respect to their HMDs (e.g., with respect to the HMDs' locations/positions). *See, e.g.*, McCulloch (Ex.1008) at 15:1-63 (describing a "scene mapping engine" for "3D space positions or position volumes for objects," which "can be aided with sensor data … from an orientation sensing unit" of the HMD); Balachandreswaran (Ex.1045) at [0010] (describing that the HMD comprises a processor able to map the physical environment and determine a field of view based on the HMD's inertial and location data); Robinett, *The Visual Display Transformation for Virtual Reality* (1995) (Ex.1087) at Abstract (describing general principle of "map[ping] points from object coordinates to screen coordinates" for display); Pirchheim (Ex.1033) at 4:37-64 (describing "tracking and mapping" in 6DOF and integrating keyframes from an image or videostream).

104. After all, in both AR and VR systems, there is a constant cycle of tracking the user's input, providing that information to an AR or VR application, and then rendering and displaying output to the user. This cycle of feedback between the user—e.g., that the user has moved locations or is interacting with a virtual object using a controller—and the AR or VR application is what generates and changes the virtual environment experienced by the user.

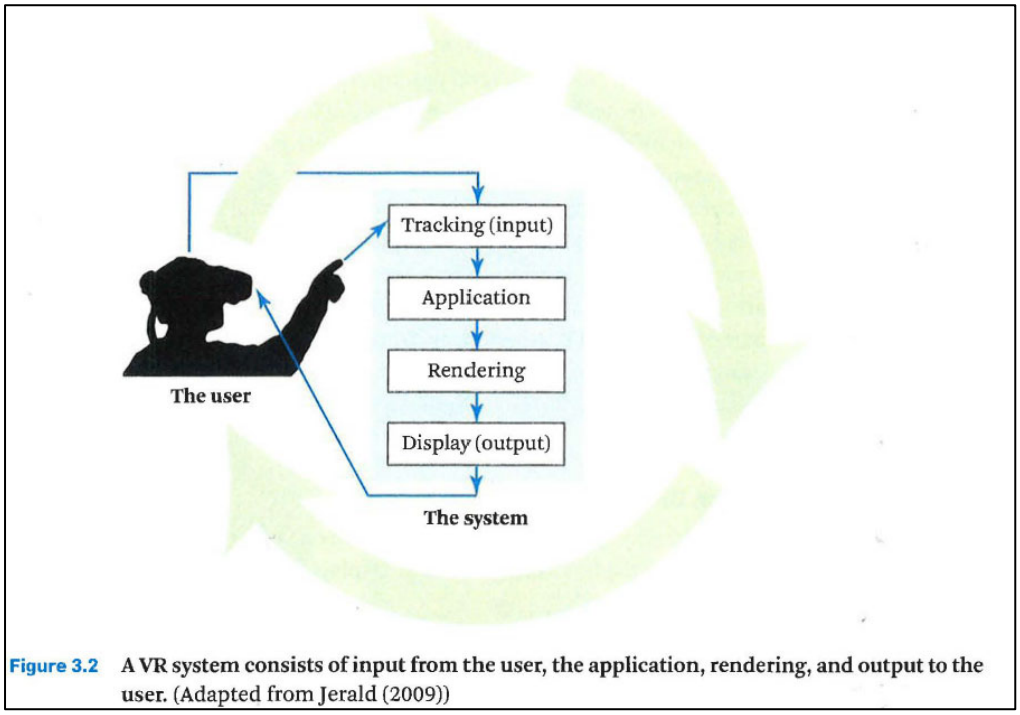


Figure 3.2 **A VR system consists of input from the user, the application, rendering, and output to the user.** (Adapted from Jerald (2009))

Jerald, THE VR BOOK (Ex.1063) at 31-32, Fig. 3.2. Accordingly, tracking has long been understood to be, and remains, one of the essential functions in any AR or VR system.

E. Sound Localization and Binaural Sound

105. Since well before June 2016, it was understood that sound localization is an important aspect of creating an immersive AR or VR experience. NSA, *Virtual Reality* (Ex.1073) at 35-36 ("Spatially localized sound has a dramatic effect on the sense of immersion in virtual environment … Sound is considered a very important aspect of VR since users often get 'lost' while moving in the virtual world."); Jerald, THE VR BOOK (Ex.1063) at 239 ("Auditory cues play a crucial role in everyday life as well as VR, including adding awareness of surroundings, adding emotional impact, cuing visual attention, conveying a variety of complex information without taxing the visual system, and providing unique cues that cannot be perceived through other sensory systems."), 240 ("Spatialized audio can be useful to serve as a wayfinding aid … to provide cues of where other characters are located, and to give feedback of where the element of a user interface is located."); Unity Manual 5.3, *Audio Spatializer SDK* (2015) ("Unity Manual 5.3") (Ex.1096) at 1 ("With the advent of virtual and augmented reality systems[,] the spatialization method more and more becomes a key component of the player's immersion.").

106. Furthermore, using HRTFs to generate localized sound, and in particular binaural sound, was a well-known technique. An HRTF "describes how a given sound wave input (parameterized as frequency and source location) is filtered before the sound reaches the eardrum and inner ear." U.S. Patent No.

8,767,968 ("Flaks") (Ex.1009) at 1:31-34; *see also* Begault (Ex.1007) at 41 (defining "HRTF" as "[t]he spectral filtering of a sound source before it reaches the ear drum that is caused primarily by the outer ear," and "binaural HRTF" as "referring to both left- and right-ear HRTFs"); U.S. Patent No. 7,710,654 ("Ashkenazi") (Ex.1044) at 11:66-12:2 ("The delay and frequency response which associate a spatial audio source location with each ear are described by a Head Related Transfer Function (HRTF) model.").[1]

107. It was known that a pair of HRTFs, one for each ear, can be used to synthesize binaural sound that appears to come from a particular point in space.

---

[1] *See also* WILEY ELECTRICAL AND ELECTRONICS ENGINEERING DICTIONARY (2004) (Ex. 1120) at 335, defining "head-related transfer function" as follows:

> Its abbreviation is HRTF. A transfer function that takes into account factors involved in sound reaching the ears of a listener, for sound localization and the determination of the arriving spectrum of sound. Variables such as the dimensions of the ear canal, the exterior part of the ear, head, and torso, and how these modify the spectrum of the sound heard are combined with the azimuth, elevation, range, and frequency of the sound source, the slightly different time at which a sound arrives at each ear, and so on. Each listener has a unique HRTF.

Begault (Ex.1007) at 41; Ashkenazi (Ex.1044) at 11:63-66 ("By artificially introducing such delays and frequency response, a monaural signal, is transformed into a binaural signal, having spatial location characteristics."); Cohen, *Integrating Graphic and Audio Windows* (1992) ("Cohen 1992") (Ex.1052) at 470 ("Binaural localization cues may be captured by head-related transfer/functions (HRTFs), impulse responses measured for the head and pinna (outer ear) of human or dummy heads. For each spherical direction, a left-right pair of these transfer functions is measured and stored as FIR filter coefficients. Sound can then be spatialized by driving digitized input signals through these HRTFs in a convolution engine, creating psychoacoustic localization effects by introducing binaural spatial cues into an originally monaural channel, 'placing' the channel within the perceptual space of the user …."); Zhou, *An Experimental Study on the Role of Software Synthesized 3D Sound in Augmented Reality Environments* (2004) ("Zhou") (Ex.1107) at 991 ("Exact spatial 3D sound in virtual and augmented environments requires perceptual externalization of the sound source, which can only be brought about by using head related transfer functions (HRTFs)").

108. Furthermore, a common technique used in generating localized sound was to store multiple HRTFs within a library of HRTFs so that a suitable HRTF for the listener could be applied to other components of a 3D audio signal to generate a spatialized audio cue to the user. Flaks (Ex.1009) at 3:35-43 ("In some

embodiments, sensor data may be analyzed to determine physical characteristics of the listener such that a suitable HRTF may be determined from a library of HRTFs. The HRTF for the listener may be applied to the different components of the 3D audio signal.").

109. HRTFs have been used to enhance immersion and intensify the 3D experience in virtual environments for decades. In the 1980s and 1990s, scientists at NASA did significant research on HRTFs and spatialized sound. *See, e.g.*, Wenzel 1988a (Ex.1104); Wenzel 1988b (Ex.1105); Wenzel 1991 (Ex.1106). In the early 1990s, NASA developed the Convolvotron™, a real-time digital signal processing system that processed HRTFs to rendered 3D localized audio for VR displays. Begault (Ex.1007) at 12. By the late 1990s the technology was integrated into PC sound cards. Free HRTF libraries made standard HRTFs available to developers over the internet, including the MIT KEMAR library (1994) and the CIPIC library (2001). Algazi (Ex.1046) at 99 (disclosing in 2001 "a public-domain database of high-spatial-resolution head-related transfer functions measured at the U.C. Davis CIPIC," i.e., Center for Imaging Processing and Integrated Computing, "Interface Laboratory"); *see also* Sodnik, Spatial Auditory Human-Computer Interfaces (2015) ("Sodnik") (Ex.1124) at 23; Begault (Ex.1007) at 140 ("Anechoic HRTFs are taken from a library of measurements, and are used to position the virtual sound source's azimuth and elevation position."), 169-70 ("The AL-204 (see Figure 5.9), was an

early four-channel DSP-based convolution device that used HRTFs based on measurements of the KEMAR mannequin head (Figure 4.25) made at Northwestern University (cf. Kendall, Martens, and Wilde, 1990)").

110. In the mid-2000s, there were already open source software development kits (SDKs) incorporating publicly available HRTFs "[f]or easy implementation of 3D sound generation." Zhou (Ex.1107) at 992-93; *see also* Doerr, *Evaluation of a Low-Cost 3D Sound System for Immersive Virtual Reality Training Systems* (2004) (Ex.1056) at 205 (describing the open-source OpenAL library, an HRTF software-based 3D sound system for "consumer-level 3D audio hardware interfaces" for immersive VR systems); Lohr, *OpenAL-MOB with openFrameworks on Android Introduction* (Dec. 18, 2014) (Ex.1067) at 1 (using "openFrameworks v0.8.4 in combination with OpenAL for Audio output" because "we need the HRTF for binaural sounds").

111. One exemplary system shows that researchers had already developed by 2004 a robust and efficient HRTF audio rendering process for AR and VR HMDs with head tracking that were "capable of making people think that the sound was coming from the external source, even though it was being rendered at the headphones." Zotkin, *Rendering Localized Spatial Audio in a Virtual Auditory Space* (2004) ("Zotkin") (Ex.1111) at 21. That system ran "in real-time on a typical office PC" and processed "multiple virtual sound sources at different positions" with

HRTFs in parallel and "no noticeable latency." Zotkin (Ex.1111) at 3. "The level of detail … (interpolation quality and number of room reflections traced) [was] automatically adjusted to match the processing power available." Zotkin (Ex.1111) at 7.

112. It is therefore unsurprising that, by 2016, numerous patent publications described AR/VR HMDs that generated HRTF spatial audio. *See, e.g.*, U.S. Patent No. 9,787,846 ("Srinivasan") (Ex.1038) at 2:3-23, 5:34-35, 11:48-12:1, Figs. 3, 7 ("audio position processor 605 may then receive the audio input signals and apply suitable head related transfer function processing" so that the resulting audio signal "appears to come from the approximate position of the object"); U.S. Patent No. 9,767,618 ("Najaf-Zadeh") (Ex.1030) at 4:41-54, Fig. 4 (HMD with "circuitry [] and applications for providing 3D audio for a HMD"); U.S. Patent No. 10,509,466 ("Miller 466") (Ex.1026) at 23:53-59 (HMD "spatially render[s]" audio to "make the user perceive various virtual audio sources as located in various x, y, z locations in world space" using "head-tracking inputs and a head-related transfer function (HRTF) to simulate acoustics"); U.S. Patent Publication No. 2012/0183161 ("Agevik") (Ex.1042) at [0044]-[0045] (HMD applies "selected HRTF to an audio signal … to generate an output signal."). By that time, AR and VR game engines offered spatial audio SDKs and the ability to use spatial audio plugins. *See, e.g.*, Parisi (Ex.1075) at 1 (as of November 2015, "[t]he Unity3D and Unreal game

engines, popular for making desktop and mobile games, have become tools of choice for native VR development"); Unity Manual 5.3 at 2 ("Adding HRTF filtering already immensely improves the sensation of direction over a conventional panning solution (a typical and famous example of this is the binaural recording of the virtual barber shop)."); RealSpace3d, *Manual of VisiSonics' RealSpace 3D Audio Unity Plugin* (Nov. 17, 2015) (Ex.1084) at 13 (default HRTF set "work[s] well for majority of users" but HRTFs could be customized by the user); Google Developers, *Spatial audio comes to the Cardboard SDK* (Jan. 13, 2016) (Ex.1060) at 1 ("The SDK combines the physiology of a listener's head with the positions of virtual sound sources to determine what users hear."); Google VR Cardboard Unity SDK, CardboardAudioSourceEditor.cs (Jan. 12, 2016) (Ex.1109) at lns. 71-73 ("Enable HRTF … [s]ets HRTF binaural rendering for the source."); UploadVR, *Google Cardboard Now Offers Spatial Audio* (Jan. 15, 2016) (Ex.1098) at 2 ("The SDK is optimized for mobile CPUs (e.g. SIMD instructions) and actually computes the audio in real-time on a separate thread, so most of the processing takes place outside of the primary CPU.").

113. It was also well known that integrated circuit chips, specifically DSP chips, available prior to 2016 were capable of processing sound with HRTFs to generate binaural sound. *See, e.g.*, U.S. Patent No. 5,173,944 ("Begault 944") (Ex.1131) at 1:21-27 (explaining that the described effects of the present invention,

"pseudo-stereophony" that "allow[s] the derivation of two channels of sound from a monoaurally-recorded, one channel source"), 6:51-54 (how pseudo-stereophony "can be implemented into hardware using off-the-shelf integrated circuit chips, such as a Motorola 56001 DSP chip"), 6:54-56 ("All of the processing described with respect to FIG. 2 can be accomplished with these or equivalent DSP chips."), and 6:57-63 (explaining that "[i]n the aforementioned embodiment of pseudo-stereophony, only four HRTF filter networks were used. However, a larger number of delay-gain-HRTF filter networks could be added in an alternative embodiment. Fewer or greater number of coefficients used to represent the HRTFs used in FIR filters 78 and 80 could also be part of an alternative embodiment."); U.S. Patent No. 5,438,623 ("Begault 623") (Ex.1132) at 8:6-15 ("Accordingly, thus what has been shown and described is a system of digital filters implemented using selectively interchangeable PROM-DSP chip combinations which generate synthetic head related transfer functions that impose natural cues to spatial hearing on the incoming signals, with a different set of cues being generated for each incoming signal such that each incoming stream is heard at a different location around the head of a user and more particularly one wearing headphones.").

F. Designating Sound Sources

114. With the advent of sound localization techniques developed in the 1980s and 1990s, it became common to use zones or regions or areas containing

sound sources to manage sound, whether by an end user of a virtual environment or a designer of that environment. *See, e.g.*, Çamci, *Interactive Virtual Soundscapes: A Research Report* (2015) ("Çamci") (Ex.1051) at 119 ("the designer can also interact with the virtual soundscape in real-time, and alter the aural reality experienced by the user … therefore allow[ing] for the mutual participation of a designer and a user in creating a real-time, non-linear sound composition presented in the form of a[] spatial structure").

115. For example, where a user wishes to listen to different streams of audio information at the user's choosing, sound zones provide a user an interface facilitation that capability. *See, e.g.*, U.S. Provisional Application No. 62/309,882 ("Marks") (Ex.1023) at [0007] ("the spectating user can decide that some location within the VR environment is interesting, and sounds to the spectating user can then be adjusted to provide the spectating user sounds that would surround the spectating user, as if the spectating user is actually located at that identified VR environment location").

116. Indeed, it was a known technique to divide sensory elements into different zones in a virtual environment. In the example shown below, which is called a "Center of Action" setup, the "world around the user" is "split … into different zones such as primary and secondary viewing directions," where "[t]he most important action occurs in the primary direction." Jerald, THE VR BOOK

(Ex.1063) at 254-55. And "[a]s a user starts looking toward another zone, cues are provided to inform the user that she is starting to look at a different part of the scene and the action and/or content is about to change if they keep looking in that direction":

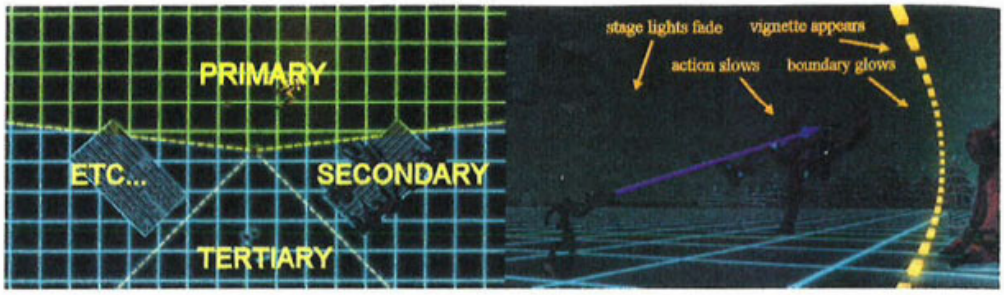


Figure 22.3 Visionary VR splits the scene into different action zones.

Jerald, THE VR BOOK (Ex.1063) at 254, Fig. 22.3.

117. Such zones could be rendered in both 2D and 3D interfaces, and as a general principle, these interfaces were implemented because they were "intuitive" and could be "quickly understood, accurately predicted, and easily used." Jerald, THE VR BOOK (Ex.1063) at 277.

118. For example, a 2015 paper—Çamci—describes the representation of a 2D environment for positioning sound sources referred to as an "Interactive Virtual Soundscape." *See* Çamci (Ex.1051) at 119.

119. Çamci describes "directional sound objects," which "act as a localized source," and also "zonal sound objects" that "demarcate regions in the virtual space"

to provide "background or textural sounds that are independent of user position and orientation":

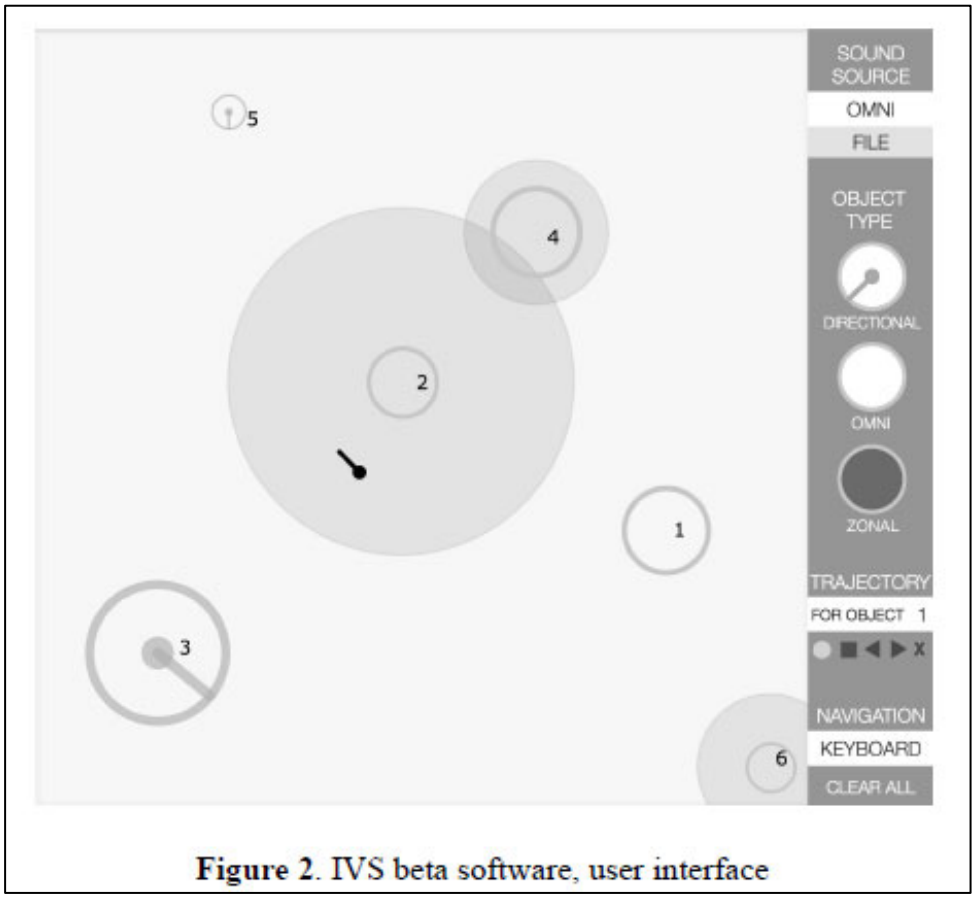


Figure 2. IVS beta software, user interface

Çamci (Ex.1051) at 119-20, Fig. 2. "The interface on the right-hand side allows the designer to choose from a variety of sound sources (i.e., audio file, external input …), assign this source to an object type (i.e. directional omnidirectional, zonal), and place the object within the virtual space," and "[t]he combination of a sound source and an object type specify an object's membership." Çamci (Ex.1051) at 120. Çamci further disclosed that "[t]he designer can [] change the amplitude (i.e., the acoustic space) or each object, as well as the coverage of zonal object," and use "the handle

on the directional objects" to set "an orientation for the sound output." Çamci (Ex.1051) at 120 ("Sound objects can be added, deleted and repositioned in real-time.").

120. Çamci further expanded this to, and disclosed, a 3D implementation:

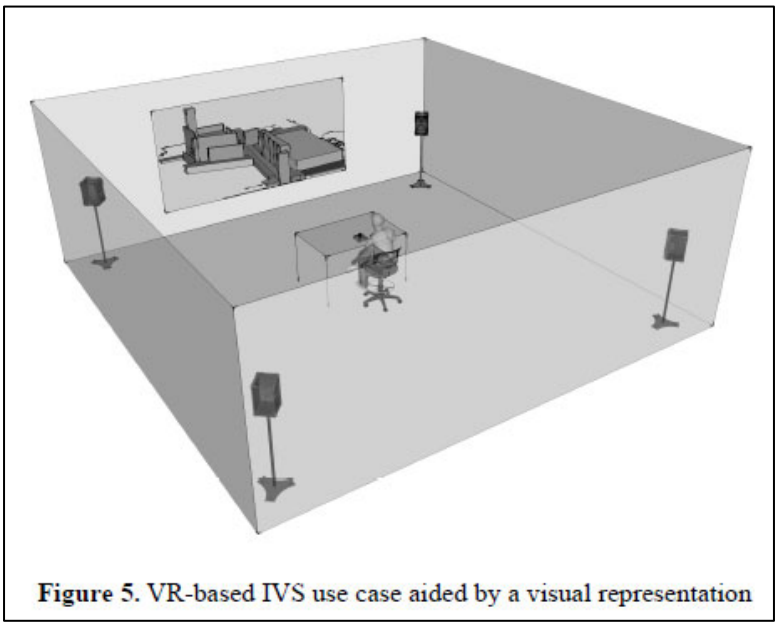


Figure 5. VR-based IVS use case aided by a visual representation

Çamci (Ex.1051) at Fig. 5. Çamci explained: "Since locomotion in the VR is not limited by physical boundaries," "we found it necessary to incorporate a two or three-dimensional landscape model of the IVS"—the Interactive Virtual Soundscape—"to give the user a sense of context and orientation." Çamci (Ex.1051) at 122.

121. In another example, as described in a series of papers from the early 1990s, MAW, which stands for Multidimensional Audio Windows, is a GUI that "integrat[es] a graphic editor with a multidimensional spatial sound engine" and

thereby "permit[s] multiple simultaneous audio sources, such as in a teleconference, to coexist in a modifiable display." Cohen 1992 (Ex.1052) at Abstract, 470-71 ("MAW is an interactive audio windowing and 2D spatial sound system suitable as a teleconferencing system as well as for asynchronous applications like voicemail"). MAW, and audio windows more generally, "are a way of organizing and controlling sound." Cohen 1992 (Ex.1052) at 470 (analogizing to "standard pointing device in a window/icon/menu/pointing device (WIMP) system"), 471 (describing "a mouse-based system [that] realizes indicating, highlighting, and relocating as pointing, clicking, and dragging" icons representing sound sources), 479 (further describing MAW as "intended to interpolate between conventional telephony and VR"). With this interface, "[i]cons for [] nonomnidirectional sources and sinks indicate both their mutual positions in virtual space and their orientation," and can be manipulated, rotated, translated, and repositioned (singly or in groups) by a cursor:

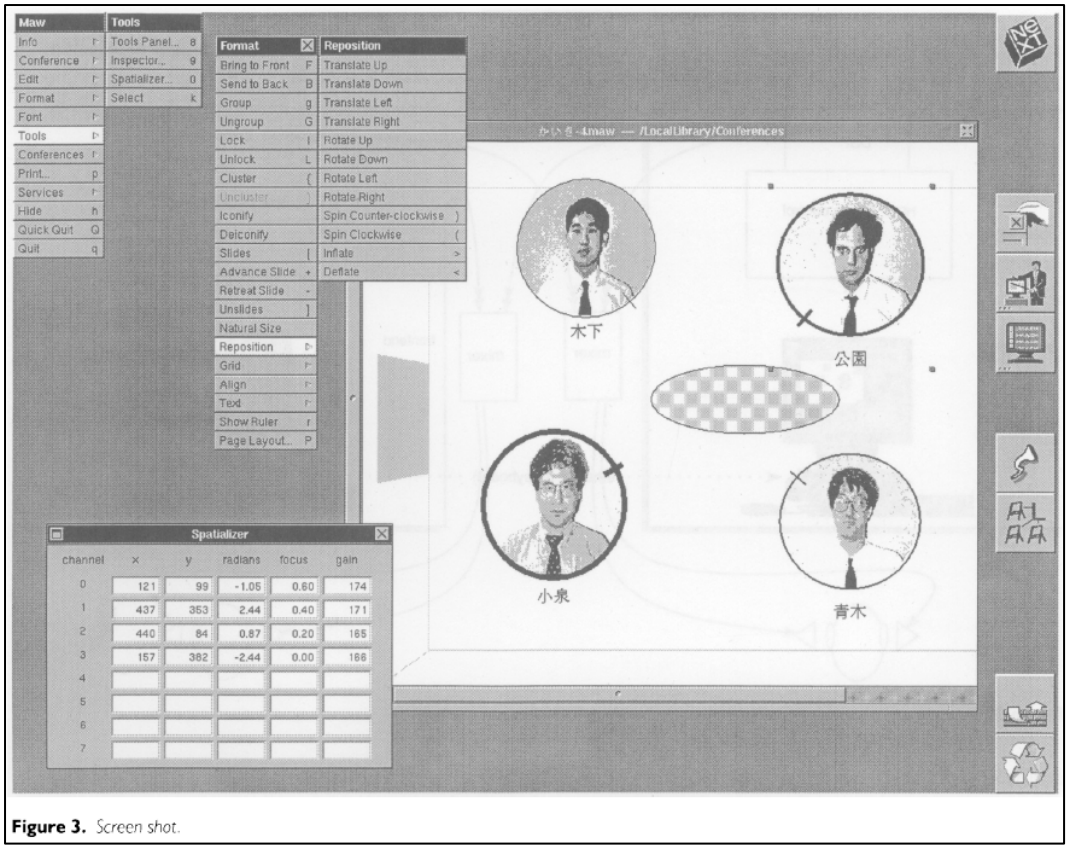


Figure 3. *Screen shot.*

Cohen 1992 (Ex.1052) at Fig. 3, 473. These icons are additionally able to be clustered and unclustered with zooming effects (e.g., a cluster appearing as a single point from a distance, or disassociating and distributing spatially as it gets closer). Cohen 1992 (Ex.1052) at 473-74 ("This focus allows navigation in arbitrarily large spaces, assuming a limited density of point sources."); *see also* Sodnik (Ex.1124) at 55 (further discussing MAW); Begault (Ex.1007) at 173-74 (further discussing Cohen's interfaces, including Cohen's "audio windows"). Additionally, "[t]he user can resize a selected atomic spatial sound icon by dragging one of the resize handles (knobs) on its bounding rectangle." Cohen 1992 (Ex.1052) at 473. As Cohen 1992 discloses, "[a]s long as visual tokens for the spatial sound objects are accessible

through the workstation, they can be manipulated … via a suite of direct and indirect manipulation techniques." Cohen 1992 (Ex.1052) at 471.

122. Relatedly, the importance of "exploit[ing] sound as a vital communication channel for computer-human interfaces" was recognized in the 1990s. Cohen 1992 (Ex.1052) at 468; *see also* Cohen, *Throwing, Pitching, and Catching Sound* (1993) ("Cohen 1993") (Ex.1053) at 274 ("Augmenting a sound system with spatial attributes opens new dimensions for audio, making spatial sound a potentially-rich analogue of 3D graphics."); McGrath, *Huron – A Digital Audio Convolution Workstation* (1995) (Ex.1069) at 4-5 ("In the emerging field of virtual reality, where the goal is to create a believable synthesis of sensory inputs for the human operator, the complexities of the auditory inputs are popularly overshadowed by the exciting animated graphics. However the acoustic simulation of the virtual world is just as complicated and requires similar levels of computational power.").

123. Begault, like Çamci's and Cohen's papers, shows that persons of ordinary skill in the art knew how to implement easy-to-use interfaces for controlling and positioning 3D audio long before June 2016. Begault disclosed an example interface in the form of a pie menu:

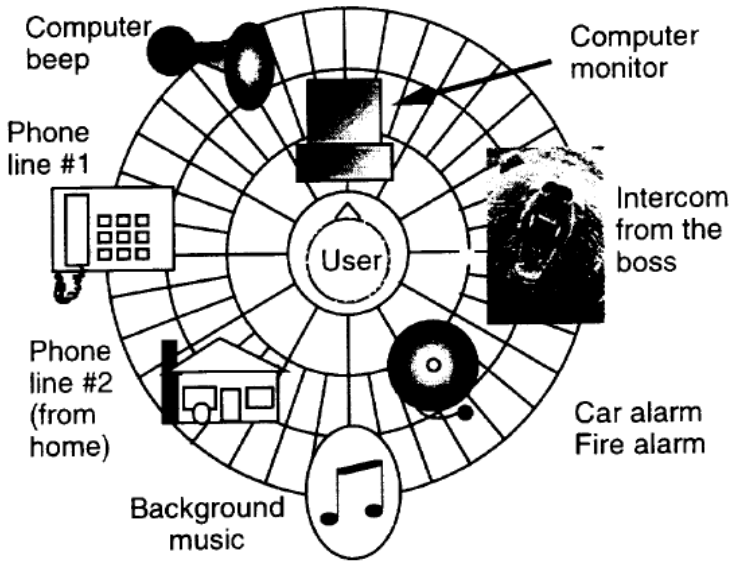


Figure 5.12. Layout for a hypothetical GUI for arranging a set of incoming sounds. By resizing the icons, volume could be adjusted independently of perceived distance. *Graphic assistance by Denise Begault.*

Begault (Ex.1007) at Fig. 5.12.[2]

[2] *See also* Jerald, THE VR BOOK (EX. 1063) at 346-47 (explaining "pie menus," which "are circular menus" where "selection is based on direction," and provides the advantage that "commonly used options are embedded into muscle memory as usage increases"), 345-49 (describing multiple "widgets and panels" patterns for UIs used to control and manipulate VR settings, including "ring" and "pie" menus and "virtual hand-held panels," among others), 346 (describing interfaces based on "2D desktop integration," borrowing "metaphors such as double-clicking on a selected window header to minimize the window," and "WIMP (Windows Icon Mouse Pointer) applications").

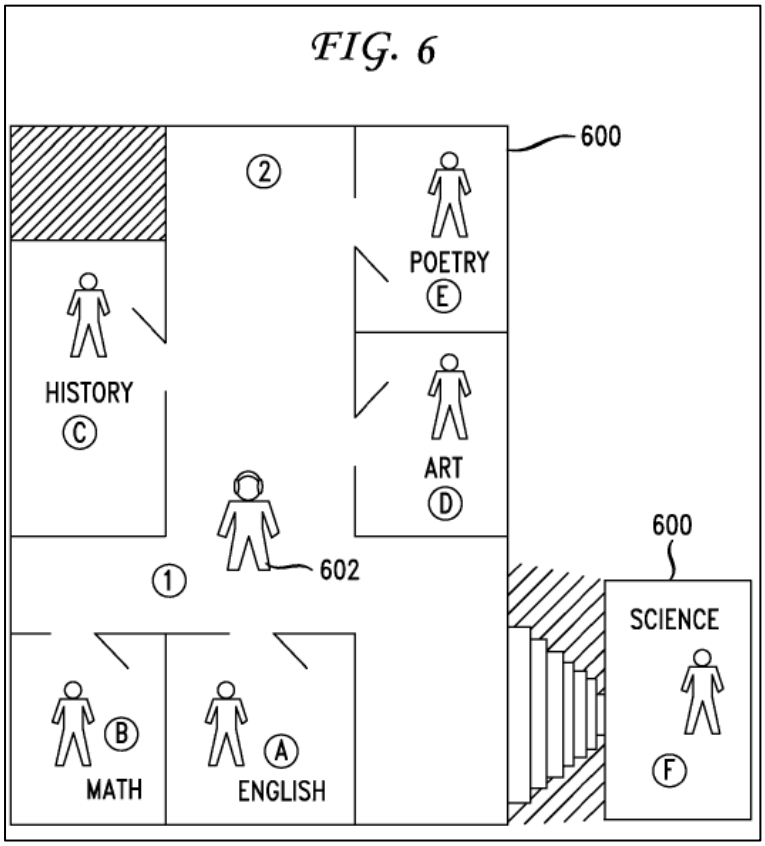
124. As Begault states, the "basic concept" with such an interface "is to represent each form of auditory input iconically on the screen and then allow manipulation of the distance and relative azimuth of each source." Begault (Ex.1007) at 172. Then, back-end computing devices "interpret[] the relative location of the icons on the screen as commands to a multiinput, 3-D sound spatialization subsystem," for positioning 3D audio in a virtual environment. Begault (Ex.1007) at 172.

125. Thus, with such interfaces, designers and users could control and/or navigate different sound zones, e.g., to position and/or listen to different sound sources in different locations, before June 2016. For example, a patent application filed in March 2016 disclosed that a "spectator may be provided with functionality to select different listening zones, which would impact the audio provided to the spectator … and listened to via headphones." Marks (Ex.1023) at [000111]-[001113]; *see also* U.S. Patent No. 8,520,872 ("Jang") (Ex.1006) at 11:64-12:5 ("For example, if a user's character moves from a basketball court to a conference room, visual, audio, or tactile elements of the basketball court may decrease in magnitude, and visual, audio, or tactile elements of the conference room may begin to be transferred to a virtual reality device or a portion of the virtual reality device."); U.S. Provisional Application No. 62/289,085 ("Mangiat") (Ex.1022) at [0050] ("the HMD can advantageously spatialize the mix of the stem tracks of the audio file"),

[0053] ("the HMD can identify a position of the wearer's hands, and as the hands move, the HMD can generate a different mix of the stem tracks for presentation (audibly or visually) to the wearer").

126. A patent issued on March 29, 2016—Seligmann—provides a useful example that describes a system that "generates a three-dimensional sound space having a plurality of sound sources playing at a same time, wherein each of the plurality of sound sources is assigned a respective location in the three-dimensional sound space relative to one another, and wherein a user is assigned a current location in the three-dimensional sound space relative to each respective location." U.S. Patent No. 9,301,069 ("Seligmann") (Ex.1037) at Abstract.

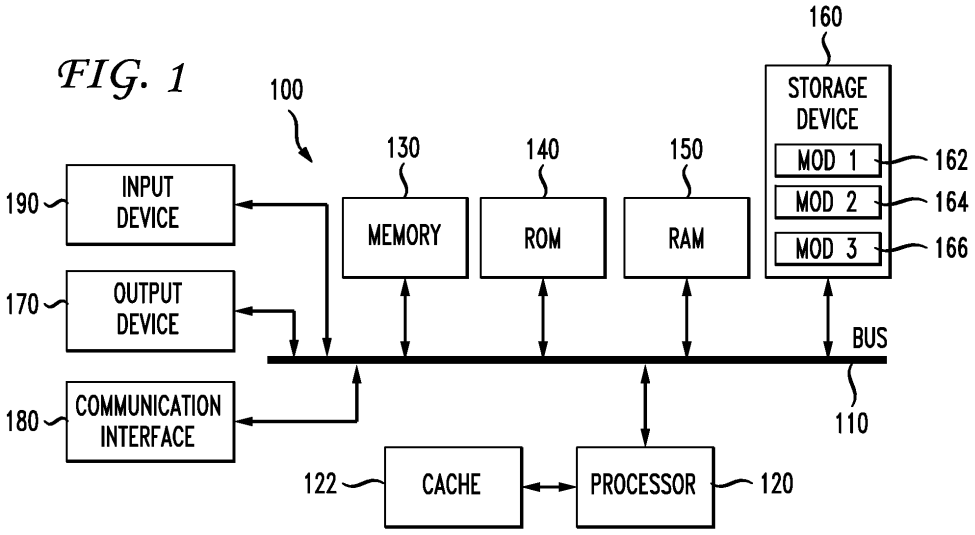
127. Seligmann's Figure 6 illustrates a user (602) experiencing a "three-dimensional sound space with multiple sound sources," specifically lectures from classrooms A-F:



Seligmann (Ex.1037) at 10:31-50, Fig. 6. As the user navigates the virtual space, "the sound perceived by the user 602 from the different classrooms will differ based on the proximity and/or location of the user 602 relative to the different classrooms," for example, sounds from classrooms A-D will be more prominent when the user is at position 1. Seligmann (Ex.1037) at 10:31-50. And this system is able to "arrange, order and/or organize the sound spaces" according to "a setting, a preference, a rule, a similarity, a relevance, a criteria, a ranking, a rating, an age, a user input, a history,

a context, a topic, a level of detail and/or granularity, etc." Seligmann (Ex.1037) at 12:53-58,

128. The concept of a computer memory hierarchy and corresponding access times goes back decades and would certainly have been well known to a person of ordering skill in June of 2016. For example, relatively slow access long-term storage (e.g., magnetic tape or hard disk drives), to random access memory (RAM), to very fast cache memory and processor registers. It was well-known that cache memory could be used automatically (e.g., via the operating system and the processor hardware), or manually/explicitly (e.g., using compiler directives). For example, Seligmann discloses the use of cache memory to store and play audio:



Seligmann (Ex.1037) at Fig. 1 (at 122). *See also* Seligmann (Ex.1037) at 4:55-57 ("The processor 120 may essentially be a completely self-contained computing system, containing multiple cores or processors, a bus, memory controller, cache,

etc.") and Seligmann (Ex.1037) at 4:36-40 ("The computing device 100 copies data from the memory 130 and/or the storage device 160 to the cache 122 for quick access by the processor 120. In this way, the cache provides a performance boost that 40 avoids processor 120 delays while waiting for data.").

129. In virtual conference settings, which, by June 2016, were well-known settings for virtual interactions, it was common to create specialized spaces for specific purposes such that a user could move from one conference space to another, and also to populate virtual conference settings with parameters including different sound sources (e.g., participants) and presentations of those sources (e.g., attendees around a table) so that a user could tell who was speaking based on the direction of that sound within the virtual conference setting. *See, e.g.*, Sodnik (Ex.1124) at 52 ("A different virtual room can be used for each call with a different seating plan, a different maximum number of participants and also a different virtual conference table. A user with headphones can identify individual participants by locating them and listening to just one of them, despite multiple talks speaking simultaneously. The proposed system can also be used in other virtual environments such as gaming and VR simulations."); Erickson, *Synchronous Interaction Among Hundreds: An Evaluation of a Conference in an Avatar-based Virtual Environment* (2011) ("Erickson") (Ex.1057) at Figs. 1-3 (showing different virtual conference locations (e.g., keynote, social event, and poster session) in IBM's Academy General

Meeting's Virtual Conference Center hosted entirely in a version of Second Life); Billinghurst, *A Wearable Spatial Conferencing Space* (1998) ("Billinghurst 1998") (Ex.1048) at 6 ("When users connect to the conferencing space their audio is broadcast to all the other users in the space. This is spatialized according to the distance and direction between speaker and listener.").

130. The principle of creating and designating sound sources applies more generally to virtual objects where the virtual content is divided into different fields of view. For example, a patent filed in September 2014—Ex.1125, Ross—describes "a system configured to present primary and secondary, tertiary, etc.., virtual reality content to a user." Ross (Ex.1125) at Abstract. For a user wearing a virtual reality headset, Ross describes "boundaries to divide a virtual space into areas where primary content, secondary content, tertiary content, etc. may be presented to the user," and that the "boundaries may be indicated to a user in the virtual space via sensory cues," such as with a "darkening of the primary virtual reality content" and "brightening of related … secondary, tertiary, etc., virtual reality content." Ross (Ex.1125) at 2:32-55, 6:55-67, 9:43-51, *see also* Ross (Ex.1125) at 3:38-56 (describing headset), 4:15-29 (explaining displaying virtual reality content based on the user's field of view), 5:45-52 (explaining boundaries), 6:5-12 (similar), 7:11-33 (describing visual sensory cues), 16:17-61 (describing other examples of sensory cues). Depending on the user's view direction, including directional and positional

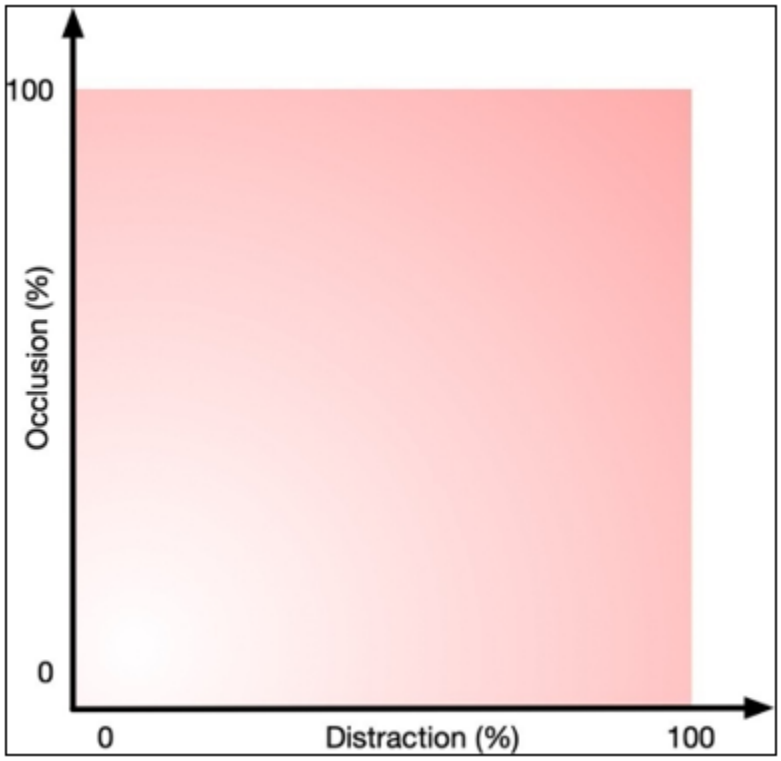
information of the user, the processor of the HMD of Ross's system determines that the user has moved "across a view boundary into an adjacent field of view," which triggers "different virtual reality [to be] displayed to the user," including different virtual objects. Ross (Ex.1125) at 20:22-40, 14:53-59 (describing the virtual reality content), 15:29-55 (same).

131. In Ross's system, a boundary can be created by tracking a user's movement, and can also be manipulated using controllers or other input, such as hand gestures. Ross (Ex.1125) at 23:22-45. And, through either a two-dimensional or three-dimensional interface, a user is able to create, customize, and adjust fields of view, the view boundaries, and also the virtual reality content within those respective boundaries. Ross (Ex.1125) at 7:51-62, 20:22-21:51, Fig. 5 (providing an example of a graphical user interface). Just as with the boundary, a user can manipulate objects in the fields using standard conventions. Ross (Ex.1125) at 22:17-29.

G. Safety and Chaperone Systems

132. Safety and chaperone systems that allowed the user to define safety boundaries or an area of gameplay were well known and frequently used with AR and VR systems before June 2016.

133. There are both occlusion concerns (e.g., 0-100% of the display) and distraction concerns (e.g., 0-100% of the user's attention), which exist on independent dimensions.



134. Because VR systems occlude the user's visual perception of physical space, the utility of safety boundaries or chaperone system with a wearable VR device is clear. Pedrotti (Ex.1005) at 1:30-33 ("Typically a HMD covers the user's eyes, so that the user sees only the virtual world while wearing the HMD and is thus unable to see the actual physical world around the user while in the virtual world."), 4:32-36 ("a boundary of a selected area is determined, for example, a 'safe area' which the user or another person has determined is clear of physical obstacles in the physical world so that the user may move freely without coming into contact with

such physical obstacles"). AR systems also are subject to occlusion concerns, as virtual objects may occlude real objects, even when virtual objects are "stand-ins" for real objects.

135. Further, even though a user may be able to perceive some of the physical surroundings through an AR device, the user can be susceptible to optical limitations and distractions. For example, a wearable AR device can impede a user's ability to shift focus from near-distance and far-distance objects. Sabelman, *The Real-Life Dangers of Augmented Reality* (2015) ("Sabelman") (Ex.1088) at 50. The user's ability to detect peripheral objects also often is diminished. Sabelman at 51. And the user's engagement with graphics presented in an AR environment can detract focus from surrounding physical objects. Sabelman (Ex.1088) at 52; *see also* Pedrotti (Ex.1005) at 16:16-19 ("Even some uses of a device such as Google Glass, which obscures only a small portion of the user's field of vision of the physical world, may benefit from some embodiments described herein."); Ross (Ex.1125) at 1:20-24 (identifying the problem of "maintain[ing] the attention of an audience member so he can be told a story if he can look wherever he wants and go wherever he wants in the virtual space").

136. As I discuss in the examples below, chaperone/safe area systems typically include an initial setup step where a user defines safety boundaries that surround an area for gameplay, and a method of continuously tracking a user's

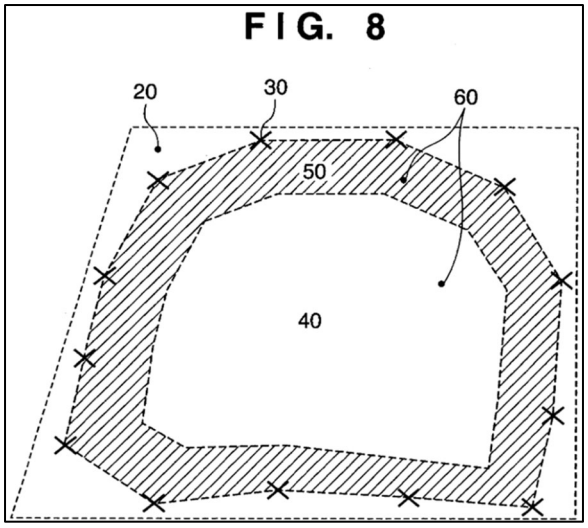
location to check whether the user is approaching or has exited the established safety boundaries.

137. A 1999 patent directed toward collision warnings for HMDs explained: "[T]he user can become immersed in the virtual environment, causing them to forget about, or become disoriented with respect to, the physical environment," and this risks the user, "in a VR game playing scenario," "tripping over a connecting cable … or possibly running into a wall." U.S. Patent No. 5,900,849 ("Gallery") (Ex.1014) at 1:43-59, 1:66-2:5.

138. Persons of ordinary skill in the art would have known before June 2016 that safety and chaperone systems permitted users to define the safety/chaperone zones, including by having a user walk around with a controller or handheld device to trace the perimeter of a play area. *See, e.g.*, Gallery (Ex.1014) at 4:14-21 ("provid[ing] for a set-up mode in which the user carries the HMD to boundary positions beyond which movement is hazardous," and "[t]hese positions are monitored by the motion detect stage 30 and stored as limits in the memory 40 (as shown by dashed line 46"); U.S. Patent Publication No. 2016/0124502 ("Sawyer") (Ex.1036) at [0034]-[0036] ("definition of Soft Bounds can be made … [b]y moving a tracked object (HMD or other worn sensors such as a game controller) to the n corners of the operating space"); U.S. Patent Publication No. 2007/0173265 ("Gum") (Ex.1015) at Abstract ("[a] wireless communications device with

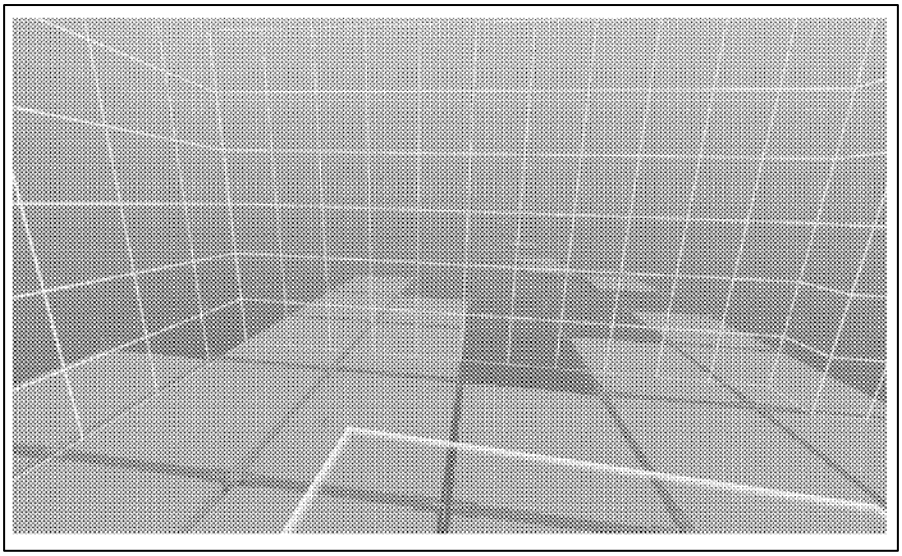
positioning capabilities is used to mark a boundary of a virtual operations area"), [0028] (device "may be carried to different points along a non-symmetric playing area boundary … to define the playing area boundary"); Pedrotti (Ex.1005) at 14:57-62 ("[a] boundary … can be defined, for example, by having the user walk around a perimeter chosen by the user with one of the trackers to define the outer boundary of a selected area"); Ross (Ex.1125) at 3:21-23 (sensor "generate[s] output signals conveying information related to a view direction of the user and/or other information"), 8:20-28 (describing hardware "to facilitate tracking physical user movements and/or position for use"), 13:28-37 (explaining that "view direction" may be based on the user's orientation or position), 20:29-34 (similar), 23:36-42 ("System 10 may be configured such that a controller" or "a body tracking system" "and/or other devices may be used to create and/or manipulate a boundary"), 23:42-45 ("System 10 may be configured to track a user's movement (e.g., walking around, leaning in, etc.) and create a boundary based on the user's movement."), Figs. 1-2 (showing the HMD with a processor).

139. In such systems, boundary points designated by the user are recorded and then connected to form a boundary:



U.S. Patent No. 7,330,197 ("Kobayashi") (Ex.1019) at Fig. 8, 5:15-20 (explaining that "by sequentially connecting the collected boundary-measured points 30 with a line, one closed area can be generated").

140. Then, in the virtual environment, it was common to display a grid, fence, or other 3D image, such as horizontal bars, to visually indicate to a user that he or she was approaching, moving toward, or crossing safety/chaperone zone's boundaries:



Sawyer (Ex.1036) at Fig. 5, [0044] ("visual warning signs displayed in the HMD"), [0054] (describing a "perimeter mesh"); *see also* Gallery (Ex.1014) at 4:22-30 (when the system "determines that one or more of the limits has been exceeded," "a visual warning to the user via display screens" is "called up from memory [] and flashed on the screen"); Kobayashi (Ex.1019) at 5:38-43 ("the positions of the boundary-measured points are presented to the user of the mixed reality apparatus when the user enters the warning area [] and a warning is used"), 13:47-52 ("where it is determined that the viewpoint position exists inside the warning area [], the plane or the boundary line of the warning area may be rendered by CG"); Pedrotti (Ex.1005) at 12:63-66 ("this visual warning is in the form of a grid of lines or a 'virtual fence' located at the boundary"), Fig. 11; Peck, *An Evaluation of Navigational Ability Comparing Redirected Free Exploration with Distractors to Walking—Place and Joystick Locomotion Interfaces* (2001) (Ex.1077) at Fig. 2 (annotated):

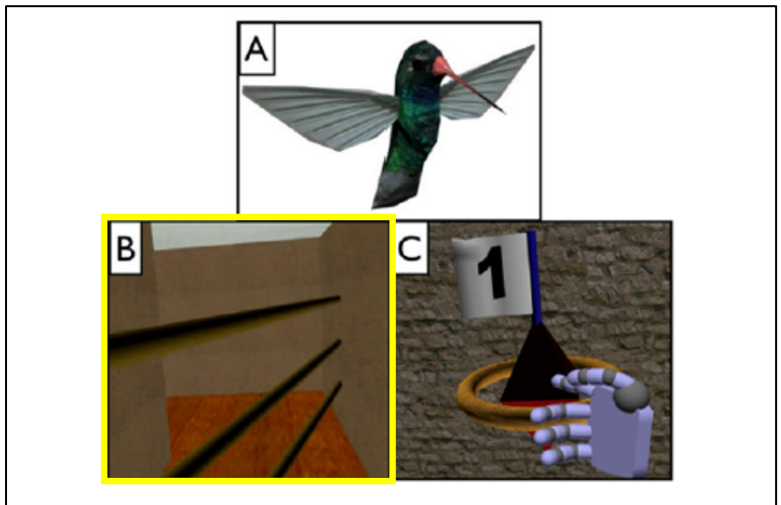


Figure 2.
Screen shots of **A**: the hummingbird distractor, **B**: the horizontal bars used as deterrents, and **C**: the virtual avatar hand selecting a target.

Jerald, THE VR BOOK (Ex.1063) at Fig. 18.3:

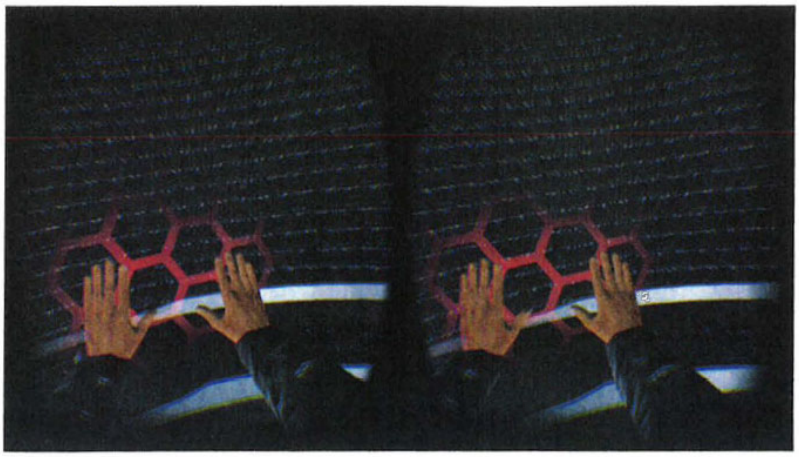


Figure 18.3 **A warning grid can be used to inform the user he is nearing the edge of tracked space.** (Image courtesy of Sixense)

Jerald, THE VR BOOK (Ex.1063) at 213 ("For a user approaching the edge of tracking, a real-world physical object not visually represented in the virtual world (e.g., a wall), or the edge of a safe zone, a warning grid (Figure 18.3), or the real world can fade in to provide a cue to the user that he should back off."). Other changes in visual presentation were also used to indicate crossing a boundary. *See, e.g.*, Ross (Ex.1125) at 16:17-39 ("a visually perceptible darkening of the primary virtual reality content, a brightening of the secondary, tertiary, etc., virtual reality content").

141. These visual warnings could change in appearance according to the user's actions. *See, e.g.*, Sawyer (Ex.1036) at [0048] (describing "an analog warning that increases in intensity (e.g., overlay of room bounds fades in [] brightness …)");

Pedrotti (Ex.1005) at 12:66-67 ("[t]he grid can be glowing or colored if desired to be more visible to the user").

142. Indeed, even in instances where a user's vision is not occluded, systems designed to create an immersive environment around the user benefit from such safety and chaperone systems. For example, in Walt Disney Imagineering's Digital Immersive Showroom (DISH) where the user is immersed in a virtual environment based on wall projections of the virtual scene, displaying a virtual image of a fence or grid indicating the boundary is useful to warn the user. See MousePlanet, *Step into the DISH – A Visit to Imagineering's Digital Immersive Showroom* (June 5, 2012) (Ex.1118) at 2 ("Approach a physical wall and a grid – vaguely reminiscent of Star Trek's holodeck – is generated, letting me know that I'm about to hit something real."); Orange County Register, *How They Did It: Cars Land's Virtual Reality* (June 25, 2012) (Ex.1117) (providing a detailed description of DISH). The DISH was developed by Mark Mine, formerly the Director of Technology Concept Design at WDI, and a close friend. I have personally experienced the chaperone system of the DISH on multiple occasions over many years. (I was there when they interviewed Mark and captured the video included with *Step into the DISH* above.)

143. It was also common to use audio cues to warn that the user is approaching, moving toward, or crossing safety boundaries. *See, e.g.*, Gallery (Ex.1014) at 4:22-30 ("an audio alarm may be triggered … to the headphone

speakers"); Sawyer (Ex.1036) at [0042] ("a warning sound"), [0047] ("a custom warning specific to the virtual environment is made (e.g., an in-game character tells the user to stop walking when the user approaches the boundaries of the operating space)"); Kobayashi (Ex.1019) at 13:20-28 ("the CPU 101 reads out of the RAM 102 the warning sound data warning that the user is inside the warning area 50 or outside the moveable area 60, and outputs the warning sound data to the audio output device 103 … to clearly notify the user of this apparatus that the user is currently near the boundary of the moveable area 60"); Begault (Ex.1007) at 171 (stating that "aural cues in virtual reality" often are "a means of replacing tactile sensation (haptic feedback) that would normally occur in a real environment," such as "activating auditory information in the form of a bumping or crashing sound, [so that] the user receives feedback that a particular physical boundary has been violated").

144. As discussed above, the warning can be provided via one or a combination of many ways, and even can be through the user "sensing" "when they are going to cross a boundary, which gives the user an opportunity to choose whether or not they want to cross a particular boundary." Ross (Ex.1125) at 6:8-12, *see also* Ross (Ex.1125) at 16:39-61 (listing a variety of visual, auditory, somatosensory, olfactory, haptic, and environment cues that serve as "sensory cues"). Regardless of the form of warning or cue, these indicators need to, and typically do, get the user's attention, e.g., via an abrupt appearance of visuals and/or audio, and distinct from

other content presented to the user (i.e., not blending in with other content). *See* Ross (Ex.1125) at 1:33-39 (explaining the general principle of "re-direct[ing] the attention" of the user, such as through "loud noises and/or characters telling and/or showing the [user] where to look").

VIII. Petition Grounds and Prior Art Combinations

145. The following table summarizes the grounds and prior art that form the bases for Petitioners' petition:

Ground	**Relevant Prior Art**	**Claims**
Ground 1 (Section X)	Pedrotti in view of Jang, and further in view of Begault	Claims 1-20 (claims 1, 8, and 14 are independent)
Ground 2 (Section XI)	McCulloch, in view of Pedrotti, and further in view of Flaks	Claims 1-20 (claims 1, 8, and 14 are independent)

146. In analyses provided below, I discuss each limitation in the challenged claims, explaining how the prior art discloses and renders obvious each limitation, and each claim as a whole.

IX. The Prior Art Relied On In The Petition

147. In this section, I provide brief overviews of the prior art references relied upon in the obviousness combinations detailed in the Petition and discussed in this declaration, some of which were mentioned above in discussion of the State of the Art. Each of these references is discussed further below, in my specific evaluations of the challenged claims.

A. Overview Of Pedrotti (Ex.1005)

148. I have been informed that U.S. Patent No. 9,851,786 ("Pedrotti"), which issued in December 2017, is prior art because it was filed in July 2015.

149. Pedrotti is titled "System and Method For Assisting A User In Remaining In A Selected Area While The User Is In A Virtual Reality Environment." Pedrotti (Ex.1005) at Cover.

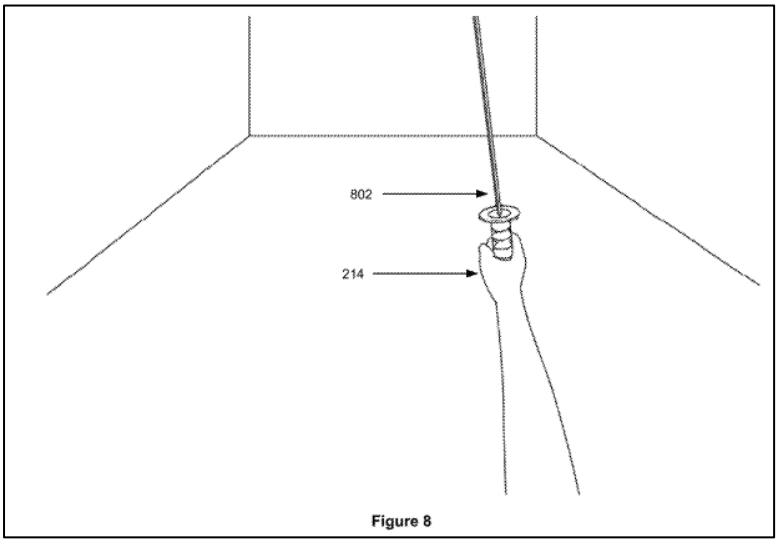
150. Pedrotti discloses a system that "allows an area in the physical world to be defined within which the user should remain, for example to avoid physical obstacles." Pedrotti (Ex.1005) at Abstract, 2:7-12 (describing the invention as "a solution that will allow a user … to remain in a selected area, for example to avoid collisions with surrounding physical objections"), 4:32-44, 11:43-12:15.

151. Pedrotti discloses that "it is difficult for the user to maintain awareness of his or her location in the physical world while the user sees only the virtual world," such that "[i]t may be desirable that the user remain within a selected area, for example, if there are physical objects in the vicinity of the user." Pedrotti (Ex.1005) at 1:57-66. Pedrotti discloses that this applies to "taking a step or moving an arm," or "any such movement [that] results in the user moving in the physical world." Pedrotti (Ex.1005) at 1:63-66.

152. Pedrotti discloses as parts of its system "a head mounted display (HMD) that … has a tracker allow[ing] a processor to track the position and

orientation of the HMD" and "physical controllers that a user may use to control certain actions or events in the virtual world." Pedrotti (Ex.1005) at 4:4-11. Pedrotti discloses that the "user is holding a handheld controller having a tracker which can be used to track the position and orientation of the handheld controller." Pedrotti (Ex.1005) at 15:7-12.

153. Additionally, Pedrotti discloses that "the user is seeing the virtual world as presented on [the] HMD" and "us[ing] the controller to interact with the virtual world to 'pick up'" virtual objections, such as "a bat, tennis racket, golf club or other sporting implement (or the handle of such an object), a gun, sword or other weapon (or again the handle thereof), or some other toy or device which will appear in the virtual world":



Pedrotti (Ex.1005) at Fig. 8 (depicting virtual sword 802), 5:47-53, 16:33-42.

154. Pedrotti provides a "flowchart of a method implemented by a processor" for the "display of a visual warning such as a virtual fence":

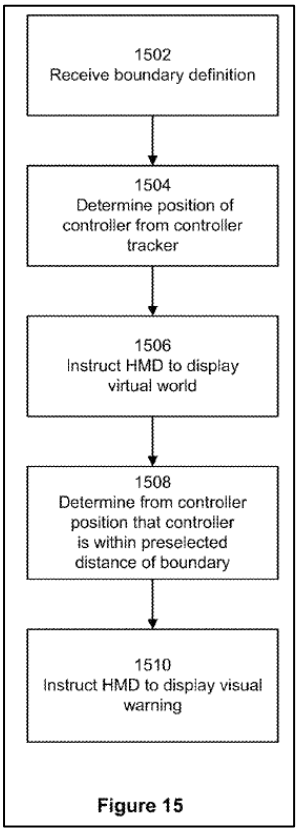


Figure 15

Pedrotti (Ex.1005) at 15:4-39, Fig. 15. This warning is displayed "to alert the user if the user approaches to within a preselected distance of the boundary." Pedrotti (Ex.1005) at Abstract.

155. Pedrotti discloses that the boundary for Pedrotti's "safe area" may be "determined in several ways." Pedrotti (Ex.1005) at 14:6-7. For example, the boundary may be defined as a circle. Pedrotti (Ex.1005) at 15:13-24 ("radius and location of the center of a circle"), Figs. 12-13. Or a boundary "around an irregularly shaped area, which is not circular can be defined, for example, by having the user

walk around a perimeter chosen by the user with one of the trackers." Pedrotti (Ex.1005) at 14:56-15:3. When a boundary is defined in this manner, "[t]he processor determines the position of the tracker at a number of sampling points as the user moves around the chosen perimeter, and from those points determines the boundary":

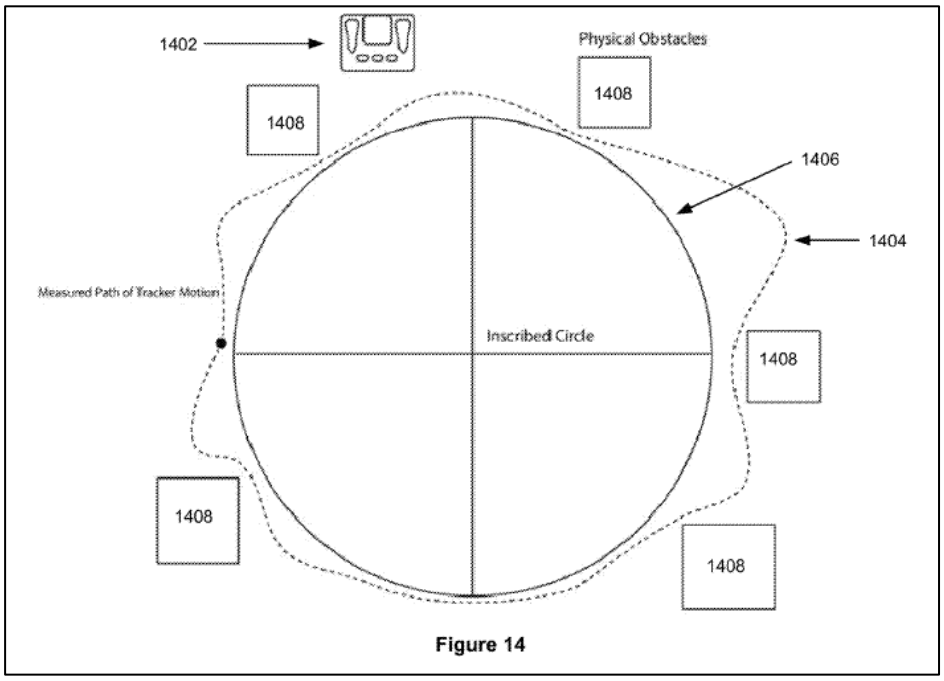


Figure 14

Pedrotti (Ex.1005) at 14:56-15:3, 15:13-22, Fig. 14.

156. Pedrotti discloses that its processor "tracks the position and orientation of the HMD tracker, and possibly the position and orientation of one or more trackers in the physical controllers," including through "various tracking techniques," such as "electromagnetic tracking." Pedrotti (Ex.1005) at 4:32-44, 4:59-5:24, 15:25-26, 16:22-26. As such, "the processor knows where the user's head and hands are located," and "if the processor has been provided with information about the

boundary of the selected area then the processor can also determine when the user's head and/or hand approaches the boundary." Pedrotti (Ex.1005) at 12:31-39. For example, "when the user's head and/or hand approaches to within a preselected distance, for example, one foot (again, either preprogrammed into the processor or user selectable), of the boundary of the selected area the processor generates a warning that the user is close to the boundary so that the user can take action to avoid the boundary and thus potential collision with the physical objects." Pedrotti (Ex.1005) at 12:40-50. Pedrotti discloses that the preselected distance "may vary by application," for example it may be "greater in an application in which larger body movements are expected from the user than in an application in which such body movements are not expected." Pedrotti (Ex.1005) at 13:46-62.

157. Pedrotti discloses that the processor "generates instructions to the HMD to generate the visual warning," e.g., "a grid of lines or a 'virtual fence' located at the boundary," which "can be glowing or colored if desired to be more visible to the user.":

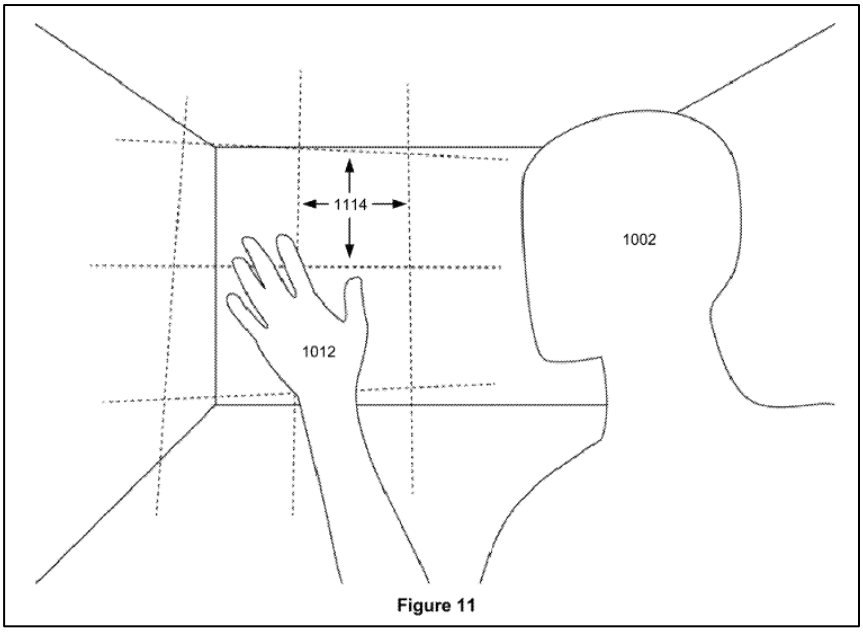


Figure 11

Pedrotti (Ex.1005) at 12:51-13:33 ("virtual fence 1114"), 15:26-29, Fig. 11.

158. Pedrotti further discloses that the type of warning may be altered, such as "with directional arrows indicating the direction of the boundary in relation to the user's view," "text or auditory warnings," or "an additional visual warning, that persists until the user returns to the selected area within the boundary." Pedrotti (Ex.1005) at 13:34-45, 13:63-14:5.

159. Pedrotti also discloses that its system is "applicable to HMDs that block the user's view of all or only part of the physical world," including "a device such as Google Glass, which obscures only a small portion of the user's field of vision." Pedrotti (Ex.1005) at 16:14-19.

B. Overview Of Jang (Ex.1006)

160. I have been informed that U.S. Patent No. 8,520,872 ("Jang") is prior art because it issued in August 2013.

161. Jang is titled "Apparatus and Method for Sound Processing In A Virtual Reality System." Jang (Ex.1006) at Cover.

162. Jang relates to "process[ing] sound in a focus area of a virtual reality system differently from sound in an un-focus[3] area." Jang (Ex.1006) at 1:18-23.

163. Jang's "sound processing may control the sound output with a sense of realism in consideration of a space shift in a virtual reality system." Jang (Ex.1006) at 2:26-28; *see also* Jang (Ex.1006) at 2:1-11.

164. As background, Jang explains that VR systems can "provide a high degree of realism in an electronically-manufactured environment, such as a in a virtual reality game or a 3D game." Jang (Ex.1006) at 1:28-30. Jang provides that VR systems "allow users to feel various manufactured sensory inputs (including visual sense, auditory sense, and tactile sense) … [that] replicate sensory experiences of the real world with varying degrees of realism." Jang (Ex.1006) at 1:31-33. For example, "life-like images and sounds may be generated," images "may be three-dimensionally realized by using … a Head Mounted Display (HMD)," and sound

[3] Jang uses the terms "un-focus area" and "non-focus area" interchangeably.

may be "generated by speakers, a headset, or any other audio device" and "use a localization technique capable of expressing the virtual location." Jang (Ex.1006) at 1:35-44.

165. Additionally, Jang discloses sound processing techniques to "model[] the path and change of sound according to relative locations of a sound-generating object, locations of surrounding things, and direction of sound propagation to give the sense of reality to the sound." Jang (Ex.1006) at 1:46-51. Jang further discloses the use of a "Head Related Transfer Function (HRTF)" to "express directionality" by modeling "the paths of the sound reaching listener's ears, which determine the direction of sound in view of the listener." Jang (Ex.1006) at 1:52-56.

166. Jang teaches that "[w]hen a user moved in a virtual environment, the real world is imitated as much as possible. However, in some situations it may be more convenient for a user if movement in the virtual environment does not precisely mimic the real world," for example, where "a user can shift between virtual spaces without having to portray the passage of distance or time to travel from one space to another." Jang (Ex.1006) at 1:57-65. Jang discloses that "[a]n example of such a virtual reality system includes a virtual reality game, 'Second Life,' developed by Linden Lab." Jang (Ex.1006) at 1:65-67.

167. To facilitate and better manage transitions that do no mimic real-world travel, Jang discloses "process[ing] and produc[ing] sound output in sound areas,"

which can be divided into "focus" and "un-focus" areas. Jang (Ex.1006) at 1:18-23. "The focus area may correspond to an area in the virtual environment in the immediate foreground of a visual perspective of a character corresponding to a user, and the non-focus area may correspond to an area that is not in the immediate foreground of the visual perspective of the character." Jang (Ex.1006) at 4:20-24; *see also* Jang (Ex.1006) at 3:39-48. Jang's Figure 2 provides an illustration of this, with focus area 203 shaded in gray:

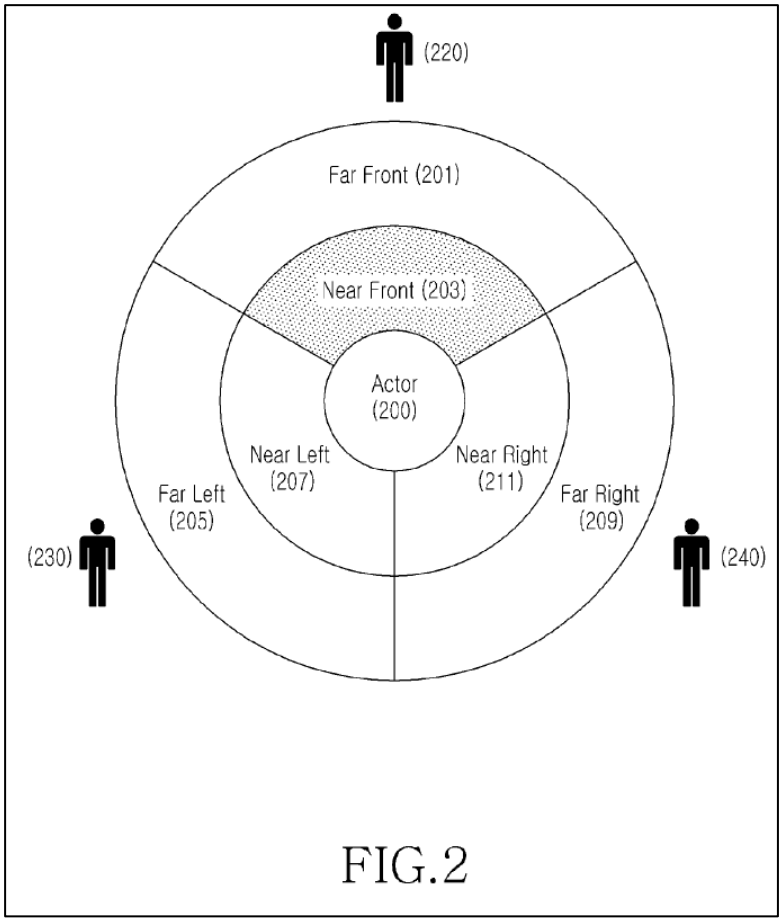


FIG.2

Jang (Ex.1006) at Fig. 2.

168. Jang discloses that "[t]he division between the focus area and the non-focus areas in FIG. 2 is only an example and may be modified in various ways according to the characteristics and/or topography of the virtual area at which [a] character is located." Jang (Ex.1006) at 8:25-40.

169. Jang taught that sound outputs for these areas is then processed differently when virtual space shifts occur. For example, "a volume of sound in a first space is gradually decreased when a space shift from the first space to the second space in the virtual reality space is detected," Jang (Ex.1006) at 2:32-48, and "sensory output corresponding to [a] focus area" can be generated "before generating a sensory output corresponding to the non-focus area." Jang (Ex.1006) at 3:62-4:9.

170. Jang further discloses that "each divided focus or non-focus area may contain any number of virtual objects represented by sensory data that may include audio and visual data," and that "at least one of the focus area and the non-focus areas may be divided into multiple areas in the virtual reality space according to a predetermined priority in controlling the volume of the sound or the left-right balance." Jang (Ex.1006) at 8:41-49; *see also* Jang (Ex.1006) at 4:25-39 ("determining a priority of each of the plurality of sensory sources"), 9:41-65 (discussing determination of priorities of sound sources), cls. 4 and 10.

171. Jang teaches a "control unit" for dividing these areas and better managing space shifts. For example, "[w]hen the control unit detects a space shift, the control unit may direct the sensory processing unit to output a sensory output signal to reduce a sensory output corresponding to the first virtual space while increasing a sensory output corresponding to the second virtual space." Jang (Ex.1006) at 2:35-47. The shifts, as Jang discloses, "may occur in various ways," such as through "key input of [a] user for character movement" or when a "scene change" is detected "due to space shift in a video output." Jang (Ex.1006) at 9:11-17.

172. Jang discloses an example where there is a "space shift in a virtual environment from basketball court 600 to conference room (610)":

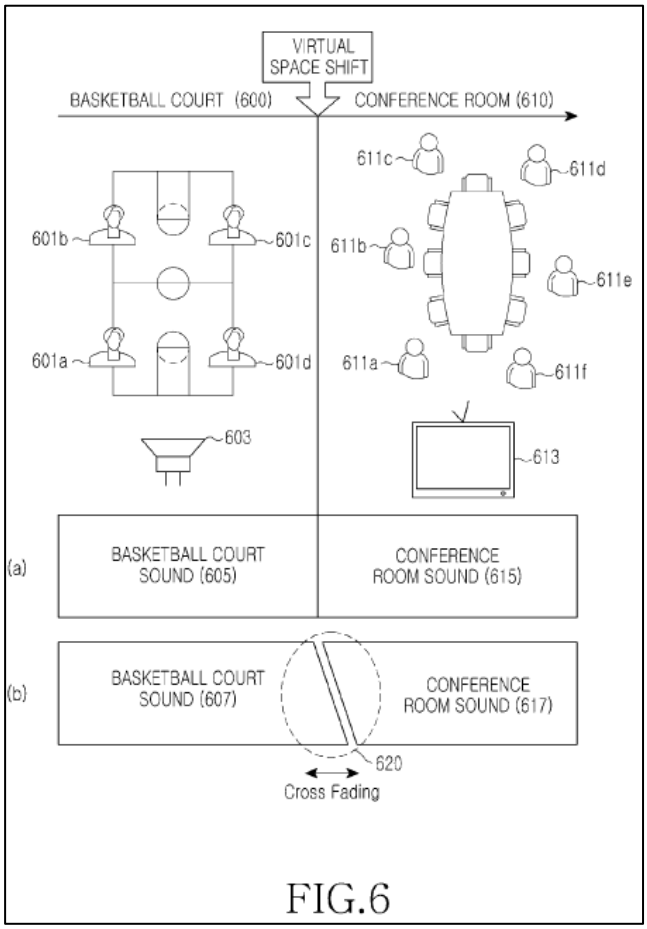


FIG.6

Jang (Ex.1006) at 10:59-60, Fig. 6.

173. When this shift in virtual spaces occurs (from the basketball court to the conference room), "priorities of the sound sources of a focus area and non-focus areas of the conference room 610 are first determined," and "the volume of the basketball court sound 607 is decreased or faded while the volume of the conference room sound 617 generated according to the priorities of the focus area or non-focus areas of the conference room 610 is increased." Jang (Ex.1006) at 11:1-16.

C. Overview Of Begault (Ex.1007)

174. I have been informed that Begault is prior art because it is a 2000 publication.

175. Begault is titled "3-D Sound for Virtual Reality and Multimedia."

176. Begault describes processes for producing "3-D sound" for VR.

177. Begault discloses that the terms "3-D sound," "binaural audio," and "spatialized sound" are "equivalent designations" in that they all "refer to techniques where the outer ears (the pinnae) are either directly implemented or modeled as digital filters." Begault (Ex.1007) at x. Begault further discloses that "[b]y filtering a digitized sound source with these filters," one can "place sounds anywhere in the virtual space about a headphone listener." Begault (Ex.1007) at x. Furthermore, "[t]he combination of 3-D sound within a human interface along with a system for managing acoustic input is termed a 3-D auditory display." Begault (Ex.1007) at x.

178. Begault explains that "[e]arly on in the development of virtual reality, it was seen that sound should have some type of interactive, spatial character imposed on it." Begault (Ex.1007) at 12. 3-D sound "improve[s] the quality and ease of interaction within a human interface, communication system, or office or home environment," and also "contribute[s] to the sense of immersivity in a 3-D environment." Begault (Ex.1007) at 13. Begault discloses that "[o]ne might be able to work more effectively within a VR environment if actions [a]re accompanied by

appropriate sounds that seemingly emit from their proper locations." Begault (Ex.1007) at 13.

179. In its Chapter 2, Begault describes in detail HRTFs and localization with HRTF cues. Begault (Ex.1007) at Chpt. 2.

180. Begault discloses that "[t]he spectral filtering of a sound source before it reaches the ear drum that is caused primarily by the outer ear is termed the head-related transfer function (HRTF)," and "[t]he use of HRTF spectral shaping is typically featured as the key component of a 3-D sound system." Begault (Ex.1007) at 41. Begault further explains that "binaural HRTF" is "terminology [used] for referring to both left- and right-ear HRTFs" and "can be thought of as a frequency-dependent amplitude and time-delay differences that result primarily from the complex shaping of the pinnae." Begault (Ex.1007) at 41. Begault discloses, too, that "inclusion of the binaural HRTF is fundamental for a 3-D sound system," and it discusses implementation details for HRTF processing and generating binaural sound. Begault (Ex.1007) at 99, 105-06 ("The basis of 3-D sound processing lies in imitation of the spatial cues present in natural spatial hearing, where the binaural HRTF imposes spatially dependent spectral modifications and time delays on an incoming wavefront to the hearing system. In virtual spatial hearing, it is possible to imitate these modifications using a DSP as a digital filter. One can obtain HRTF data by several methods (described later) and then use digital filters—specifically,

two different *h(n)*s, termed a binaural impulse response—to produce a desired virtual acoustic source position."), 118 ("A review of the literature shows that KEMAR's HRTFs have been used many times in both 3-D sound applications and localization studies (e.g., Kendall, Martens, and Wilde, 1990)."), 139 ("Some of these methods have been worked into 3-D sound systems, where HRTF processing is applied not only to the direct sound but to the indirect sound field as well, resulting in a synthetic spatial reverberation.").

181. Begault discloses various examples of in which "distributed 3-D audio devices" were "integrated within a dedicated virtual reality application," such as the Convolvotron 3-D audio device within NASA'S VIEW system.[4] Begault (Ex.1007) at 170.

182. Another example Begault discloses is "Computer Workstation 3-D Audio," where "the audio signal is brought into the computer and then spatialized,"

[4] *See* Jerald, THE VR BOOK (EX. 1063) at Fig. 2.13 (photograph of NASA's VIEW system):



Figure 2.13 The NASA VIEW System. (Courtesy NASA/S.S. Fisher, W. Sisler, 1988)

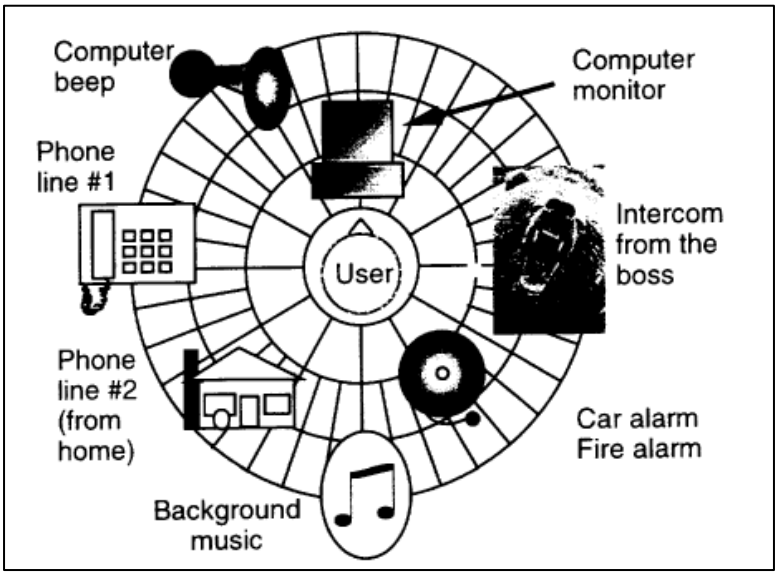
and "the communication source can be usefully arranged in virtual space." Begault (Ex.1007) at 172. As Begault explains, this feature "becomes particularly important in multiconversation teleconferencing," or "spatial audio teleconferencing," or "an audio window system." Begault (Ex.1007) at 172; *see also* Begault (Ex.1007) at 173-74 (providing further detail on "audio windows").

183. Begault also discussed a system called Multidimensional Audio Windows ("MAW"), which allowed "teleconference participants to wander around in the virtual room and to focus their voice toward particular conference participants by using a binaural HRTF to process each virtual source." Begault (Ex.1007) at 173. Begault notes that, with MAW, users could "leapfrog between teleconference sessions," or "move to a 'private conference' by moving the icons of the participants to a special region on the computer screen, symbolized as a separate room." Begault (Ex.1007) at 173.

184. Begault discloses that audio spatialization is not limited to teleconferencing environments, but "all types of sonic input," which "could be directionalized to a specific location, controlled by the user." Begault (Ex.1007) at 172.

185. Begault explains that "it is not necessary to place [] audio sources in their corresponding visual locations" because "audio spatial mapping can correspond to a prioritization scheme." Begault (Ex.1007) at 172. And Begault

presents "a hypothetical GUI for arranging [] various sound inputs in virtual auditory space in a manner configurable by each individual listener":



Begault (Ex.1007) at 172-73, Fig. 5.12.

186. As Figure 5.12 depicts, "[t]he basic concept is to represent each form of auditory input iconically on the screen, and then allow manipulation" of the exact locations of the icons. Begault (Ex.1007) at 172. In turn, "[t]he computer interprets the relative location of the icons on the screen as commands to a multiinput, 3-D sound spatialization subsystem." Begault (Ex.1007) at 172. This means a sound spatialization subsystem will take the relative location of manipulated icons and generate 3D sound, or binaural sound, to users at locations around the user corresponding to the icons' relative locations, including "the distance and relative azimuth of each source." Begault (Ex.1007) at 172.

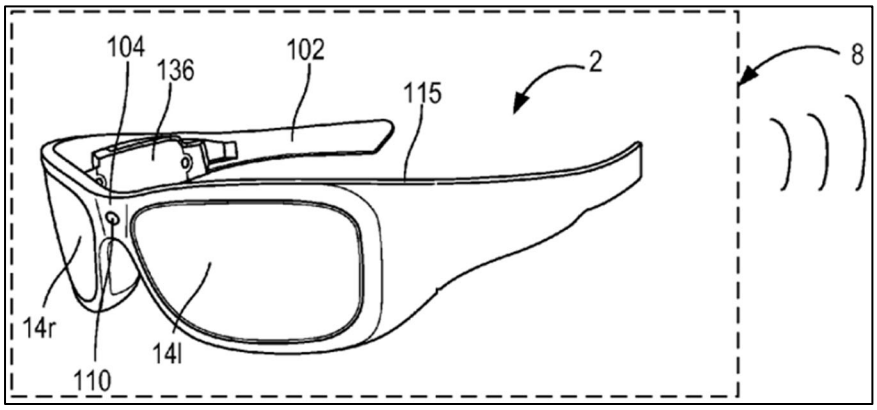
D. Overview Of McCulloch (Ex.1008)

187. I have been informed that U.S. Patent No. 9,041,622 ("McCulloch") is prior art because it issued on May 26, 2015.

188. McCulloch is titled "Controlling A Virtual Object With a Real Controller Device." McCulloch (Ex.1008) at Cover.

189. McCulloch discloses a system for "controlling a virtual object displayed by a near-eye, augmented reality display with a real controller device." McCulloch (Ex.1008) 1:18-21, 1:46-48, Fig. 5.

190. McCulloch discloses a "display device system" (item 8) that includes a display device (e.g., an HMD) (item 2) and control circuitry (item 136) and communicates with real controller devices (e.g., a handheld inertial motion unit ("IMU")):



McCulloch (Ex.1008) at Fig. 1B, 4:25-42 (providing examples of real controller devices), 4:49-55 (describing the HMD), 6:55-7:3 (describing the real controller device), 7:4-22 (also describing the HMD).

191. As shown below, the control circuitry (item 136) for this "display device system" includes a processing unit (item 210), memory (item 244), wireless interface (item 137), and power supply (239):

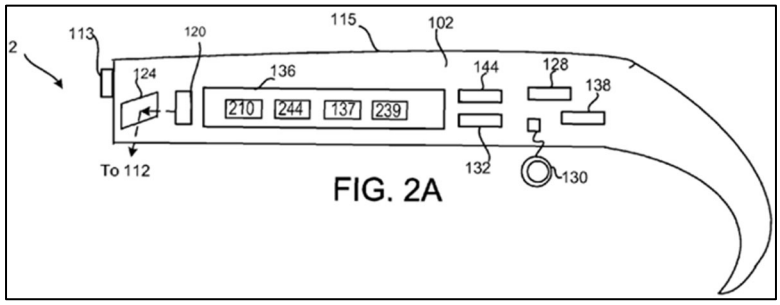


FIG. 2A

McCulloch (Ex.1008) at Fig. 2A, 8:1-39.

192. McCulloch further discloses that the software computing environment (item 54) for its "display device system" (again, item 8) includes an image and audio processing engine (item 191), device data (item 198), and real controller device interface software (item 188), among other components:

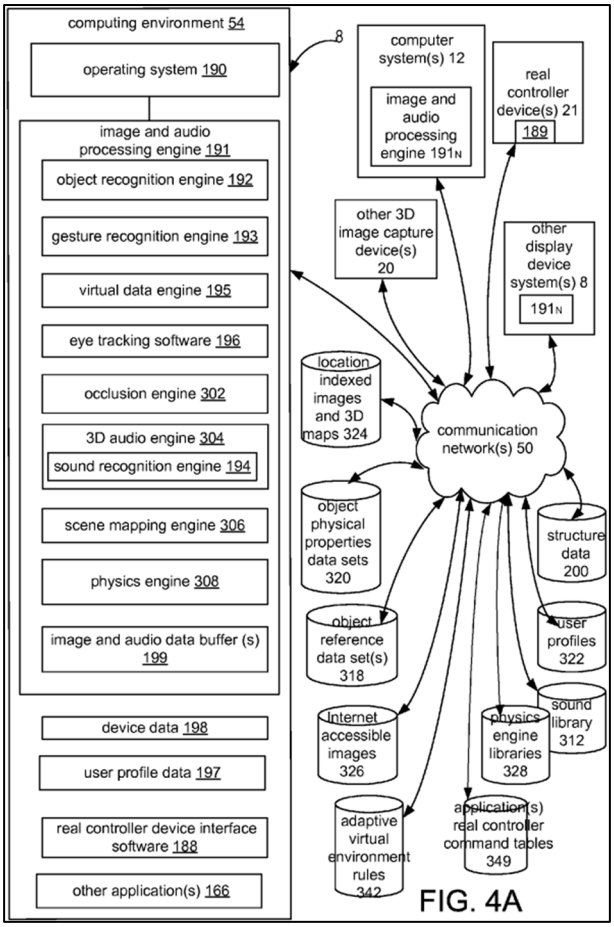


FIG. 4A

McCulloch (Ex.1008) at 13:56-14:11 (describing computing environment), Fig. 4A.

193. The "[i]mage and audio processing engine 191 includes object recognition engine 192, gesture recognition engine 193, virtual data engine 195, eye tracking software 196," "an occlusion engine 302, a 3D positional audio engine 304 with a sound recognition engine 194, a scene mapping engine 306, and a physics engine 308 which may communicate with each other." McCulloch (Ex.1008) at 14:5-11.

194. Scene mapping engine 306 maps the user's environment and "identifies the position and tracks the movement of real and virtual objects in [a] volumetric

space based on communications with the object recognition engine" and "applications [] generating virtual objects." McCulloch (Ex.1008) at 16:58-63, 19:8-27, Fig. 4C; *see also* McCulloch (Ex.1008) at 15:30-47 (describing mapping the user's environment with position and orientation data). For a virtual object, "the virtual data engine 195 has a target 3D space position of where to insert the virtual object." McCulloch (Ex.1008) at 23:39-56.

195. The 3D audio engine 304 "plays audio data for the virtual object projected from a 3D space position of the virtual object." McCulloch (Ex.1008) at 25:60-26:19, 21:21-29 (further describing 3D audio engine 304), 22:66-34:4 (describing sound library). Each virtual object is associated with "audio data… projected from a 3D space position of the virtual object" generated through HRTFs processed by the 3D audio engine. McCulloch (Ex.1008) at 26:7-19. With respect to the 3D audio engine, McCulloch incorporates by reference U.S. Patent Application No. 12/903,610, issued as U.S. Patent No. 8,767,968, which I discuss in further detail below (*see* Section IX.E). Flaks provides implementation details for an audio engine that processes HRTFs to "accurately localize a sound as coming from a virtual sound source." McCulloch (Ex.1008) at 21:21-38; Flaks (Ex.1009) at 1:44-46.

196. Device data 198 on McCulloch's system includes "data from sensors or sensing units," which are associated with the HMD itself. McCulloch (Ex.1008) at

24:9-21. In this manner, McCulloch's system tracks its HMD's position and orientation with an inertial sensing unit, sensing "position, orientation, and sudden accelerations," and depth cameras that "transmit and detect infrared light from which depth data may be determined." McCulloch (Ex.1008) at 7:24-67 (describing capture devices), 8:17-39 (describing the different sensors incorporated into McCulloch's HMD), 15:31-38 (explaining that sensor data, e.g., head position data, is used to map what is around the user's environment in a depth map). Device data 198 "makes available … location data, head position data, data identifying an orientation with respect to the ground and other data from sensing units of the display device," along with gestures, sounds, and "positions of objects from the scene mapping engine." McCulloch (Ex.1008) at 14:53-67.

197. Data from McCulloch's sensors is also shared with the HMD's image generation unit that "can display virtual objects at various depths" and "a user perspective of the virtual object [] determined from a position and orientation." McCulloch (Ex.1008) at 8:40-9:16 (describing the image generation unit that is used to display virtual objects at various depths), 11:56-58 (describing that the virtual object is displayed according to the user's perspective), 12:4-17 ("virtual objects are tracked in the display field of view"), 12:41-51 ("both real and virtual objects are displayed in the display field of view as they are seen from the user perspective").

McCulloch discloses that "[i]n some examples, virtual objects are tracked in the display field of view and real objects are ignored." McCulloch (Ex.1008) at 12:3-4.

198. McCulloch's HMD tracks real controller devices, which can be used to select and control virtual objects and virtual object representations of real objects. McCulloch (Ex.1008) at 4:14-31 (describing object selection by a real controller device), 26:20-24 ("a virtual object representing the real object can be generated and controlled by the data received from the real controller device"), 28:12-20 (describing selection of an object to be controlled), 29:6-12 ("changes in position and orientation of the handheld controller causes its inertial motion unit to generate one or more signals which are converted … to be user input requesting display of an actual by the virtual object"), 29:40-43 ("speed, acceleration and direction of motion of the [real controller] device … is sent as data to the display device system"), Figs. 8B, 8D (showing examples of a user controlling a virtual basketball). McCulloch's system "receives user input data from a real controller device requesting an action to be performed by the virtual object," "appl[ies] the user input data," and "display[s] the action." McCulloch (Ex.1008) at 1:59-66, 11:42-46 (describing Figs. 3A-3F), (describing object selection by a real controller device), Figs. 3A-3F, McCulloch (Ex.1008) at 25:29-38.

199. McCulloch also discloses creating user-defined, 3D zones for gameplay: "For example, a gaming application may receive user input identifying

boundaries for a playspace in which virtual objects can be positioned." McCulloch at (Ex.1008) 20:11-13. And McCulloch discloses that its system can "execute an application" using a "current physical environment as a factor in the execution of a game," as "applications store adaptive virtual environment rules 342 for effecting the placement and display of one or more virtual objects in a 3D mapping of an environment during their execution." McCulloch (Ex.1008) at 20:4-11.

E. Overview Of Flaks (Ex.1009)

200. I have been informed that U.S. Patent No. 8,757,968 ("Flaks") is prior art because it issued on July 1, 2014.

201. Flaks is titled "System and Method for High-Precision 3-Dimensional Audio For Augmented Reality." Flaks (Ex.1009) at Cover.

202. Flaks discloses techniques "for providing 3D audio," where "the 3D audio signal may include a number of components that are determined based on collected sensor data and the listener's location." Flaks (Ex.1009) at Abstract. Flaks discloses that "sensor data may be used to collect physical characteristics of the listener such that a suitable HRTF may be determined from a library of HRTFs." Flaks (Ex.1009) at Abstract.

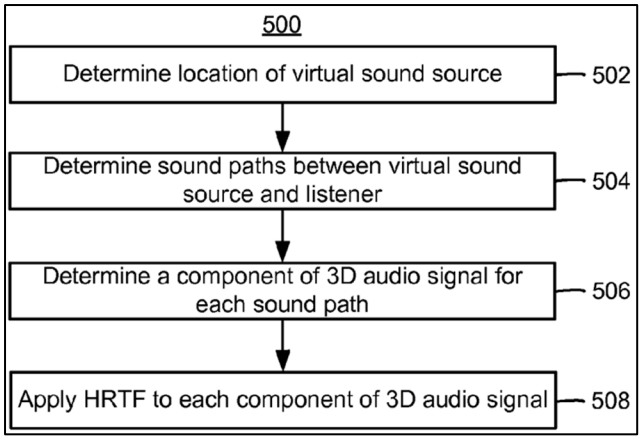
203. Flaks discloses that "[a] 3D audio signal may be generated based on sensor data collected from the actual room in which the listener is located and the actual position of the listener in the room." Flaks (Ex.1009) at 3:21-24. As Flaks

explains, "the physical characteristics of a room can be factored in," as "a sound reflecting off from a hardwood floor will be different than a sound reflecting from a carpet." Flaks (Ex.1009) at 7:6-21.

204. Flaks discloses that "[t]he audio signal may represent a 'virtual sound' that represents a sound coming from some specific location in 3D space," where the "location might represent some object being displayed on a video screen, or even a real physical object in the listener's room." Flaks (Ex.1009) at 3:23-28, 4:10-20. Flaks teaches that the room model capturing these details "may be updated at any desired interval." Flaks (Ex.1009) at 9:60-61.

205. Flaks discloses that the 3D audio signal "is provided to the listener through a set of headphones." Flaks (Ex.1009) at 3:28-29, 4:2-5.

206. Flaks also discloses a process of "determining components of a 3D audio signal" that includes identifying the virtual sound source and determining the 3D audio signal for each sound path. Flaks (Ex.1009) at 9:4-64. In this process, the listener's HRTF is applied to each component in order to "generate the 3D audio signal":



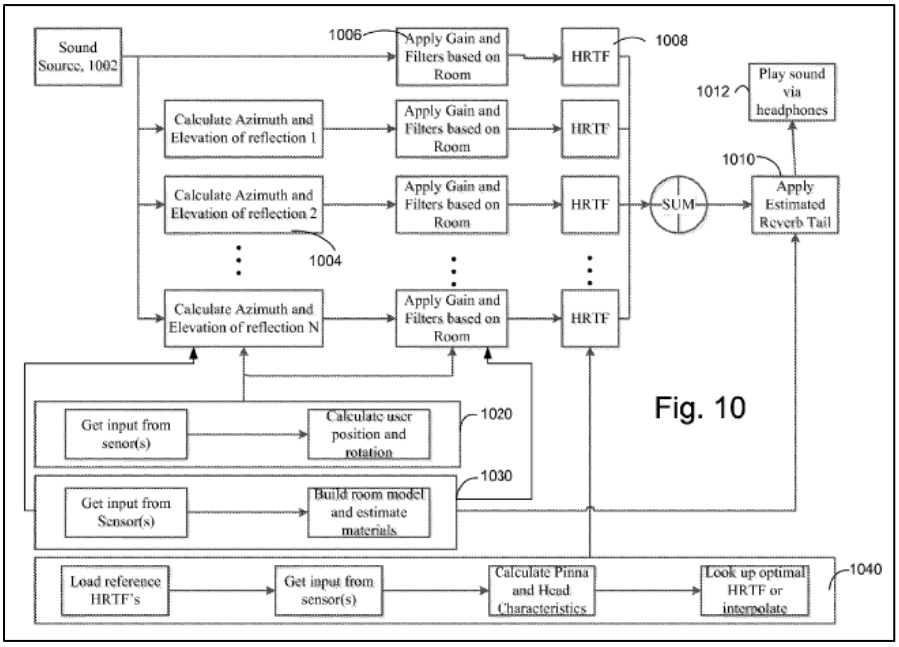


Fig. 10

Flaks (Ex.1009) at 9:65-10:4, 13:55-14:4, Figs. 5A, 10 (block diagram of one embodiment of generating a 3D audio signal).

207. Flaks further discloses a process of "determining an HRTF for a particular listener," which can be stored for the user and updated "in real time" based on "changing user position." Flaks (Ex.1009) at 11:44-12:57, 14:27-39 (describing playing a 3D audio signal for the user so the user points to the apparent source of the sound, which allows the system to determine the effectiveness of the HRTF), Fig. 7.

Because "determining detailed characteristics of the listener 8 such that an HRTF may be stored for the user might be done infrequently," Flaks also teaches selecting HRTFs from previously determined HRTFs based on "stored detailed user characteristics." Flaks (Ex.1009) at 12:58-13:16, Fig. 8.

208. Flaks discloses that its system uses cache memory (e.g., level 1 cache 102 and level 2 cache 104) to "temporarily store data and hence reduce the number of memory access cycles, thereby improving processing speed and throughput":

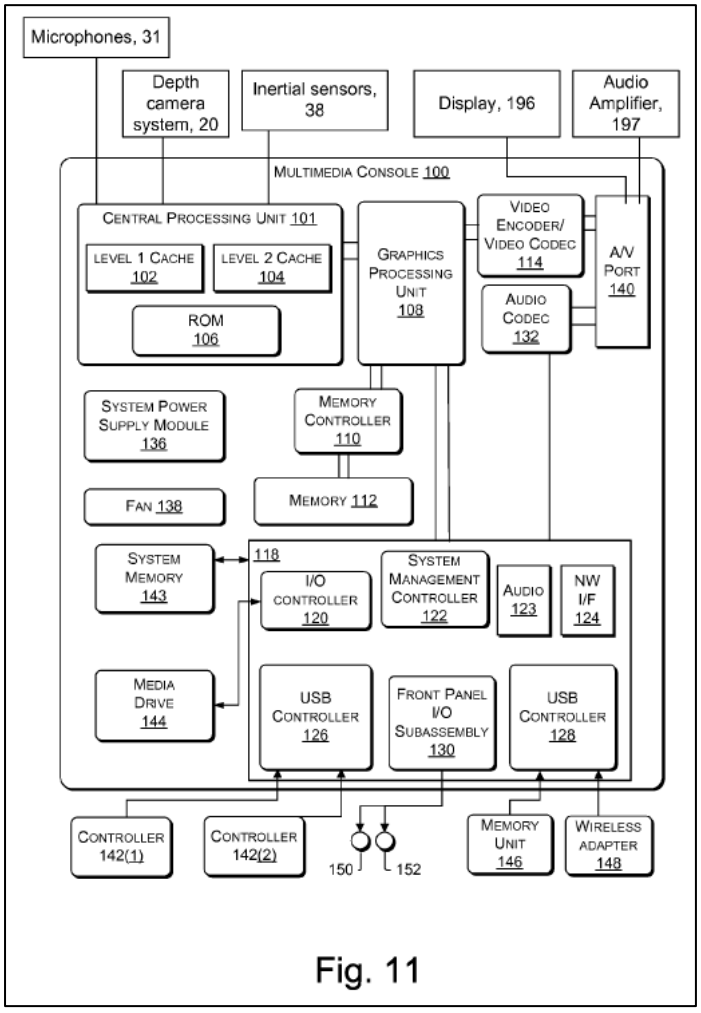


Fig. 11

Flaks (Ex.1009) at 14:60-67, Fig. 11.

X. Ground 1: Claims 1-20 Are Unpatentable Over Pedrotti In View Of Jang, And Further In View Of Begault

209. In this section, I explain why every limitation of claims 1-20 of the '737 patent, and each of claims 1-20 as a whole, would have been obvious to persons of ordinary skill in the art over Pedrotti in view of Jang, and further in view of Begault.

A. Reasons Persons Of Ordinary Skill In The Art Would Combine Pedrotti And Jang

210. Persons of ordinary skill in the art would have understood and been motivated to combine Pedrotti's system and method for assisting a user in remaining within a selected area with Jang's sound processing methods.

211. First, Pedrotti and Jang are analogous art because both relate to improving VR applications, including VR gaming. Pedrotti (Ex.1005) at 1:8-10 ("The present invention relates generally to virtual reality devices …"); Jang (Ex.1006) at 1:18-23 ("The present general inventive concept relates to an apparatus and a method to perform sound processing in a virtual reality system …"), 1:28-30 ("Virtual reality systems may be used to provide a high degree of realism in an electronically-manufactured environment, such as in a virtual reality game or a 3D game.").

212. Second, persons of ordinary skill in the art designing a VR system and reading Pedrotti—which recognizes the importance of sound but does not

specifically address sound processing—would have been motivated to look to references disclosing advantageous sound processing techniques, including references like Jang that disclose such techniques. Pedrotti itself recognizes the importance of sound in creating a sense of realism. Pedrotti (Ex.1005) at 1:18-20 ("While virtual reality can recreate a number of sensory experiences, the senses most commonly used today to create virtual reality appear to be sight and ***sound***.") (emphasis added). And as Jang explains, its described sound processing techniques aid in "provid[ing] a virtual reality that can give a higher sense of realism." Jang (Ex.1006) at 2:7-11. Jang discloses that, in accordance with its techniques, "it is possible to make a change in the sound by modeling the path and change of sound according to relative locations of a sound-generating object, locations, or surrounding things, an direction of sound propagation, to give the sense of reality to the sound." Jang (Ex.1006) at 1:46-51, 1:52-56 (additionally disclosing use of HRTFs to express directionality for sound reaching the listener's ears).

213. Persons of ordinary skill in the art designing a VR system would have understood that Jang's disclosed sound processing techniques can be used with HMDs, such as the HMD in Pedrotti. *See* Jang (Ex.1006) at 1:38-41; Pedrotti (Ex.1005) at 15:53-58 (discussing that the HMD is able to provide audio). Relevant to Pedrotti's existing disclosure directed to help "avoid collisions with surrounding physical objects" in the physical world (Pedrotti (Ex.1005) at 2:7-12), Pedrotti is

compatible with the sound processing techniques of Jang, which are directed to help guide the user in the virtual world.

214. Because Pedrotti's teachings limit the user's physical movements to within a "safe area" (Pedrotti (Ex.1005) at 4:32-44), persons of ordinary skill in the art would have recognized that Jang teaches how to navigate a virtual reality space (e.g., moving from a virtual basketball court to a virtual conference room) without needing to walk in the virtual world the same distance the user would have to walk in the physical world, the latter of which is constrained based on Pedrotti's teachings. *See* Jang (Ex.1006) at 2:1-11 (explaining that the "virtual reality space shifts from a first space to a second space"). Persons of ordinary skill in the art would have been motivated to incorporate the teachings of Jang into Pedrotti's system in order to enable the user to experience the full breadth of the virtual world, even with physical constraints imposed by Pedrotti's "safe area." Furthermore, persons of ordinary skill in the art would have had a reasonable expectation of success in implementing the space shifts taught by Jang with Pedrotti's system because Pedrotti's handheld controller provides a common way for the user to provide the "key input" Jang teaches, such as selection of a second space to effect the space shift. *See* Pedrotti (Ex.1005) at 1:40-45 (describing Pedrotti's handheld controllers); Jang (Ex.1006) at 9:11-17 ("The shift from the first space to the second space may occur in various ways, for example, when the control unit 114 detects a key input of the user for

character movement through a key input unit (not shown) of the virtual reality apparatus 110 or when the control unit 114 detects scene change due to space shift in a video output (not shown).").

215. Third, Pedrotti and Jang are Sixense and Samsung patents, respectively. As I mentioned in Section VII.A, persons of ordinary skill in the art would have known that both Sixense and Samsung were working on VR systems, including collaboratively. As was known in the field, Sixense had made a name in the field through its full body motion STEM system, which was a form of wireless hand and body tracking. Parisi (Ex.1075) at 24. As indicated in LEARNING VIRTUAL REALITY—which is a guide for VR development essentials for desktop, mobile, and browser-based applications and a compendium for commercially available systems including OculusVR, Samsung Gear VR, and Google Cardboard VR—persons of ordinary skill in the art were advised to "[e]xpect to see a lot of innovation in this area [relating to VR input devices] over the next few years." Parisi (Ex.1075) at 24. Thus, in view of the express urging of individuals well-versed in the field, persons of ordinary skill in the art would have been motivated to look to the technologies being developed by Samsung, such as the Samsung Gear VR, and Sixense, including but not limited to Sixense's positional tracking of controllers. *See also* Section VII.A (discussing available VR systems, including for headsets and input devices). Furthermore, persons of ordinary skill in the art would have known that companies

specializing in different aspects of a VR system (e.g., headsets versus input devices) likely would have collaborated since such technologies complemented one another and could (or at a minimum would obviously) be paired in future research and development. Parisi (Ex.1075) at 24 ("At this point in time, there is no one way to interact in VR using these new input devices. Much depends on the type of application being created, and the system to which the devices are connected … In the meantime, all this research is a big part of the fun. Expect to see a lot of innovation in this area over the next few years.").

216. Fourth, Pedrotti and Jang reference commercially available and compatible VR hardware and VR applications, respectively. Persons of ordinary skill in the art would have been motivated to look to pair VR hardware with VR applications, especially where the application has been specifically created for use on that particular device. *See, e.g.*, Parisi (Ex.1075) at 14 (referring, as an example, to a "3D third-person platform experience that was created exclusively for Oculus" by a game studio), 86 (referring to "an Oculus-enabled version" of a game).

217. In discussing HMDs, Pedrotti references "the Oculus Rift" HMD. Pedrotti (Ex.1005) at 1:28-29 ("One type of HMD presently available is the Oculus Rift from Oculus VR, now owned by Facebook."). In discussing games for which its techniques are useful, Jang references "'Second Life,' developed by Linden Lab," Jang (Ex.1006) at 1:65-67, which persons of ordinary skill in the art would have

known could and would be "compelling" on an Oculus Rift. As of 2014, it was known that Second Life, which is an "immersive 3D environment that represents users as avatars," was compatible with Oculus devices such as the Oculus Rift. Second Life Community, *Using the Oculus Rift with Second Life* (Oct. 13, 2014) ("Second Life Community") (Ex.1089); YouTube, *How to Use Oculus Rift with Second Life* (posted May 22, 2014), *available at* https://www.youtube.com/watch?v=TLL5JVwG118, at 0:06-11 ("With the Oculus Rift, Second Life is more compelling than ever."), 1:56-2:03 ("You'll soon experience Second Life in a whole new, yet natural, way."); Erickson at 504 (further describing an entire IBM conference held virtually using a "version of Second Life [that] supported spatialized audio"). Also, as of August 2015, Linden Labs, the creator of Second Life, was calling for help testing its new virtual-reality world with "3D audio" that was to include "multi-user, interactive virtual experiences" and "optimized for VR headsets like Oculus Rift." VentureBeat, *Second Life Creator: Linden Lab Starts Testing Its Virtual-Reality World: Project Sansar* (Aug. 18, 2015) (Ex.1099) at 1-2.

B. Reasons Persons Of Ordinary Skill In The Art Would Combine Pedrotti, Jang, and Begault

218. Persons of ordinary skill in the art would have understood and been motivated to further incorporate Begault's sound processing and management

techniques, e.g., Begault's HRTF processing, and hardware, e.g., Begault's digital signal processors ("DSPs") into the combination of Pedrotti and Jang (discussed above in Section X.A).

219. First, Begault is analogous art to Pedrotti and Jang because it addresses the importance of "immersiveness" in "virtual reality and multimedia systems," which includes "both the interactivity and the quality of the rendering." Begault (Ex.1007) at 10. Furthermore, Begault explains: "3-D sound can contribute to the sense of immersivity in a 3-D environment. One might be able to work more effectively within a VR environment if actions were accompanied by appropriate sounds that seemingly emit from their proper locations." Begault (Ex.1007) at 13; *see also* Business Insider, *Three-Dimensional Audio Makes Virtual Reality So Much Better It's Crazy* (Apr. 3, 2015) (Ex.1137); The Verge, *Surrounded by Sound: How 3D Audio Hacks Your Brain* (Feb. 12, 2015) (Ex.1138).

220. Second, Begault is complementary to Pedrotti and Jang in that it emphases building a "rich auditory environment" in order to enhance the experience of a virtual environment. Begault expressly states that a "solution for improving the immersivity and perceived quality of a visual display and the virtual simulation in general is to focus on other perceptual senses—in particular, sound." Begault (Ex.1007) at 10. Begault additionally quotes a virtual reality developer who indicated that "in the video game business," it is important to focus on the quality of

sound because better audio quality influences people to perceive that visual quality is better as well: "really high-quality audio will actually make people tell you that games have better pictures … but really good pictures will not make audio sound better; in fact, they make audio sound worse. So in the (virtual) world we're building, one of the features is a rich auditory environment." Begault (Ex.1007) at 10-11. Persons of ordinary skill in the art thus would have known that use of HRTFs and implementation of binaural audio, as described in Begault (*e.g.*, Begault (Ex.1007) at Chs. 2 and 4), "represents a clear signpost for increased realism (and thus immersiveness)." Dionisio (Ex.1054) at 34:12-34:13; *see also* Begault (Ex.1007) at 99 (describing in detail HRTFs and noting the "inclusion of the binaural HRTF is fundamental for a 3-D sound system"); Polygon, *Google Cardboard Adds 'Inexpensive' Spatial Audio to Its SDK* (Jan. 13, 2016) (Ex.1139).

221. Additionally, several of the teachings from Pedrotti and Jang are consistent with those of Begault, with Begault providing further technical details that persons of ordinary skill in the art would have known to use with Jang's sound processing techniques. For example, Jang discloses two dedicated sound processors (one for focused sound and another for non-focused sound) in its sound processing unit. *See, e.g.*, Jang (Ex.1006) at 3:8-15, Fig. 3. Begault, in turn, discloses the history and technical detail behind "digital signal processing (DSP) chips" that offer advantages over regular processors. *See, e.g.*, Begault (Ex.1007) at 20 (discussing

that advantages of DSP "include relatively smaller hardware size, greater predictability of noise, and ease of reconfiguration—one can write different software specifications to the signal processor" and DSP chips "can be configured as filters that modify sound in the same way as in natural spatial hearing"), 100-109 ("3-D sound processing is almost always best accomplished digitally, using audio DSP chips to manipulate signal sources" because they "are designed to perform a limited set of digital DSP instructions ***very quickly***—i.e., in real time") (emphasis in original). In this way, persons of ordinary skill in the art would have been motivated to take the teachings of Jang's sound processing techniques (e.g., using dedicated sound processors) and apply them using the detailed disclosures of Begault (e.g., based on detail regarding DSPs).

222. Relatedly, persons of ordinary skill in the art combining Pedrotti's systems and methods with Jang's sound processing methods, including with the techniques and processors (e.g., DSPs) that Begault discloses, would have had a reasonable expectation of success. These references disclose and utilize hardware that was well-known and frequently used long before June 2016, such as HMDs and handheld controllers and systems that include tracking of HMDs and handheld controllers. *See* Sections VII.B-VII.D (discussing processing ability in the HMDs, and also the ability to track such HMDs and handheld controllers, which have at least 6DoF). Additionally, persons of ordinary skill in the art would have known

that by June 2016, there were several patent applications and issued patents in the industry that described HMDs with all-in-one tracking. *See* Section VII.D (discussing multiple examples).

223. Moreover, hardware appropriate for carrying out Jang's sound processing techniques, e.g., processing sound with HRTFs, was also commonly known for years in AR and VR applications. As discussed above, the use of DSPs to handle specifically 3-D sound processing was proven and commonly used. Begault (Ex.1007) at 100 ("3-D sound processing is almost always best accomplished digitally, using audio DSP chips"), 109 ("One can obtain the HRTF of an individual or of a dummy head by playing an analytic signal at a desired position at least a meter distant, and measuring the impulse response with probe microphones placed in the vicinity of the ear canals. This measurement then can be formatted for use directly within spatial filtering DSPs."), 111-12 (section discussing "Using Digital Filters" and explaining "[s]etting up a DSP to filter a sound with an HRTF").

224. It was also well known to use HRTF cues to generate binaural sound, which also is carried out using DSPs:

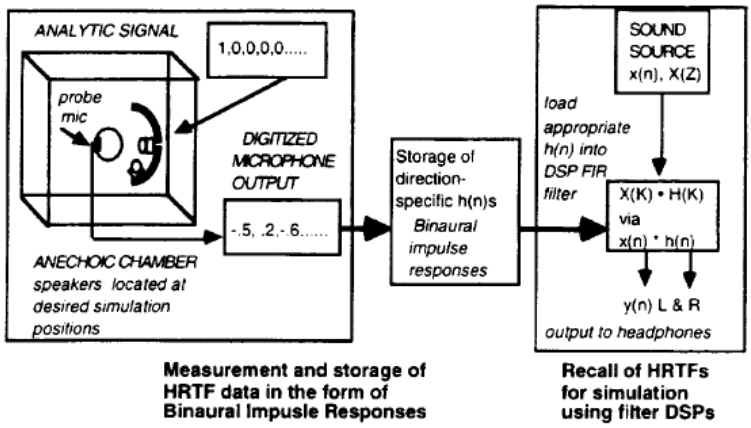


Figure 4.17. Overall plan of the HRTF measurement-storage-simulation technique. HRTFs are obtained using acoustic signals from loudspeakers that are recorded with probe microphones in the vicinity of the ear canals. The data are stored for input to DSP filters during the simulation stage. Usually, both ears are measured simultaneously. Not shown are the translation and possible compression of the measurements for use in the DSP. Note that each stage of measurement and simulation possibly can contribute significant influences to the overall character of the output signal, to the degree that each element is nonlinear (deviates from a flat frequency and phase response). In practice, some of these nonlinearities are difficult to control, although it is not certain how important they are psychoacoustically within a particular application.

Begault (Ex.1007) at 109 ("The binaural impulse response of the outer ear then is obtained from the pressure responses of the microphones and digitally recorded in stereo as a series of sampled waveform points … The sound source to be spatialized is filtered by these DSPs during simulation."), 4.17; *see also* Jerald, THE VR BOOK (Ex.1063) at 240 ("For more realistic audio and where auditory cues are especially important, ***auralization***—the rendering of sound to simulate reflections and binaural differences between the ears—can be used … Multiple HRTFs from different directions can be interpolated to create an HRTF from any direction relative to the ear.") (emphasis in original); Hollier, *Spatial Audio Technology for Telepresence* (1997) (Ex.1062) at 35 (describing a solution for "head-tracked binaural" sound

comprising "a pair of headphones with a rotational position sensor mounted on top and DSP-based hardware which encodes each of the two audio signals with the appropriate HRTF filters."), Fig. 2.

* * *

225. For the reasons I explained above, persons of ordinary skill in the art would have been motivated to combine the teachings of Pedrotti and Jang, and additionally Begault. And persons of ordinary skill in the art would have had a reasonable expectation of success in making these combinations since combining the teachings from Pedrotti, Jang, and Begault require only combining well-known elements through well-known methods. For example, the input for signaling a space shift as taught in Jang would have been easily managed with Pedrotti's system, which includes common elements of a VR system—an HMD and a handheld controller. As another example, incorporating Jang's sound processing techniques into Pedrotti's system would have been successfully accomplished using DSPs, since the use of DSPs for processing HRTFs to binaural sound was well known in the art, as explained in Begault.

C. Independent Claim 1

1. 1[pre]: "A method executed by one or more electronic devices, the method comprising:"

226. Pedrotti teaches the preamble of claim 1. At a minimum, Pedrotti renders the preamble obvious.

227. Pedrotti teaches a method executed by one or more electronic devices—its "method of assisting a user," which is executed by, among other things, an "HMD" and "handheld controller[s]." Pedrotti (Ex.1005) at 2:27-59 ("One embodiment discloses a method of assisting a user wearing a head-mounted display (HMD) in remaining within a selected area of the physical world, the user holding a handheld controller having a controller tracker which provides information regarding a position of the handheld controller …"). Both HMDs and handheld controllers are commonly known to be electronic devices in an AR and VR system. *See* Sections VII.B-VII.C (describing these common components of AR and VR systems).

228. I further note that Jang also teaches a method executed by one or more electronic devices, as Jang discloses a method "to perform sound processing" that is carried out by a virtual reality apparatus comprising several electronic devices. *See* Jang (Ex.1006) at 2:15-20, 5:40-42 (describing Figure 4), 6:24-8:16 (describing Figures 1A-1B), 8:54-58 (describing Figure 3), Figs. 1A-1B, 3-4.

2. 1[a]: "tracking, with a wearable electronic device (WED) worn on a head of a user, movement of a handheld portable electronic device (HPED) held in a hand of the user such that the movement of the HPED defines a size and a shape of a three-dimensional (3D) zone that extends from a physical floor and around the user;"

229. Pedrotti teaches, or at a minimum renders obvious, limitation 1[a].

230. Pedrotti discloses a WED worn on a head of a user. Pedrotti (Ex.1005) at 1:21-29 (disclosing a "head-mounted display, or HMD," such as "the Oculus Rift from Oculus VR, now owned by Facebook.").

231. Pedrotti discloses a handheld portable electronic device (HPED) held in a hand of the user—Pedrotti's "handheld controllers." Pedrotti (Ex.1005) at 1:40-45 ("a user may wish to use a handheld controller, such as might be used to play a video game, while in a virtual world, and perhaps even two controllers, one for each hand"), Figs. 2-5, 7 (depicting Pedrotti's controllers).

232. Pedrotti teaches tracking, with a WED, movement of an HPED. Pedrotti discloses that the user "wear[s] a head-mounted display (HMD)." Pedrotti (Ex.1005) at 2:44-47. The user "hold[s] a handheld controller… [with] a controller tracker on the handheld controller which provides information regarding a position of the handheld controller." Pedrotti (Ex.1005) at 2:44-47. Pedrotti's processor "determine[s] the position of the handheld controller in the physical world using information from the controller tracker." Pedrotti (Ex.1005) at 2:49-57, 12:31-41

("the processor knows where the user's head and hands are located"), 15:7-12 ("the user is holding a handheld controller having a tracker which can be used to track the position and orientation of the handheld controller"). And because Pedrotti teaches that the processor tracking movement of the handheld controller may be "in the HMD," Pedrotti discloses an HMD tracking a handheld controller. Pedrotti (Ex.1005) at 16:22-24.[5]

233. Pedrotti teaches using the movement of the WED-tracked HPED to define a size and shape of a 3D zone extending from a physical floor and around a user. Pedrotti teaches a "safe area" (a 3D zone) that "can be defined, for example, by having the user walk around a perimeter chosen by the user with one of the trackers to define the outer boundary of a selected area":

[5] In addition to the disclosures and teachings of Pedrotti, in a related patent, U.S. Patent No. 10,162,177 ("Pedrotti 177") (Ex.1032) to Pedrotti, the processor is also described as being in the HMD. *See, e.g.*, Pedrotti 177 (Ex. 1032) at 10:63-65 ("a processor may be located in the HMD"). Also, persons of ordinary skill in the art would have known it was common for tracking capabilities to be wholly contained in an HMD. *See* Section VII.D (describing all-in-one and inside-out tracking).

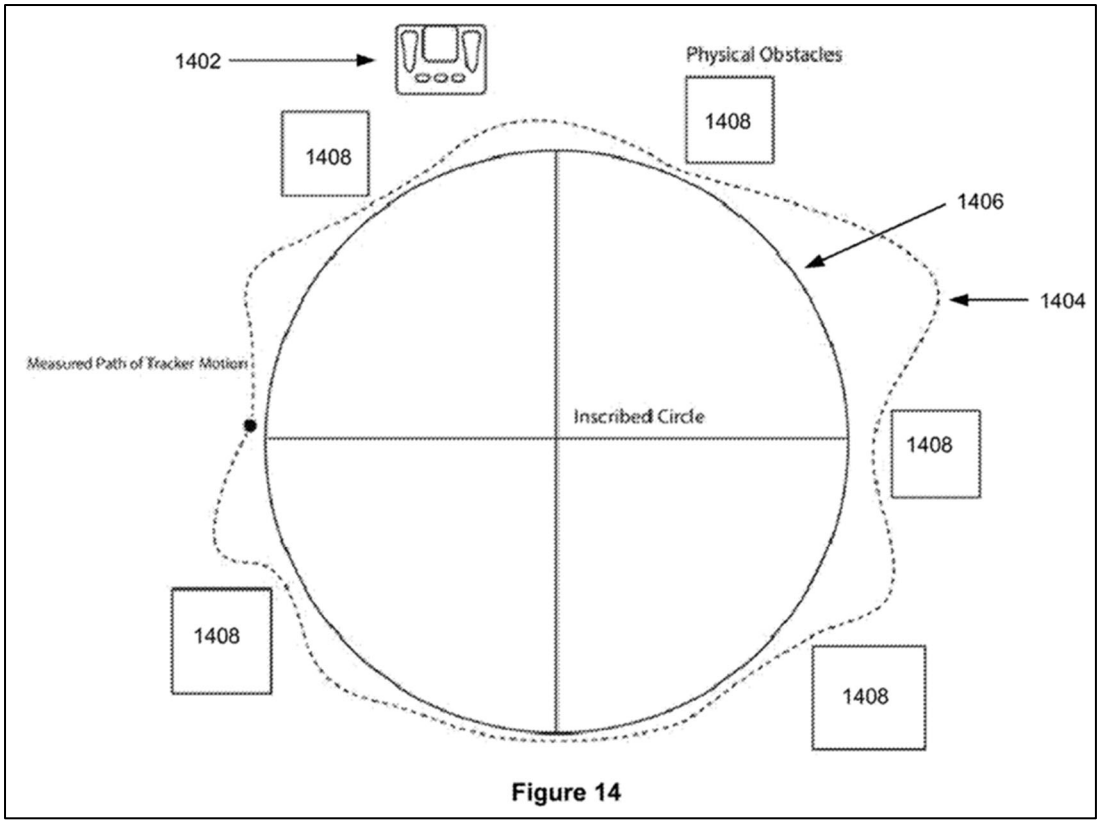


Figure 14

Pedrotti (Ex.1005) at 14:56-65, 15:13-22, Figs. 14-15 (boundary 1404 reflecting the user-defined, irregularly shaped boundary defining a 3D zone).

234. Pedrotti discloses that the handheld controller "provides information regarding position of the handheld controller" and the "processor" "in the HMD" is configured to "receive as an input a definition of a boundary of the selected area." Pedrotti (Ex.1005) at 2:44-51. This, combined with Pedrotti's disclosure that "[t]he processor determines the position of the tracker at a number of sampling points as the user moves around the chosen perimeter, and from those points determines the boundary," demonstrates that persons of ordinary skill in the art would have known and understood from Pedrotti that the processor in Pedrotti's HMD tracks the

handheld controller as the user carries it and walks around a perimeter to define the "safe area." Pedrotti (Ex.1005) at 14:62-65.

235. Persons of ordinary skill in the art also would have understood that this perimeter or boundary defines a 3D zone because it defines the user's 3D "safe area" playspace. This was a common principle applied to safety and chaperone systems. *See* Section VII.G (providing visual examples of boundaries existing in 3D space, and thereby defining a 3D zone).

236. Similarly, Pedrotti's boundary defines a size and shape of a 3D zone extending from a physical floor and around a user because it delineates the "safe area" (or 3D zone) in which users move around. This is shown in Pedrotti's figures, which depict the "visual warning in the form of grid lines or a virtual fence" that is presented "when the user comes within a preselected distance of the boundary":

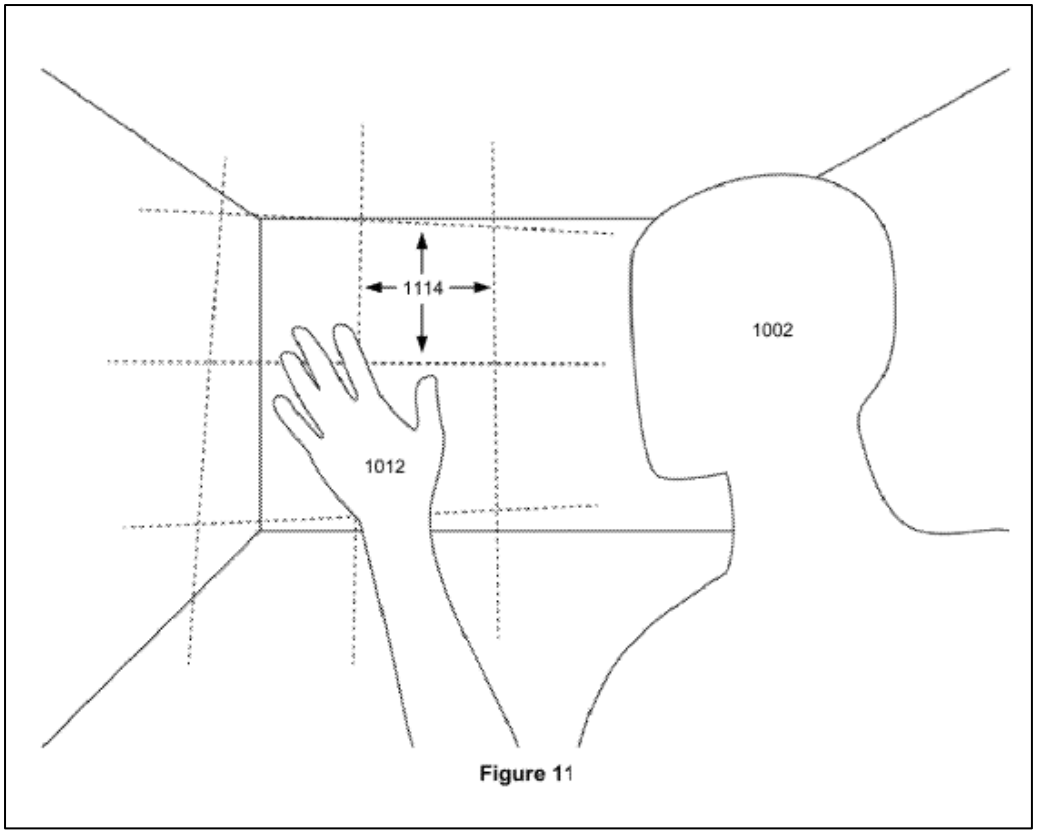
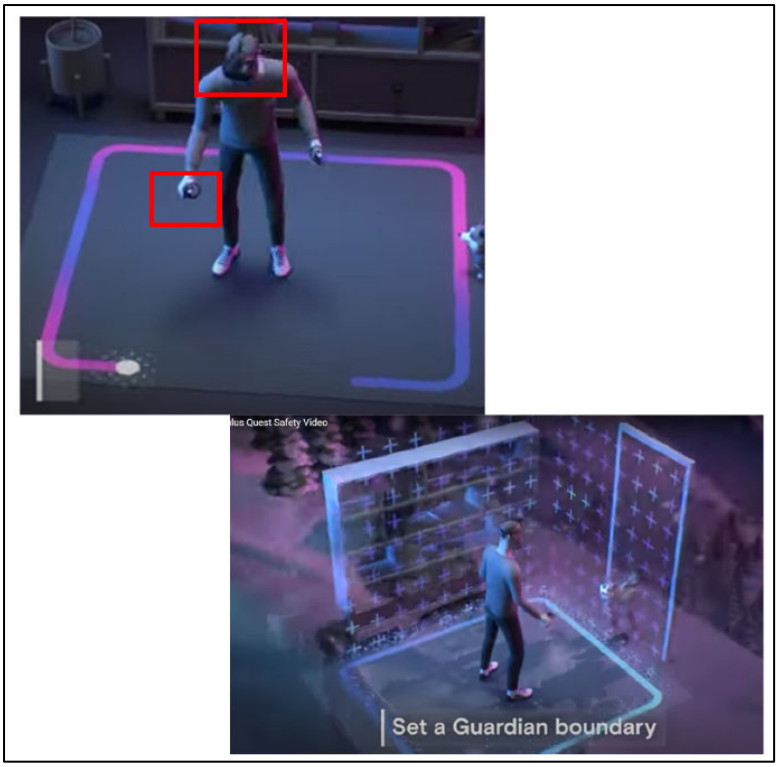


Figure 11

Pedrotti (Ex.1005) at 15:46-55, Figs. 10-11.

237. Additionally, I have reviewed the infringement contentions 8K served on Petitioners in district court. *See* '737 8K Infringement Contentions, Ex. 16 ("'737 8K Infringement Contentions") (Ex.1121). In discussing limitation 1[a] in those contentions, and specifically the language requiring a "three-dimensional (3D) zone that extends from a physical floor and around a user," 8K contends that a fence-like feature akin to Pedrotti's defines the claimed "three-dimensional (3D) zone that extends from a physical floor and around a user":



'737 8K Infringement Contentions (Ex.1121) at 3; *compare* First Am. Compl. (Ex.1122) at ¶ 92 ("Accused Products have… 'safe area' functionality"), *with* Pedrotti (Ex.1005) at 4:32-36 ("boundary of a selected area" defines "a 'safe area'"). Consequently, it appears from 8K's infringement contentions that, in 8K's view, "defin[ing] a size and shape of a three-dimensional (3D) zone that extends from a physical floor and around the user" requires only a 2D perimeter drawn on a floor and the display of select boundary walls along such a perimeter. This supports my conclusion that Pedrotti disclosed, or at a minimum rendered obvious, limitation 1[a].

3. 1[b]: "designating, with the HPED held in the hand of the user, a sound localization point (SLP) in empty space in the zone above the physical floor from where binaural sound originates to the user;"

238. As noted, I reviewed the infringement contentions 8K served on Petitioners in district court. *See* '737 8K Infringement Contentions (Ex.1121).

239. In discussing limitation 1[b] in those contentions, 8K contends that two images of a game character "taken from a video depicting the user experience with the 'Bogo' application" show the character in different locations, and this satisfies the claim language requiring "designating, with the HPED held in the hand of a user, a sound localization point (SLP) in empty space in the zone above the physical floor from where the binaural sound originates to the user":



'737 8K Infringement Contentions (Ex.1121) at 4.

240. Consequently, it appears that, in 8K's view, limitation 1[b] merely requires a game character that can be "moved by direction of the HPED" because, as a result, an "SLP will likewise move along with the corresponding location of the game character." *See* '737 8K Infringement Contentions (Ex.1121) at 4.

241. If 8K's interpretation applies and limitation 1[b] requires only moving sound-producing virtual objects, such as game characters, this limitation would have been basic, straightforward, and of course obvious to persons of ordinary skill in the art long before June 2016, over numerous AR and VR references. *See, e.g.*, U.S. Patent No. 9,037,468 ("Osman") (Ex.1031) at 10:3-15 (user uses a controller to fly a sound-producing virtual helicopter), 10:60-66 (user uses a controller to fire a sound-producing virtual cannon); McCulloch (Ex.1008) at 26:12-19 (user uses a controller to crash a sound-producing virtual helicopter into a wall), 29:46-55 (user uses a controller to break a monitor with a virtual basketball); Slater, *Acting in Virtual Reality* (2000) ("Slater") (Ex.1091) at 105 (user-controlled talking avatars sharing a rehearsal space); Erickson (Ex.1057) at 504 (user-controlled talking avatars at a virtual conference); Zhou (Ex.1107) at 1006-07 (describing 3D audio used in an AR and VR game played by two co-players, where images of planes are displayed at the locations of the co-players' handheld controllers (their "wands"): "A constant buzz sound is applied to the co-player's airplane," and "[s]ince the plane

is attached to the wand, the 3D positions can be easily obtained from the tracker in the wand," so "the user can always hear where is the location of the co-player, even when the co-player is not visually in the scene"), Figs. 9-11; Ross (Ex.1125) at 17:22-18:35 (describing "interactions" with sound-producing virtual objects, such as "physical fights, side adventures with a particular character, moving objects and/or character, and knocking things over").

242. Thus, Pedrotti and Jang, separately and in combination, render limitation 1[b] obvious to persons of ordinary skill in the art under 8K's interpretation of this limitation.

243. Pedrotti discloses that a controller held in the hands of a user can be "a gun, sword, or other weapon," or "a bat, tennis racket, golf club or other sporting implement." Pedrotti (Ex.1005) at 16:33-42, Fig. 8 (showing the controller represented as a sword). Persons of ordinary skill in the art would have known that manipulating such objects (e.g., hitting a ball with a bat) or operating such objects (e.g., a gun shooting or a sword slicing through the air) produces sound such that they are also considered sound-producing virtual objects. And Pedrotti discloses manipulating these objects by "grasping" and moving them. Pedrotti (Ex.1005) at 4:4-15, 5:25-36 ("the user 102 holding a controller 110 which the user may pick up with his or her hand(s), and which allows the user to perform various functions in the virtual world"), 8:14-35, 9:26-52 ("a user may use a controller to have a character

on a television screen 'pick up' a weapon displayed on the screen"). Thus, Pedrotti alone renders limitation 1[b] obvious to persons of ordinary skill in the art, who would have long understood that sound-producing objects can be manipulated and moved in AR and VR.

244. Further, persons of ordinary skill in the art would have known that Pedrotti's movement of virtual objects occurs "in empty space in the zone above the physical floor from where binaural sound originates to the user." Pedrotti's Figure 8 shows a virtual sword in empty space above the floor, and that sword, in the user's hand, would be in the user's playspace (i.e., the claimed zone).

245. Jang likewise renders limitation 1[b] obvious to persons of ordinary skill in the art.

246. Jang discloses accepting "input [from] the user for character movement" and that the user's avatar or character produces sound or can be used in with environments that persons of ordinary skill in the art would have known require the avatar or character to communicate (e.g., produce sound) with others, such as a virtual conference. *See, e.g.*, Jang (Ex.1006) at 6:44-47 (describing "sensory data of the virtual environment including a user's avatar or character and other avatars, characters, objects, or features of the virtual environment"), 9:11-17 ("the control unit 114 detects a key input of the user for character movement"), 11:53-55 (also discussing moving the character), 10:32-36 (referring to the character in a

conference room, for example), 12:26-56 (referring to "sensory output producing objects or characters," e.g., a sound-producing character). This input can come from "a game joystick or controller," for example, and allows the user to "interact with the virtual environment" while the user senses the virtual environment "from the perspective of the avatar." Jang (Ex.1006) at 1:35-38, 6:32-38.

247. Jang also teaches, or at a minimum renders obvious, using binaural sound for designated SLPs (e.g., game characters or other sound-producing objects).

248. Jang discloses that its sound processing system "check[s] sound source information on other characters and other objects" and provides "sound sources occurring in real time according to the relative locations or situations of the character in the virtual reality environment." Jang (Ex.1006) at 7:24-32.

249. In conjunction with this, Jang discloses that "the sound of the virtual reality system may use a localization technique capable of expressing the virtual location" of "a sound-generating object." Jang (Ex.1006) at 1:42-56. These localization techniques include using HRTFs, and Jang's sound-shifting technique, "to give the sense of reality to the sound." Jang (Ex.1006) at 1:42-56 (describing use of HRTFs to give directionality), 7:24-63 (using HRTFs "as an algorithm for identifying the sound-generating location"), 8:65-9:1 (describing sound processing in the focus and non-focus areas), 11:47-53 ("[a] space shift occurs, for example, if

the user's character moves suddenly within the virtual environment from a first virtual space to a second virtual space").

250. Jang's reference to "Second Life" also would have indicated to persons of ordinary skill in the art that users would have been able to manipulate sound-producing virtual objects in Jang's system, including by assigning sounds to objects. Jang (Ex.1006) at 1:65-67. This is because in Second Life, including in its "immersive, VR experience," users interacted with other users using avatars that spoke with one another. Second Life Community (Ex.1089) at 1 (describing Second Life's beta test with the Oculus Rift headset); The Guardian, *Virtual World Second Life to be Reincarnated, with Oculus Rift* (Jun. 24, 2014) (Ex.1095) (explaining that users still interacted in this manner in the VR integration).

251. Indeed, before Jang, fully immersive social VR experiences where users appeared as avatars and could move sound-producing objects, e.g., their avatars, were well-known:



Figure 22.6 An example of a fully immersive VR social experience. (Courtesy of VRChat)

Jerald, THE VR BOOK (Ex.1063) at 259, Fig. 22.6 (depicting "VRChat," which is "[a]n example of a fully immersive VR social experience"); Ross (Ex.1125) at 8:59-67 ("For example, a user may communicate with presented characters, and/or may socially interact in other ways with virtual character and/or other users in the virtual space. Socially interacting may include communicating" or "chatting."), Ross (Ex.1125) at 17:22-18:35 ("Interaction may include conversing (e.g., textual chatting, voice communication, etc.) with and/or otherwise socializing with virtual characters such as avatars, other characters, and/or other users.").

252. As THE VR BOOK states, "VR cannot exist without content," and this includes "computer- or user-controlled characters." Jerald, THE VR BOOK (Ex.1063) at 43; *see also* Ross (Ex.1125) at 8:45-59 (describing further examples of "content presented to the user," including "characters, objects, [and] settings"), 14:53-15:28 (explaining that virtual reality content may include "characters, objects," "avatars of

other users (e.g., prerecorded and/or live)," "individual characters," among a number of exemplary virtual objects). And having sounds for computer- or user-controlled virtual objects move with their objects, including in response to user manipulation of the virtual object, was a fundamental, and extremely important feature to making virtual environments immersive, long before June 2016, as Begault and other references show. *See, e.g.*, Begault (Ex.1007) at 13 ("3-D sound can contribute to the sense of immersivity in a 3-D environment. One might be able to work more effectively within a VR environment if actions were accompanied by appropriate sounds that seemingly emit from their proper locations, in the same way that texture mapping is used to improve the quality of shaded images."), 95 ("[i]n virtual reality and multimedia applications, most sounds are somehow connected to visual events"); Brungart, *Near-Field Virtual Audio Displays* (2000) (Ex.1050) at 9 ("In an environment where listeners are able to grab virtual sound sources and move them around the head, realistic near-field audio cues are extremely important."), Jerald, THE VR BOOK (Ex.1063) at 240 ("Spatialized audio" "provide[s] cues of where other characters are located"), 281 ("objects can make a sound … when a hand collides with them or they have been selected" and "[f]eedback is essential for interaction").

253. Other references further confirm the obviousness of moving sound-producing virtual objects in AR and VR settings, such that an object's sound travels with the object. *See, e.g.*, Osman (Ex.1031) at 10:60-66 ("For example, user 406b

has a game cannon, which is fired by the remote player … the firing shot is heard first, and is followed by the sound of the cannonball as the cannonball travels through the air from the location of player 406b to the location of player 406a."); U.S. Patent Publication No. 2015/0119130 ("Lovitt") (Ex.1021) at [0038] ("the interactive digital environment of game 208 includes virtual space sound source 238 (e.g., weapon muzzle brake of a user-controlled weapon) and virtual space sound source 242 (e.g., tank muzzle brake) … each virtual space sound source includes one or more associated sounds such that, during interaction with the virtual environment, one or more of the associated sounds are programmed to be 'output' from a particular virtual space sound source"), [0043] ("this adjusted location would take more movement of the user's on-screen avatar to see and/or engage with the approaching avatar"); Ross (Ex.1125) at 4:30-34 (describing sensory cues, including "visual" and "auditory"), 10:47-62 (describing computing device processing "visual information" and "object/position information", 17:32-18:9 (explaining that a guiding character and/or avatar that "walks the user through a scene in the virtual space and points things out" is "like a commentary track on a DVD"), 20:65-21:16 (describing creating those virtual objects in a scene), 25:21-39 (describing displaying sensory cues, including virtual reality content).

254. For these reasons, limitation 1[b] would have been obvious over Pedrotti in view of Jang under 8K's apparent interpretation of this limitation.

255. Additionally, if limitation 1[b] is interpreted to require that an HPED actually designate locations for binaural sound, as the limitation's language states, limitation 1[b] would have been obvious over Pedrotti in view of Jang, or over Pedrotti in view of Jang, and further in view of Begault.

256. As I explained above in Section IV, the '737 patent is directed to designating or assigning sounds "to different zones or different sound localization points" so sounds "localize as binaural sound into the assigned zone or to the assigned SLP." '737 patent (Ex.1001) at 1:22-26, 11:33-38.

257. This type of sound management and control would have been obvious to persons of ordinary skill in the art over Pedrotti and Jang, or over Pedrotti, Jang, and Begault.

258. Jang discloses "process[ing] and produc[ing] sound output in sound areas," which can include focus and un-focus areas. Jang (Ex.1006) at 2:32-47, 2:60-3:4. Jang discloses that these sound areas have "sensory sources," which "may be audio sources." Jang (Ex.1006) at 4:19.

259. Jang discloses that each of its sound areas "may contain any number of virtual objects represented by sensory data that may include audio and visual data." Jang (Ex.1006) at 8:43-46. Jang discloses that these areas may be further "divided into multiple areas in the virtual reality space according to a predetermined priority" or "predetermined scheme." Jang (Ex.1006) at 8:46-49, 9:47-50, 9:66-10:5 (further

disclosing decreasing volume of a first space while increasing volume of a second space "according to predetermined sound priorities of the second space").

260. Jang's system "output[s] sensory elements of the focus area differently than sensory elements of the non-focus areas" to better manage space shifts between virtual environments, such as from a virtual basketball court to a virtual conference room. Jang (Ex.1006) at 6:47-59, 11:1-16 (explaining that priorities are first determined to minimize time delay when a space shift occurs), 11:47-63, Fig. 6A. These space shifts are common in virtual environments, and occur in different ways, but all require some transition experienced by the user and the sensory data related to the environment that the user perceives. *See, e.g.*, Jerald, THE VR BOOK (Ex.1063) at 153-54 (describing "pointing to fly" as a means to "mov[e] from one place to another" in VR and "viewpoint control via a joystick"), 251 ("[P]oint on the map where to go and then 'enter into' the map with the map becoming the surrounding world"), 256 ("Fully walkable systems enabl[ing] users to stand up and physically walk around," including "[f]ully walkable untethered systems," "can work extremely well") (emphasis in original omitted), 290 ("Real walking for VR navigation" provides a "high sense of presence"), 337 ("real walking is an ideal interface for many VR experiences"); Ross (Ex.1125) at 22:34-44 (describing specifying "sensory cue(s) used to indicate to a user that his view direction has moved across a view boundary"), 20:22-40 (explaining changes in view direction

based the user choosing to "move [] position in the virtual space across a boundary," "lean into another field of view, walk into another field of view, move (e.g., run, drive, fly, etc.) into another field of view, and/or otherwise move himself across a view boundary into an adjacent field of view").

261. Specifically, Jang discloses: "For example, if a user's character moves from a basketball court to a conference room, visual, audio, or tactile elements of the basketball court may decrease in magnitude, and visual audio, or tactile elements of the conference room may begin to be transferred to a virtual reality device," with sensory data for a focus area in the conference room being processed and output before sensory data for that room's non-focus area. Jang (Ex.1006) at 11:64-12:16.

262. In view of Jang's disclosures regarding sound areas and predetermined priorities and schemes, persons of ordinary skill in the art would have been motivated to set those predetermined priorities and schemes for "sound areas" and "audio sources" by assigning locations from where different audio sources will produce sound. Using the '737 patent's terminology, those are "sound localization points" or "SLPs." And the assignment of those locations is the designation of SLPs required by limitation 1[b].

263. For example, in the context of Jang's virtual basketball court, a virtual visiting team's bench could and would be designated into a focus area, and the nearby stands for the virtual visiting team could and would also be designated into

that focus area. Between these two, the virtual visiting team's bench could and would be given priority over the stands. Similarly, the user could and would assign priorities to characters and other sound-generating objects such as an announcer, cheerleaders, a pep band, or an air horn, which also could and would be assigned locations in the focus area. Also, persons of ordinary skill in the art would have understood based on Jang's disclosures that the same type of audio control could and would be applied to a non-focus area.

264. As another example, in the context of Jang's virtual conference room, one side of the conference room could and would be set as a "focus area," with priority characters and other sound-generating objects such as key attendees or a monitor. Additionally, among the key attendees, there could and would be a highest priority given to the boss, and lower priorities given to other attendees based on seniority. Persons of ordinary skill in the art also would have known and been motivated to assign specific locations for these characters and sound-generating objects (i.e., designate their SLPs). For years before Jang, it was understood that with simple user interfaces, sound sources such as conference attendees could and would be organized, clustered, and moved, e.g., into "special region[s]" or a "private conference." *See, e.g.*, Cohen 1992 (Ex.1052) at 477 (describing "[a] simple teleconferencing configuration [that] typically consists of several icons, representing the distributed users, moving around a shared conference space," and where "[e]ach

of these icons represents a source, the voice of the associated user, as well as a sink, the user's ears."). To persons of ordinary skill in the art, these assignments or designation of SLPs would have facilitated obvious, advantageous organization for a user's soundscape, consistent with the disclosures of multiple publications describing interfaces for, and allowing users to make, such designations. *See* Section VII.F.

265. Jang further taught, or at a minimum rendered obvious, the designation of an SLP in empty space in a zone above a physical floor. Jang discloses that its "audio sources" exist in a virtual environment, and persons of ordinary skill in the art would know this means that Jang's audio sources are "in empty space." As the '737 patent provides, "empty space" is "a location void of a tangible object," that is, the empty space is instead "occupied with a VR image or an AR image," "such as an image occurring in a VR game or VR software application." Ex.1001, '737 patent at 53:28-36, 53:50-55. Further, persons of ordinary skill in the art would have known that Jang's audio sources in the virtual environment are within Jang's "sound areas," which in a Pedrotti-Jang combination would be, or would obviously be, above a physical floor in Pedrotti's "safe area" for game play (i.e., the claimed zone).

266. Additionally, as discussed above, Jang taught, or at least rendered obvious, binaural sound originating from its audio elements' respective locations (i.e., from the claimed SLPs). Jang disclosed using sound localization techniques to

localize 3D or binaural sound to sound sources, including through HRTFs. Jang (Ex.1006) at 1:42-56 (describing use of HRTFs to give directionality), 7:24-63 (using HRTFs "as an algorithm for identifying the sound-generating location"), 8:65-9:1 (describing sound processing in the focus and non-focus areas), 11:47-53 ("[a] space shift occurs, for example, if the user's character moves suddenly within the virtual environment from a first virtual space to a second virtual space"); *see also* Section VII.E (discussing references demonstrating that skilled artisans knew how to generate binaural audio from designated locations in virtual environments for years before June 2016).

267. Jang also taught, or at least rendered obvious, designating SLPs with a HPED because persons of ordinary skill in the art reading Jang would have known and been motivated to use a HPED, such as a controller, to manage and assign (i.e., designate) sound areas and locations for audio sources. Furthermore, persons of ordinary skill in the art would have known that an end user or an author (e.g., a creator or designer of the virtual environment) could and would perform managing and assigning (i.e., designating) sound areas and locations for audio sources, consistent with Jang's teachings. Managing and assigning (i.e., designating) sound areas and locations for audio sources is an example of immersive authoring, which refers to creating and developing content for a virtual environment from within that target virtual environment—thus enabling the individual to perceive the virtual

content when authoring or setting up a virtual scene. Immersive authoring was a well-known approach for users or authors to create 3D virtual environments and assign and position virtual objects in those environments. *See, e.g.*, Mine 1996 (Ex.1114) at 1 (Chapel Hill Immersive Modeling Program (CHIMP) "is an immersive system" where "users work directly within a virtual world"); Mine ISAAC 1997 (Ex.1115) at 548 ("During the session, you choose objects from the working set (for example a particular type of chair) and interactively place them in the environment"). And, immersive authoring, including managing sound sources, was obvious in view of existing systems where users could manage sound sources. *See, e.g.*, Mine 1996 (Ex.1114) at 2 ("[s]everal other systems have moved beyond the limitations of two-dimensional input and output in the interactive design of virtual objects"); Çamci (Ex.1051) at 122, Fig. 5 (explaining 3D implementation of its Interactive Virtual Soundscape); Ross (Ex.1125) at 22:14-17 ("view 500 and/or other views may be presented to a user, content creator, and/or other people within the virtual space (e.g., in three dimensions) and/or in any other form"), Fig. 5, 23:22-32 ("creation, customization, and/or adjustment may be presented to the user in three dimensions (e.g., via three dimensional display devices described herein)").

268. As Ross confirms, it was known that, in VR, a user could author and control VR content, including "view boundaries," which can reflect a "view direction of the user"—e.g., "a position of the user within the virtual space, and/or

other directional and/or positional information"—and "may move his position in the virtual space across a boundary." Ross (Ex.1125) at 20:22-34, 20:34-40 ("the boundaries of the fields of view, the virtual reality content displayed to the user in the fields of view, and other characteristics of system 10 may be created, customized, and/or adjusted by the user"), 20:41-64 (discussing authoring the boundaries), 20:65-21:22 (discussing authoring virtuality content).

269. Persons of ordinary skill in the art also would have understood the advantages of using a HPED and well-known selection patterns to control and assign (i.e., designate) sound source locations (SLPs). *See* Section VII.C (discussing well-known selection methods for use with handheld controllers in AR and VR); *see, e.g.*, Jerald, THE VR BOOK (Ex.1063) at 327 ("[T]he Pointing Pattern is one of the most fundamental and often-used patterns for selection"); Ross (Ex.1125) at 22:17-23 ("[a] user, a content creator, and/or other persons may create, customize, and/or adjust using a controller (e.g., pointer) of user interface 14"), 22:27-29 ("[t]he user may virtually reach out and grab and/or move the fields and/or objects in the fields to make changes as described herein."), 21:52-22:2 (similar), 23:36-42 ("System 10 may be configured such that a controller (e.g. part of user interface 14), a body tracking system," "and/or other devices may be used to create and/or manipulate a boundary.").

270. For these reasons, limitation 1[b] would have been obvious persons of ordinary skill in the art over Pedrotti in view of Jang.

271. Additionally, limitation 1[b] would have been obvious to persons of ordinary skill in the art over Pedrotti in view of Jang, and further in view of Begault, which describes advantageous ways the predetermined schemes and priorities for Jang's "sound areas" and "audio sources" can be set.

272. For example, Begault discloses that "[a]ll types of sonic input could be directionalized to a specific location, controlled by the user." Begault (Ex.1007) at 172. Begault further discloses that "the audio spatial mapping can correspond to a ***prioritization*** scheme." Begault (Ex.1007) at 172 (emphasis in original). Begault's reference to a prioritization scheme aligns with Jang's disclosure of implementing predetermined priorities and schemes.

273. As with the virtual basketball court and virtual conference room examples I explained above, Begault similarly provides an example of how priorities work: "calls from subordinates could be signaled by a phone ringing from the rear; a call from home could always ring from front right; and the intercom from the boss could be from front and center." Begault (Ex.1007) at 172.

274. In fact, Begault discloses "a hypothetical GUI for arranging [] various sound inputs in virtual auditory space in a manner configurable by each individual listener":

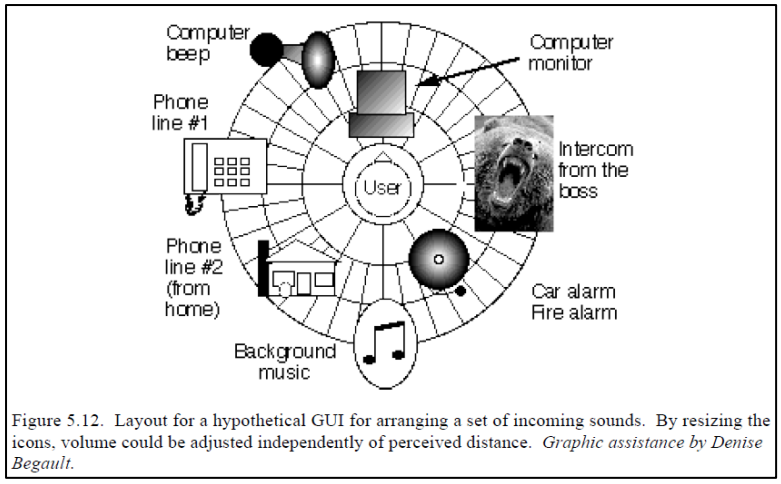


Figure 5.12. Layout for a hypothetical GUI for arranging a set of incoming sounds. By resizing the icons, volume could be adjusted independently of perceived distance. *Graphic assistance by Denise Begault.*

Begault (Ex.1007) at Fig. 5.12. As I explained above, "[t]he basic concept is to represent each form of auditory input iconically on the screen and then allow manipulation of the distance and relative azimuth of each source," and "[t]he computer interprets the relative location of the icons on the screen as commands to a multiinput, 3-D sound spatialization subsystem." Begault (Ex.1007) at 172.

275. Begault further discloses that other types of interfaces could and would be used for managing 3D or binaural audio, including the interfaces described in Cohen 1992 and Cohen 1993. *See* Begault (Ex.1007) at 173 (describing "audio windows" as one such interface); Cohen 1992 (Ex.1052) at 473-74 (allowing users to adjust the spatial sound icons and cluster sound sources); Cohen 1993 (Ex.1053) at 273 (describing "audio imaging" as creating "sonic illusions by manipulation of separate channels"), 274-75 (describing "audio windows" as "an auditory-object manager"); *see also* Ross (Ex.1125) at 22:3-7 (describing "graphical user interface presented to the user via user interface 14 to facilitate creation, customization, and/or

adjustment of the fields of view, the view boundaries, the virtual reality content, and/or other characteristics of system 10"), 22:12-14 ("view 500 and/or other views may be presented to a user, a content creator, and/or other people on a two dimensional display screen"), Fig. 5.

276. Thus, in view of Begault, as well as other references I discussed in Section VII.F, which demonstrate what persons of ordinary skill in the art would have known and understood, it would have been routine and obvious to persons of ordinary skill in the art to designate locations for 3D audio sources to produce sound, and then to manage those 3D audio sources through a user interface (e.g., Begault's GUI, a windowing system like Cohen's MAW, a "glove-based system" for grabbing and moving sound sources like DataGlove, or graphical map as described in Çamci).

277. In the Pedrotti-Jang-Begault combination, persons of ordinary skill in the art thus would have known and been motivated to use Begault's teachings in designating SLPs in accordance with Jang's disclosure of sound areas and audio sources that have predetermined priorities and schemes.

278. Begault also disclosed designating SLPs in empty space. In the context of its pie menu GUI, "various sound inputs in virtual auditory space" are represented "iconically on the screen" and then can be manipulated based on "distance and relative azimuth of each source." Begault (Ex.1007) at 172. Persons of ordinary skill in the art would have understood that "arranging a set of incoming sounds," i.e.,

changing the "gain and azimuth heard for each icon," as taught by Begualt, is designating the SLPs in empty space. Begault (Ex.1007) at 172-73. This is because Begault taught that the user is able to set the distance and azimuth angle from the user, who is centered in this GUI, and that the arrangement of icons is used by the backend 3D audio engine to produce localized sound. Begault (Ex.1007) at 172 ("The computer interprets the relative location of the icons on the screen as commands to a multiinput, 3-D sound spatialization subsystem."), Fig. 5.12. As Begault taught that these interfaces operate based on WIMP principles, skilled artisans would have found that easily implemented in Pedrotti's system, which uses a tracked handheld controller that can be used to point. *See* Begault (Ex.1007) at 173-74; Pedrotti (Ex.1005) at 4:4-11.

279. As discussed above, Begault also taught that binaural sound originates to the user from these sources, and disclosed details for using HRTFs for sound localization, and specifically binaural sound. *See* Section IX.C (overview of Begault).

280. For these reasons, limitation 1[b] would have been obvious to persons of ordinary skill in the art over Pedrotti in view of Jang, and further in view of Begault.

4. 1[c]: "tracking, with the WED worn on the head of the user, the HPED held in the hand of the user such that the HPED provides a location to the WED of the SLP in empty space in the zone above the physical floor from where the binaural sound originates to the user;"

281. For the reasons I explained in addressing limitation 1[a], Pedrotti teaches a WED worn the head of a user that tracks a HPED held in the hand of a user. *See* Section X.C.2. The additional recitations in limitation 1[c] would have been obvious over Pedrotti in view of Jang, or over Pedrotti in view of Jang and further in view of Begault, for the reasons that follow.

282. As noted above, I reviewed the infringement contentions 8K served on Petitioners in district court. *See* '737 8K Infringement Contentions (Ex.1121).

283. In discussing limitation 1[c] in those contentions, 8K contends that two images of a game character in separate locations shows that the game character has moved and that "the user may cause the game character to move through movement of the HPED," and "the WED will track that movement and provide corresponding movement of the SLP":



’737 8K Infringement Contentions (Ex.1121) at 6.

284. Consequently, it appears that, in 8K’s view, limitation 1[c] requires only moving sound-producing virtual objects, such as game characters because then an SLP moves with the game character. *See* ’737 8K Infringement Contentions (Ex.1121) at 6. If that interpretation applies, limitation 1[c] would have been obvious to persons of ordinary skill in the art long before June 2016, over numerous AR and VR references.

285. Using a handheld controller to move sound-producing virtual objects, including game characters, was commonly known and routine for virtual

environments. *See* Section X.C.3 (discussing limitation 1[b] and examples from Pedrotti, Jang, and multiple other references that taught and rendered obvious the use of controllers to move sound-producing virtual objects).

286. Additionally, if limitation 1[c] is interpreted such that it relates to HPED-designated SLPs as I discussed above for limitation 1[b], it would have been obvious over Pedrotti and Jang, or over Pedrotti, Jang, and Begault.

287. As I explained in discussing limitation 1[b], in view of the disclosures in Jang regarding setting "sound areas," "audio sources," and respective predetermined priorities and schemes thereof, persons of ordinary skill in the art would have known and been motivated to implement Jang's sound processing techniques with Pedrotti's handheld controllers, to assign or "designate" SLPs into sound areas, including in view of Begault. *See* Section X.C.3. And, as I explained above, these SLPs exist in empty space in the zone above the physical floor from where the binaural sound originates to the user. *See* Sections X.C.2-X.C.3.

288. A handheld controller being used to designated SLPs would have, or at least obviously would have, provided to Pedrotti's HMD, which tracks the controller, the locations of pertinent SLPs. Persons of ordinary skill in the art would have known and understood this occurs because the sound processor in this system (the processor in Pedrotti's HMD) has to receive those locations to facilitate the generation of binaural sound from those locations, as Jang teaches (or at minimum

renders obvious). *See* Jang (Ex.1006) at 4:19-39 (discussing generating output for sensory sources, e.g., "audio sources," in the "focused" and "non-focused" areas "based on a respective priority"), 6:39-59 (discussing "divid[ing] the sensory data into a focus area and non-focus area[]"), 7:24-32 (system "receives an input of a selected virtual reality character from the user" and "provides the virtual reality apparatus 110 with sound sources occurring in real time according to the relative locations or situations of the character in the virtual reality environment"), 8:43-49 ("each divided focus or non-focus area may contain any number of virtual objects represented by sensory data that may include audio and visual data"); 8:54-9:3 (describing sound processing for the focus and non-focus areas), 10:32-43 (discussing output of sounds for sound sources depicted in Jang's Fig. 5), Fig. 5.

289. Furthermore, Begault confirms the obviousness of this limitation, as it discloses "arranging [] various sound inputs" with its pie menu GUI. Begault (Ex.1007) at 172-73, Fig. 5.12. Also, as Begault explains in discussing audio windowing, even a mouse can control the relative position of an icon representing 3D audio, e.g., "mov[e] the icons of the [virtual conference] participants to a special region on the computer screen." Begault (Ex.1007) at 173.

290. Persons of ordinary skill in the art would have known and been motivated to implement the same functionalities of arranging sound inputs or icons in a 3D virtual reality environment, such as in Pedrotti's "virtual world"; whereas a

mouse or cursor is used in the 2D GUIs as disclosed in Begault, a tracked handheld controller performs the same functions in a 3D environment. *See* Jerald, THE VR BOOK (Ex.1063) at 346 (explaining that "mouse control via pointing" is "typically not ideal from a 3D interaction perspective"), 314 ("[t]racked hand-held controllers are currently the best option for a majority of interactive VR applications"); Pedrotti (Ex.1005) at 11:48-52. Furthermore, persons of ordinary skill in the art would have known and understood that in a system implementing the teachings of Pedrotti, Jang, and Begault, Pedrotti's handheld controllers (the WED-tracked HPEDs of the claim) would provide the locations of designated sound sources (e.g., the locations of sound sources positioned with Pedrotti's controllers in a Begault-type interface for "spatial audio mapping") to the processor in Pedrotti's HMD, so that the processor could and would generate binaural sound from the designated locations (consistent with Jang's and Begault's teachings). *See* Sections VII.C (discussing well-known selection methods for use with handheld controllers in AR and VR); Section X.C.3 (explaining the designated sound sources taught by Pedrotti in view of Jang and further in view of Begault).

291. As discussed in Section VII.E, providing the locations of designated sound sources were well-known and critical to localizing binaural sound, to ensure users hear sound as if it originates from the correct locations in virtual space. *See* Section VII.E (discussing this concept as part of sound localization implemented in,

for example, Srinivasan, Najaf-Zadeh, Miller 466, and Agevik); *see also* Flaks (Ex.1009) at Fig. 7 (step 714 and 716 requiring "[a]sk user to indicate to apparent location of sound source" and "[d]etermine location to which user is indication," respectively, as part of the process of saving an exemplary HRTF for the user); Begault (Ex.1007) at 2 ("In addition, there is the virtual sound source (sound image) to be localized; and the linear distance between it and the listener to be interpreted as perceived distance.") (emphasis in original omitted), Fig. 1.1 (indicating key parameters such as "elevation," "azimuth," and "distance" between the listener with respect to the location of the virtual sound source); McGrath at 4-5 (explaining that acoustic simulation is difficult because "[n]ot only is it necessary to make sound sources appear in different locations in space, but the echoes and reverberations of those sounds must be realistic, and the whole experience must twist and turn in response to the user's head movements.").

292. Thus, continuing with the example implementation I explained in the context of limitation 1[b], it follows that persons of ordinary skill in the art would have known that if a Pedrotti handheld controller were used to designate locations for visual elements in Jang's virtual spaces (e.g., an announcer and an air horn in the virtual basketball court, or conference attendees and a monitor in the virtual conference room), those designations—made with or without a "spatial audio mapping" interface like those disclosed in Begault—would provide locations for the

generation of such visual elements' binaural sound as claimed. Jang (Ex.1006) at 10:37-43 ("Ideally, basketball court sound 515 including sound of people 501a to 501d and sound of a speaker 503 in the basketball court 500 is first provided as shown in (a) of Fig. 5"), Fig. 5; Begault (Ex.1007) at 172-74, Fig. 5.12.

5. 1[d]: "processing, by a processor, sound with head-related transfer functions (HRTFs) to generate the binaural sound that externally localizes to the user at the location of the SLP in empty space in the zone above the physical floor; and"

293. Limitation 1[d] would have been obvious to persons of ordinary skill in the art over Pedrotti in view of Jang, and/or over Pedrotti in view of Jang, and further in view of Begault.

294. Jang discloses that "the sound of the virtual reality system may use a localization technique capable of expressing the virtual location" of "a sound-generating object." Jang (Ex.1006) at 1:42-51 (explaining that the sound processing method "give[s] the sense of reality to the sound"). Jang further discloses that "to express directionality, the paths of sound reaching listener's ears, which determine the direction of sound in view of the listener, may be modeled by using a sound processing technique, such as a Head Related Transfer Function (HRTF), so as to determine the output sound." Jang (Ex.1006) at 1:52-56.

295. Jang's "sound processing unit" "process sound" and identifies "exact sound-generating location[s]." Jang (Ex.1006) at 7:38-63, 8:54-9:3. Thus, Jang

discloses, or at a minimum renders obvious, processing, by a processor, sound with HRTFs to generate binaural sound that externally localizes to the user at a SLP.

296. Indeed, it was known that binaural sound often provides a more realistic representation of sound, and that binaural sound is generated using HRTFs. Jerald, THE VR BOOK (Ex.1063) at 240 ("For more realistic audio and where auditory cues are especially important, ***auralization***—the rendering of sound to simulate reflections and binaural differences between the ears—can be used … Ideally, HRTFs model a specific user's ears, but in practice a generic ear is modeled.") (emphasis in original); *see also* Section VII.E (discussing background for sound localization techniques, including use of HRTFs and generating binaural sound). And as discussed for limitations 1[a] and 1[b], the SLPs pertaining to a Pedrotti-Jang implementation exist (or at a minimum obviously exist) in empty space in a zone above the physical floor from where binaural sound originates to a user. *See* Sections X.C.2-X.C.3.

297. Furthermore, limitation 1[d], and in particular the generation of binaural sound using HRTFs, would have been obvious over Pedrotti in view of Jang, and further in view of Begault.

298. Begault, which published in 2000, discloses the use of HRTFs to localize sound, and how processors process sound with HRTFs to generate binaural sound. Begault (Ex.1007) at 12 ("The audio subsystem" for "a sound subsystem in

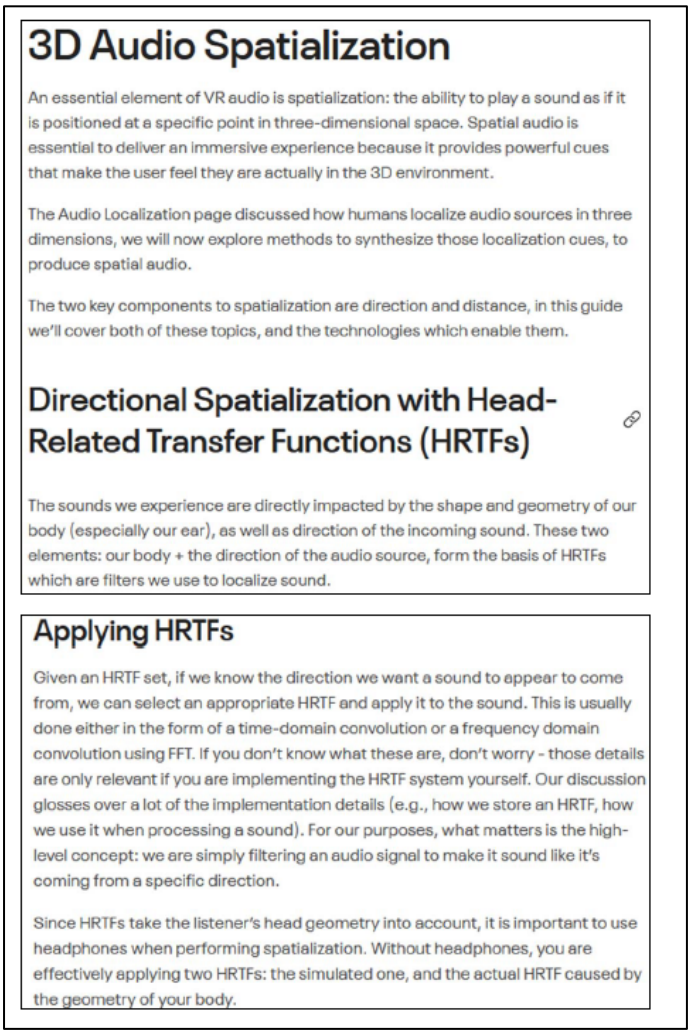
a virtual reality system" "contains two fundamental parts: a signal source, such as a synthesizer, and a signal processor that contains components for spatializing and mixing the outputs from the signal sources."), Fig. 1.8 (depicting a "signal processor" for "spatialization and mixing of multiple monaural channels into binaural output"), 41 ("The use of HRTF spectral shaping is typically featured as the key component of a 3-D sound system … The binaural HRTF (terminology for referring to both left- and right-ear HRTFs) can be thought of as a frequency-dependent amplitude and time-delay differences that result primarily from the complex shaping of the pinnae."), 99 ("the inclusion of the binaural HRTF is fundamental for a 3-D sound system"); *see also* Section IX.C (overview of Begault).

299. Begault further discloses that "3-D sound processing is almost always best accomplished digitally, using audio DSP [digital signal processing] chips to manipulate signals sources." Begault (Ex.1007) at 100.

300. Also, as I already explained, the SLPs pertaining to a Pedrotti-Jang-Begault implementation exist (or at a minimum obviously exist) in empty space in a zone above the physical floor from where binaural sound originates to a user. *See* Sections X.C.2-X.C.3.

301. It bears noting that, in discussing limitation 1[d] in its district court infringement contentions, 8K contends that portions of articles discussing "3D Audio Spatialization" and "Directional Spatialization with Head-Related Transfer

Functions (HRTFs)" demonstrate the claimed "processing … sound with head-related transfer functions (HRTFs) to generate the binaural sound." '737 8K Infringement Contentions (Ex.1121) at 8. Specifically, with reference to the below-reproduced image, 8K contends that "[p]ublic literature confirms … use of sound localization and 3D audio spatialization" as claimed:



3D Audio Spatialization

An essential element of VR audio is spatialization: the ability to play a sound as if it is positioned at a specific point in three-dimensional space. Spatial audio is essential to deliver an immersive experience because it provides powerful cues that make the user feel they are actually in the 3D environment.

The Audio Localization page discussed how humans localize audio sources in three dimensions, we will now explore methods to synthesize those localization cues, to produce spatial audio.

The two key components to spatialization are direction and distance, in this guide we'll cover both of these topics, and the technologies which enable them.

Directional Spatialization with Head-Related Transfer Functions (HRTFs)

The sounds we experience are directly impacted by the shape and geometry of our body (especially our ear), as well as direction of the incoming sound. These two elements: our body + the direction of the audio source, form the basis of HRTFs which are filters we use to localize sound.

Applying HRTFs

Given an HRTF set, if we know the direction we want a sound to appear to come from, we can select an appropriate HRTF and apply it to the sound. This is usually done either in the form of a time-domain convolution or a frequency domain convolution using FFT. If you don't know what these are, don't worry - those details are only relevant if you are implementing the HRTF system yourself. Our discussion glosses over a lot of the implementation details (e.g., how we store an HRTF, how we use it when processing a sound). For our purposes, what matters is the high-level concept: we are simply filtering an audio signal to make it sound like it's coming from a specific direction.

Since HRTFs take the listener's head geometry into account, it is important to use headphones when performing spatialization. Without headphones, you are effectively applying two HRTFs: the simulated one, and the actual HRTF caused by the geometry of your body.

'737 8K Infringement Contentions (Ex.1121) at 8.

302. Thus, it seems that, in 8K's view, limitation 1[d] covers any "use of sound localization" or "3D audio spatialization" using HRTFs. If that interpretation applies, a Pedrotti-Jang or Pedrotti-Jang-Begault combination plainly renders limitation 1[d] obvious to persons of ordinary skill in the art, for the reasons I explained above.

6. 1[e]: "displaying, with the WED worn on the head of the user a virtual image at the location of the SLP in empty space in the zone above the physical floor from where the binaural sound originates to the user."

303. As discussed for limitation 1[a], Pedrotti and Jang both disclose HMDs. *See* Section X.C.2. Pedrotti's HMD displays virtual images, and so does Jang's. Pedrotti (Ex.1005) at Abstract ("processor causes the HMD to display a virtual world"); Jang (Ex.1006) at 1:38-41 ("image of a virtual reality system" is realized using "Head Mounted Display (HMD)"). Jang also discloses, as persons of ordinary skill in the art would have known, that an HMD is primarily a "visual display device." Jang (Ex.1006) at 1:38-41.

304. Thus, both Pedrotti and Jang render obvious HMDs (WEDs worn on users' heads) that display virtual images. The additional recitations in limitation 1[e] would have been obvious over Pedrotti and Jang, or over Pedrotti, Jang, and Begault, for the reasons that follow.

305. In discussing limitation 1[e] in its district court infringement contentions, 8K contends that an "image taken from a video depicting the user experience with the 'Bogo' application" demonstrates "displaying a virtual image at the location of the SLP." '737 8K Infringement Contentions (Ex.1121) at 9. Specifically, with reference to the below-reproduced image, 8K argues that "the SLP is located at the virtual image of the game character displayed by the WED":



'737 8K Infringement Contentions (Ex.1121) at 9.

306. Thus, it appears that, in 8K's view, limitation 1[e] requires only that a sound-producing video game character be presented or displayed to the user wearing the WED. *See* '737 8K Infringement Contentions (Ex.1121) at 9 ("the SLP is located at the virtual image of the game character displayed by the WED").

307. If this interpretation applies and limitation 1[e] merely requires visually presenting a sound-producing virtual object, such as a game character, then limitation 1[e] would have been basic, straightforward, and of course obvious to persons of ordinary skill in the art reading Pedrotti, Jang, or any number of VR references for reasons I previously explained in Sections X.C.3-X.C.4 (discussing Pedrotti's virtual images, e.g., a sword and sports equipment, Jang's virtual characters and avatars, and the fact that persons of ordinary skill in the art knew 3D sounds and associated virtual images move together).

308. Additionally, if limitation 1[e] is interpreted such that it relates to HPED-designated SLPs as I discussed above for limitation 1[b], it would have been obvious over Pedrotti and Jang, or over Pedrotti, Jang, and Begault.

309. Jang discloses outputting "audio, sound, and/or other sensory data," and that visual data is important to creating an immersive, life-like virtual environment. Jang (Ex.1006) at 6:15-23 (explaining that "[t]he life-like ***image*** and sounds give a view and/or listener an impression of 'being in the life-like virtual location") (emphasis added), 6:36-42 ("user may ***see***, hear, and otherwise sense the virtual environment") (emphasis added).

310. Jang also discloses that its system "check[s] sound source information on other characters and other objects existing in the virtual reality spaces" to "provide[] the virtual reality apparatus 110 with sound sources occurring in real time

according to the relative locations or situations of the character in the virtual reality environment." 7:24-32. Thus, persons of ordinary skill in the art would have known that if a HPED, such as Pedrotti's handheld controller, were used to set predetermined priorities and schemes for Jang's "sound areas" and "audio sources" by assigning (i.e., "designating") SLPs as discussed for limitation 1[b] (*see* Section X.C.3), Jang's system would, or at a minimum obviously would, display a virtual image at the designated SLP.

311. It would have been obvious to render an image of the SLP at the SLP to convey the SLP's location and presence to the user. This is because one of "[t]he primary output devices used for VR are visual displays." Jerald, THE VR BOOK (Ex.1063) at 32, 42 ("VR largely focuses on the display component"). As I explained in my overview of tracking, "display," which is a form of output to the user, is part of a feedback loop that enables the user to interact with the virtual environment; that is, the user's actions are tracked (e.g., designating or moving a game character), and the system provides the responsive output to the user as a result of that action (e.g., displaying that character). *See* Section VII.D; *see also* Section VII.C (overview of handheld controllers).

312. To provide a more specific example in the context of Jang's system, persons of ordinary skill in the art would have understood that if a user designated a location for an announcer in Jang's virtual basketball court, Jang's system would

display a virtual image of the announcer. As another example in the context of Jang's system, Jang's system would display a virtual image of a monitor used in the virtual conference room. This is consistent with and supported by Begault's teachings that virtual images are presented at the locations where SLPs are designated by the user using the user interface. Begault (Ex.1007) at 172 ("The basic concept is to represent each form of auditory input iconically on the screen and then allow manipulation of the distance and relative azimuth of each source."), Fig. 5.12. As Begault taught, the icon for the "computer monitor" would be placed by a user, and then the corresponding virtual image of the computer monitor (the arranged sound source) would be displayed at the location in 3D virtual space for that arranged sound source, or SLP. Begault (Ex.1007) at 172-73, Fig. 5.12.

313. I further note that, as I explain more in Section X.D.5.a below, the display of virtual monitors in 3D virtual environments was routine. *See, e.g.*, U.S. Patent Publication No. 2013/0141421 ("Mount 421") (Ex.1028) at [0017] (describing "a virtual monitor" "playing a video stream of moving or static images"), [0026] (similar); U.S. Provisional Application No. 62/340,110 ("Martin") (Ex.1024) at [0009], [0014]-[0019] (discussing "mixed-media panel[s]" that include "images, text, sound samples, videos"); U.S. Patent Publication No. 2015/0302652 ("Miller 652") (Ex.1025) at [0422] (disclosing a "virtual user interface" that "may be a floating virtual screen").

314. Finally, the displayed virtual image would be located in empty space in the zone above the physical floor because, for reasons discussed in the context of limitations 1[a] and 1[b], that is where the image's associated SLP from where binaural sound originates to the user is located. *See* Sections X.C.2-X.C.3.

* * *

315. For the reasons set out above, it is my opinion that every limitation of claim 1 of the '737 patent, and claim 1 as a whole, would have been obvious to persons of ordinary skill in the art over Pedrotti in view of Jang and over Pedrotti in view of Jang and further in view of Begault.

D. Dependent Claims 2-7

316. I understand that claims 2-7 depend on independent claim 1.

317. Thus, it is my opinion that dependent claims 2-7 would have been obvious to persons of ordinary skill in the art for the same reasons as independent claim 1 (*see* Section X.C), and additionally for the reasons I discuss in the following subsections.

1. Claim 2

a. 2[a]: "The method of claim 1, wherein the binaural sound is a voice of a virtual reality (VR) character that talks to the user while the user plays a VR game,"

318. Pedrotti discloses that its system is designed to be used while a user is "playing a game within a virtual world." Pedrotti (Ex.1005) at 11:48-52.

319. Persons of ordinary skill in the art would have known that such games would include VR characters, including characters that talk to the user during the game. *See, e.g.*, Pedrotti (Ex.1005) at 9:29-32 (noting, for example, that a user-controlled "character" is "conventional" in video games). It was well known before June 2016 that many virtual applications, including VR games, included user-controlled avatars and characters or computer-controlled game characters that talked in those contexts:



Figure 22.5 Robotic characters without legs prevent breaks-in-presence that often occur when characters walk or run due to the difficulty of animating walking/running in a way that humans perceive as real. (Courtesy of NextGen Interactions)



Figure 22.6 An example of a fully immersive VR social experience. (Courtesy of VRChat)

See, e.g., Jerald, THE VR BOOK (Ex.1063) at 257-59 ("In VR, we can explicitly define and design ourselves from a third-person perspective … audio filters and prerecorded audio can be used to modify the sound of our own voice. Providing the capability for users to personalize their own avatar has proven to be very popular in both 2D virtual worlds (e.g., Second Life) as well as fully immersive worlds."), Figs. 22.5-22.6 (providing examples of VR characters that talk, including in VRChat where users spend "hours at a time in fully immersive social VR"); *see also* Osman (Ex.1031) at 10:44-53 ("Remote player 406b is assigned a position in the physical space of player 406a … when player 406b speaks, the speech is captured by portable device 408b and then transmitted to game console 422 or portable device 408a. The speech from user 406b is then transformed using HRTF, or some other sound localization algorithm, to deliver the speech to user 406a as if player 406b were

standing near player 406a."); Ross (Ex.1125) at 17:32-35 ("[i]nteraction may include conversing (e.g., textual chatting, voice communication, etc.) with and/or otherwise socializing with virtual characters such as avatars, other characters, and/or other users"), 17:63-18:9 (explaining that "the character and/or avatar walks the user through a scene in the virtual space and points things out"). Where avatars, which are representations of a real live person, are used, it would have been obvious to allow those avatars to transmit the user's voice since being able to communicate with fellow users—such as in Second Life—would have been known by persons of ordinary skill in the art to be very basic.

320. An example of a specific VR game where characters talk to the player is *Job Simulator: The 2050 Archives*, which was available on the HTC Vive at its launch on April 5, 2016. Wikipedia, *Job Simulator* (Ex.1108) at 2. In this game, floating robots speak to the player and order the player to complete tasks. For example, in the task for the "Store Clerk" portion of the game where the player assumes the role of a store clerk, a robot walks in the store to ask for a hot dog, and says, "No, no[,] I'm talking to you, no you[,] yeah you. You got that hot dog already?" Fandom, *Job Simulator Wikia: Are You Talking to Me?* (Ex.1065) at 1. In another example from the same game, a robot named Job Bot "walked [the user] through the prep" in a cooking demonstration. VentureBeat, *Valve's Virtual Reality Apps with the HTC Vive Headset Won't Make You Seasick* (May 2, 2015)

("VentureBeat Valve") (Ex.1102) at 6. The same VentureBeat review of Job Simulator indicates that the HTC Vive is configured to play "3D positional audio, so you can tell what direction the sounds are coming from." VentureBeat Valve (Ex.1102) at 4.

321. As another example, from July 1, 1994 until September 8, 1995, Disney's Imagineering ran a "high-fidelity virtual reality (VR) attraction where guests fly a magic carpet through a virtual world based on the animated film 'Aladdin.'" Pausch, *Disney's Aladdin: First Steps Toward Storytelling in Virtual Reality* (1996) ("Pausch") (Ex.1076) at 193. The experience included talking VR characters, such as a parrot. Pausch (Ex.1076) at 197 ("The show began with instructions from a parrot who told the pilots to nod their heads."; "All the characters had a small set of dialog sequences that could be triggered."). These voices from the characters were generated as binaural audio. Pausch (Ex.1076) at 194-95 ("The HMD contained two speakers that rested close to, but not in physical contact with, the guest's ears. We used a combination of stereo ambient sound, binaural recorded sound, and eight channels of localized sound … The localized channels provided main characters and sound effects."); Mine, *Towards virtual reality for the masses: 10 years of research at Disney's VR studio* (2003) ("Mine 2003") (Ex.1134) at 12 (describing the need for intuitive use of the Aladdin game, "This means that, unlike a conventional PC game, there is very little time for teaching the guest how to use

the attraction's controls and play the game."). Persons of ordinary skill in the art would have understood that these developments and techniques used for VR immersive attractions such as Aladdin are forms of VR games.

322. Indeed, it was well known before June 2016 to have VR characters or avatars speak with voices that sounded as if they were coming from the respective characters or avatars:



Figure 1. Group voice chatting in Traveler via lip-sync emotive avatars.

See, e.g., DiPaola, *A 3D Virtual Environment For Social Telepresence* (2002) (Ex.1055) at 1 (describing the Traveler application where "users are immersed in a shared 3D world" with "other participants as fully modeled 3D characters," where "[a]s a user speaks, his or her voice emanates from the corresponding avatar on each of the other clients"), Fig. 1; *see also* Slater (Ex.1091) at 105 (describing a study of a virtual rehearsal where "actors were embodied as avatars who could see and talk

to one another in the shared virtual space"); Pan, *Virtual Character Personality influences Participate Attitudes and Behavior – An Interview with a Virtual Character About Her Social Anxiety* (2015) (Ex.1074) at Introduction ("Participants in an immersive virtual reality (IVR) can interact with proximal life-sized virtual human characters, which can talk with them, look them in the eye, smile, walk around, move into their space – with the possibilities only limited by the capabilities of the programing and system") (collecting references where studies were conducted in virtual applications involving talking virtual characters); Erickson (Ex. 1057) at 504 ("The version of Second Life used supported spatialized audio. Users wore headsets and as they spoke their in-world voices came from the correct direction, and varied in volume according to the distance between speaker and hearer.").

323. Jang further disclosed a control unit for processing audio in a VR environment that mixed visual sensory elements, "including a user's avatar or character and other avatars, ***characters***, objects, or features of the virtual environment," with audio data before outputting same to the user. *See* Jang (Ex.1006) at 6:39-59 ("The control unit 114 may mix sensory data of the virtual environment including a user's avatar or character and other avatars, characters, objects, or features of the virtual environment."); 7:14-19 ("The virtual reality server 100 may include a control unit 104, a storage unit 102, and a communication unit 106 to provide predetermined virtual reality environments, such as a virtual reality

game, and various sound sources provided in the virtual reality environments to the virtual reality apparatus 110 of the user."), 7:19-23 ("the control unit 104 controls the general operation of the virtual reality server 100 and provides sound sources as well as image sources occurring in the virtual reality environments to the virtual reality apparatus 110."), 7:24-37 ("The control unit 104 may receive an input of a selected virtual reality character from the user to which the virtual reality environment is provided, check sound source information on other characters and other objects existing in the virtual reality spaces already stored in the storage unit 102, and provides the virtual reality apparatus 110 with sound sources occurring in real time according to the relative locations or situations of the character in the virtual reality environment.").

324. Furthermore, persons of ordinary skill in the art would have known and been motivated to use audio spatial mapping to manipulate SLPs for VR characters, e.g., in setting the predetermined priorities or schemes for Jang's focus areas, the same way audio spatial mapping is used to manipulate SLPs for any sound-producing VR object, e.g., a virtual monitor, conference attendees, etc. Begault, (Ex.1007) at 174, Fig. 5.12.

b. 2[b]: "and the voice externally localizes to the user at the VR character that is at the location of the SLP in empty space in the zone above the physical floor."

325. It would have been obvious to externally localize a VR character's voice to the location of an SLP (e.g., where the VR character's image is displayed) for the same reasons it would have been obvious to persons of ordinary skill in the art to externally localize other sounds to the SLPs (and the corresponding images of those SLPs). *See* Sections X.C.3-X.C.6 (limitations 1[c]-1[e]).

326. As discussed, such localization is the key concept behind 3D audio and binaural sound, and is aligned with the general understanding that sounds and images for virtual objects should be associated and positioned to enhance a user's experience in a virtual environment. *See* Section VII.E (discussing sound localization). Persons of ordinary skill in the art would have known and understood, long before June 2016, that a VR character's voice should not appear to originate from a location distinct from that VR character. For example, a user should not hear a robot displayed to the front of a user as if the robot is speaking (or beeping) from behind the user.

2. Claim 3

a. 3[a]: "The method of claim 1 further comprising: tracking, with the WED worn on the head of the user, the HPED held in the hand of the user as the HPED moves in a trajectory having a shape of an arc;"

327. For the reasons that I have discussed for limitation 1[a], Pedrotti teaches tracking a HPED held in the hand of a user with a WED worn on a user's head. *See* Section X.C.2.

328. Additionally, persons of ordinary skill in the art would have known and been motivated to track Pedrotti's handheld controller as it moves in an arc trajectory, a typical trajectory tracking gestures that users frequently make in virtual environments.

329. Indeed, Pedrotti discloses and depicts multiple virtual objects that persons of ordinary skill in the art would have known would be moved in an arc trajectory, including "a bat, tennis racket, golf club, or other sporting implement (or the handle of such an object), a gun, a sword or other weapon (or again the handle thereof), or some other toy or device which will appear in the virtual world":

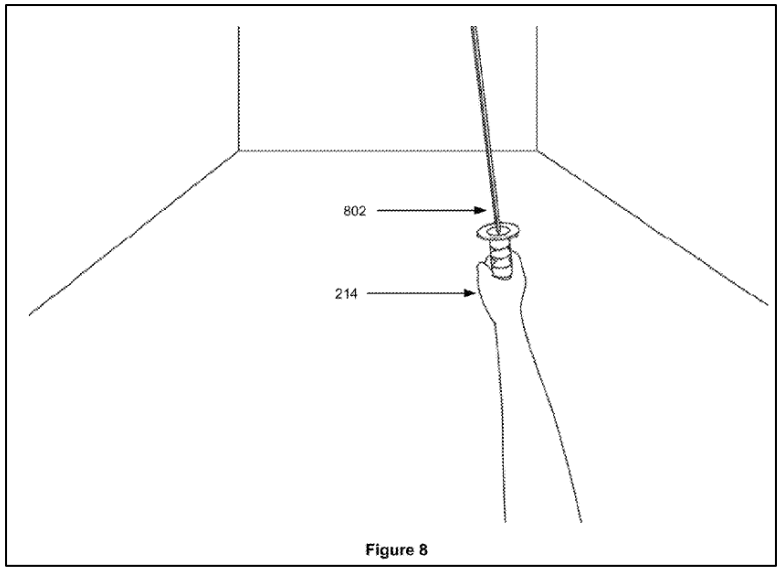


Figure 8

Pedrotti (Ex.1005) at Fig. 8 (depicting a virtual sword being controlled by a user), 9:29-52 (describing "picking up" a "virtual weapon"), 16:33-42; *see also* Ross (Ex.1125) at 23:29-32 (describing "a throwing motion" as one kind of gesture).

b. 3[b]: "processing, by the processor and with the HRTFs, the sound to generate SLPs of the binaural sound that moves through the empty space along the trajectory having the shape of the arc; and"

330. For the same reasons it would have been obvious to process sound with HRTFs to generate binaural sound that externally localizes at the location of a SLP in empty space in a zone above a physical floor—which I explained in the context of limitations 1[c] and 1[d] (*see* Sections X.C.4-X.C.5)—it would have been obvious to process sound with HRTFs to generate SLPs of binaural sound that move along an arc trajectory.

331. Doing this would have been a straightforward matter of updating audio output after updating location information to reflect a virtual object's location in space as it was being moved in an arc trajectory, and persons of ordinary skill in the art would have readily understood how to do this. *See, e.g.*, Begault (Ex.1007) at 77 (noting that "sound sources used in a 3-D sound system are more than likely dynamically changing in location"); *see also* Section VII.E (discussing sound localization).

332. Further, just as I explained for a VR character in the context of limitation 2[b] (*see* Section X.D.1.b), persons of ordinary skill in the art would have known and understood, long before June 2016, that sound for a virtual object moving in an arc should not appear to originate from a location distinct from that object's trajectory. A user should not hear the swing of a virtual tennis racket as if it originates from the chair umpire, or hear the swing of a virtual golf club as if it originates from the pin marking the hole the user is shooting at hundreds of yard away.

c. 3[c]: "displaying, with the WED worn on the head of the user, virtual images that follow the trajectory having the shape of the arc that shows the user the

trajectory of the SLPs of the binaural sound moving through the empty space."

333. For the same reasons limitations 3[a] and 3[b] would have been obvious to persons of ordinary skill in the art, limitation 3[c] would have been obvious. *See* Sections X.D.2.a-X.D.2.b.

334. For example, persons of ordinary skill in the art would have known and been motivated to track a user's movement of Pedrotti's handheld controller, which is displayed to the user as a virtual sword; update the sound coming from the sword slicing through the air based on the handheld controller's position (and also the virtual sword's position); and display the virtual image of the virtual sword based on the handheld controller's position (and also the virtual sword's position).

335. Persons of ordinary skill in the art would know that the display of the virtual image of the virtual sword as it arcs through the air shows the trajectory of the SLPs of the binaural sound associated with the sword's movement, as the sword moves through empty space in the virtual environment.

3. Claim 4

a. 4[a]: "The method of claim 1 further comprising: determining, with the WED worn on the head of the user, when a location of the user conflicts with a boundary of the zone; and"

336. Pedrotti discloses that a processor "determine[s] from the position of [a] handheld controller that the handheld controller is within a first preselected

distance from [a] boundary." Pedrotti (Ex.1005) at 2:44-59. The processor then "generate[s] and output instructions to the HMD to include in a display of a virtual world a visual warning such as a grid or virtual fence when the user comes within a preselected distance of the boundary, thus providing a warning that the user is about to move out of the selected area." Pedrotti (Ex.1005) at 2:44-59.

337. Pedrotti also discloses that the warning is provided "when the user comes within a preselected distance of the boundary, thus providing a warning that the user is about to move out of the selected area," regardless of whether the user's location is determined based on the location of the HMD or the location of the handheld controller. Pedrotti (Ex.1005) at 4:37-44 (indicating that this is done when "[t]he processor [] tracks the position and orientation of the HMD tracker, and possibly the position and orientation of one or more trackers in the physical controllers"), 12:35-13:2 ("[T]he processor knows where the user's head and hands are located; if the processor has been provided with information about the boundary of the selected area then the processor can also determine when the user's head and/or hands approaches the boundary.").

338. Pedrotti's Figure 15, which is a flowchart of this method, discloses that this method "result[s] in the display of a visual warning such as the virtual fence." Pedrotti (Ex.1005) at 15:4-39, Fig. 15.

339. Pedrotti further discloses that "the preselected distance" triggering its warning "may vary by application, so that, for example, it is greater in an application in which larger body movements are expected from the user than in an application in which such body movements are not expected." Pedrotti (Ex.1005) at 13:46-62.

340. Pedrotti also teaches that "if the user's head goes beyond the boundary, the processor can cause the HMD to fade to black, and present, for example, only a warning message and/or a beacon or arrows directing the user to move in the direction of the boundary and the selected area," meaning that Pedrotti's system is able to identify conflicts with its boundaries. Pedrotti (Ex.1005) at 13:67-14:5.

341. For these reasons, Pedrotti discloses (or at a minimum renders obvious) limitation 4[a].

b. 4[b]: "displaying, with the WED, the boundary of the zone to alert the user that the location of the user conflicts with the boundary of the zone."

342. As discussed for limitation 1[e], Pedrotti discloses an HMD that displays virtual images. *See* Section X.C.6.

343. Pedrotti further discloses that "when the user comes within a preselected distance of the boundary," the processor "generates instructions to the HMD to include in a display of a virtual world a visual warning such as a grid of virtual fence," "thus providing a warning that the user is about to move out of the selected area":

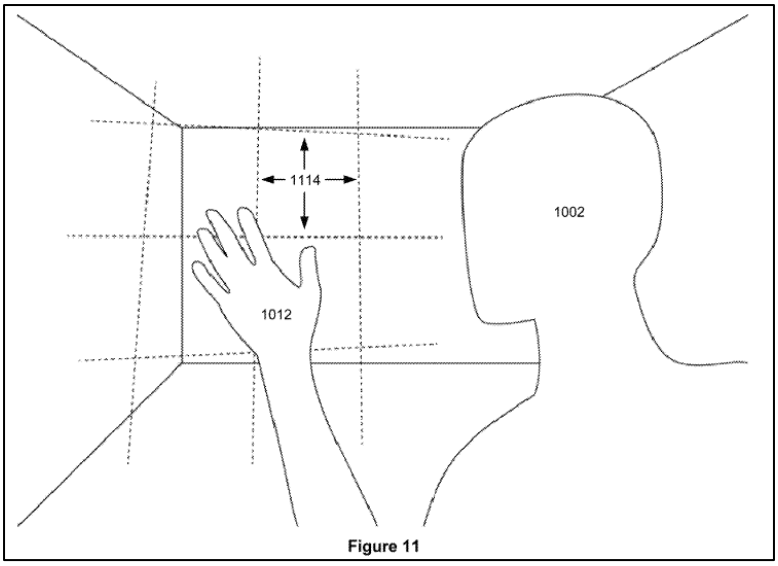


Figure 11

Pedrotti (Ex.1005) at 4:37-44, Fig. 11 (depicting a "visual warning [] in the form of a grid of lines or a 'virtual fence' located at the boundary"); *see also* Pedrotti (Ex.1005) at 12:40-50 ("the processor generates a warning that the user is close to the boundary so that the user can take action to avoid the boundary and thus potential collision with the physical objects"), 12:60-66 ("In addition, since the hand of the user 1002 is within the preselected distance of the boundary of the selected area, the processor generates instructions to the HMD to generate the visual warning. As illustrated in this embodiment, this visual warning is in the form of a grid of lines or a 'virtual fence' located at the boundary, as indicated in FIG. 11 by the dashed lines 1114."), 13:63-67 ("If the user's head or hands go beyond the boundary as determined by the trackers, the processor can provide additional messaging or

warning, such as text or auditory warnings, or an additional visual warning, that persists until the user returns to the selected area within the boundary.").[6]

344. Moreover, as I explained in Section VII.G, numerous safety and chaperone systems for virtual environments, which alerted users that their locations conflicted with boundaries, existed and were known to persons of ordinary skill in the art before June 2016.

4. Claim 5

a. 5[a]: "The method of claim 1 further comprising: displaying, with the WED worn on the head of the user, a virtual image of the zone as lines that extends from the physical floor and around the user,"

345. As discussed for limitation 4[b], Pedrotti discloses an HMD that displays at the boundary of a safe area a "visual warning [] in the form of a ***grid of lines*** or a 'virtual fence.'" Pedrotti (Ex.1005) at 12:10-15 ("[t]he processor provides instructions to the HMD display to include a display of a virtual fence at the boundary when the user comes within a preselected distance of the boundary of the selected area, thus providing a warning that the user is approaching the boundary of

[6] *See also* '737 8K Infringement Contentions (Ex.1121) at 21 (contending that the display of a fence just like Pedrotti's "alert[s] the user that the location of the user conflicts with the boundary of the zone" as claimed).

the selected area"), 12:51-13:11 (describing Figure 11), 15:4-55 (describing "flowchart of a method implemented by a processor that might result in the display of a visual warning such as the virtual fence [] of Fig. 11"), Fig. 11; *see* Section X.D.3.b.

346. Persons of ordinary skill in the art would have known and understood that such a grid of lines or virtual fence would, or obviously would, extend from a floor and around a user, as depicted in Pedrotti. Pedrotti (Ex.1005) at Figs. 10-11 (depicting before and after Pedrotti's visual warning is displayed), Figs. 12-14 (depicting boundaries that surround a user), 3:51-58, 12:16-14:5 (describing Figs. 10-11).[7]

[7] *See also* '737 8K Infringement Contentions (Ex.1121) at 18 (contending that the display of two Guardian walls shows a "boundary of the 3D zone that extends from the physical floor and around the user" as claimed. I further note that, if 8K argues that Pedrotti's virtual fence does not extend (i) from the floor or (ii) entirely around the user, that type of a display would have been obvious in view of Pedrotti's disclosures, in view of Pedrotti's disclosures (discussed above) and other safety and chaperone systems (*see* Section VII.G).

b. 5[b]: "wherein the zone has a customized shape drawn by user with the HPED, and the WED stores coordinate locations of the customized shape."

347. Pedrotti discloses that a user is able to define a zone with "[a] boundary 1404 around an irregularly shaped area by having the user walk around a perimeter chosen by the user with one of the trackers." Pedrotti (Ex.1005) at 14:56-65, Fig. 14 (depicting an irregular, customized shape of boundary 1404). Through this process, the user draws a customized shape for the claimed zone. *See* Pedrotti (Ex.1005) at 14:62-65 ("The processor determines the position of the tracker at a number of sampling points as the user moves around the chosen perimeter, and from those points determines the boundary 1404."); *see also* Kobayashi (Ex.1019) at 5:15-20 (describing drawing a boundary); Sawyer (Ex.1036) at [0034]-[0036] (describing moving a tracked game controller to draw the operating space); Jerald, THE VR BOOK (Ex.1063) at 298 (a common gesture of indicating is to "point or draw a path"); Section VII.G (discussing multiple variations of how other safety systems accepted user input to create customized boundaries, e.g., Pedrotti, Gallery, Sawyer, Gum, Kobayashi, and Peck).[8]

[8] *See also* '737 8K Infringement Contentions (Ex. 1121) at 20 (8K contending that limitation 5[b] is satisfied by a user "moving [an] [H]PED along [a] desired boundary," just like in Pedrotti).

348. Additionally, in view of Pedrotti's disclosure that "if the processor has been provided information about the boundary of the selected area then the processor can also determine when the user's head and/or hands approaches the boundary" (Pedrotti (Ex.1005) at 12:31-50), it would have been obvious to persons of ordinary skill in the art that the Pedrotti's system stored the coordinate locations of the "sampling points" defining the boundary—or, "information about the boundary." In order to make the comparison between the user's location (either by the user's head or hands) and the boundary, those values would need to be stored and retrievable in memory.

349. Persons of ordinary skill in the art also would have known that such memory preferably would be in the HMD, since Pedrotti discloses that its processor is located in the HMD. Pedrotti (Ex.1005) at 16:22-24. Indeed, Jang teaches this, disclosing a "storage unit" in its "virtual reality apparatus" that a person or ordinary skill in the art would have known could and would be used for the purpose of storing Pedrotti's "sampling points" defining the boundary. *See* Jang (Ex.1006) at 4:5-10 ("software code may be stored in a software-code-storing medium, ***such as a memory module***, a server in communication with a virtual reality display device, by a CD, DVD, or any other disk, ***memory storage device***, including a computer-readable medium") (emphasis added), 12:57-67 (further disclosing examples of computer-readable media that can store Jang's programs and data relied upon,

including "read-only memory (ROM), random-access memory (RAM), CD-ROMs, DVDs, magnetic tapes, floppy disks, and optical data storage devices"), Fig. 1A ("storage unit" 102 in "virtual reality apparatus" 110). In fact, by June 2016, it was conventional to store information directly in the memory of HMDs. *See, e.g.*, McCulloch (Ex.1008) at 8:1-11 ("memory 244 accessible to the processing unit 210 for storing processor readable instructions and data"), Fig. 2A (depicting memory 244 as part of the HMD); Ross (Ex.1125) at Figs. 1-2 (showing "electronic storage 30" in its computing device 12), 5:26–27 (indicating that computing device 12 is a "virtual reality headset computing device"), 23:46-67 ("[e]lectronic storage may store files, software algorithms, information determined by processor(s) 20, and/or other information that enables the respective devices to function"), 24:10-19 (describing the processing devices that executes "instructions stored electronically on an electronic storage medium"), 24:59-62 ("virtual reality content … for display to the user may be obtained from electronic storage").

5. Claim 6

a. 6[a]: "The method of claim 1 further comprising: displaying, with the WED, a virtual monitor in a field of view (FOV) of the user;"

350. Jang teaches that visual sensory elements are displayed in the "visual perspective of the character," which reflects the field of view (FOV) of the user. Jang (Ex.1006) at 3:39-45 ("the perspective of the character may be the perspective

of the user" such that "[t]he focus area may correspond to a location in the virtual environment that is in the immediate foreground of the character visual perspective of the character"); 4:20-24 (similar). Jang also explains that "the virtual reality device [may] display a life-like image," which would reflect the field of view of the user, as well as manipulations of the display of those areas to the user. Jang (Ex.1006) at 6:15-17 (explaining that "the virtual reality device [may] display a life-like image"), 6:55-59 (describing blurring or darkening of certain displayed areas).

351. In an example of a virtual environment, Jang depicts a monitor in a virtual conference room:

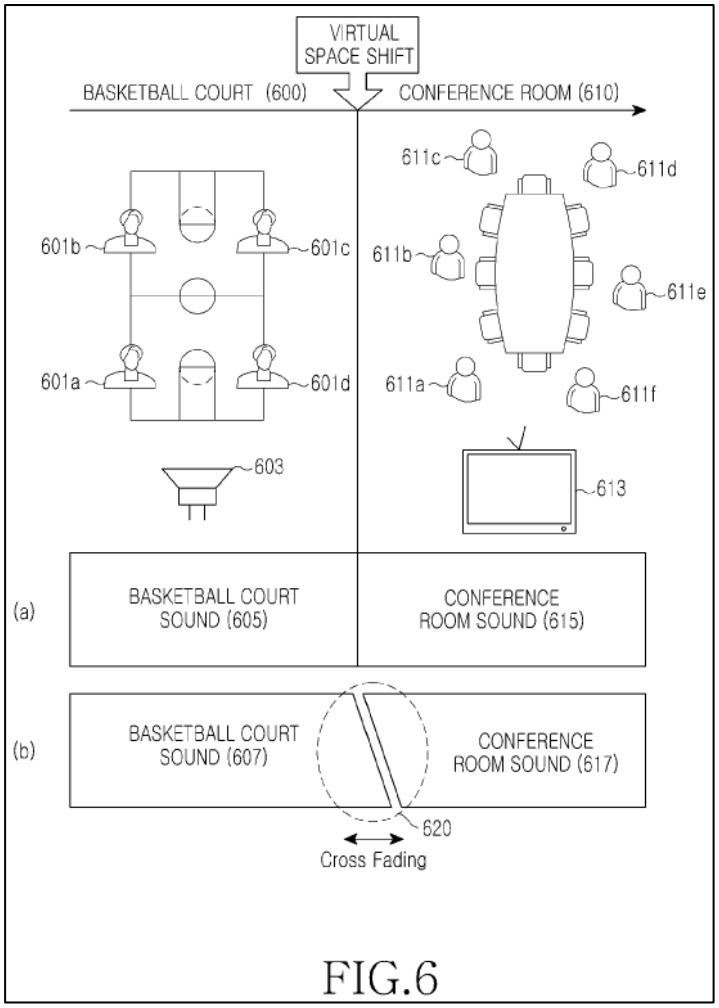


FIG.6

Jang (Ex.1006) at Figs. 5-6 (items 513 and 613); *see also* Jang (Ex.1006) at 10:59–60 ("FIG. 6 illustrates a space shift in a virtual environment from a basketball court 600 to a conference room 610"), 10:65-66 ("television 613 in the conference room"). In the Pedrotti-Jang combination, persons of ordinary skill in the art would have been motivated to display on Pedrotti's HMD the visual sensory elements as taught by Jang and in accordance with Jang's examples, including Jang's virtual monitors.

352. As discussed for limitation 1[e] in Section X.C.6, it would have been obvious to persons of ordinary skill in the art that the Pedrotti-Jang system would

display a virtual image (e.g., a virtual image of a computer monitor) at a location corresponding to the location that is set using a user interface, such as the one taught in Begault. Furthermore, it would have been obvious that the image would be in the user's field of view, which is also taught by Begault as the "computer monitor" icon appears in front of the user:

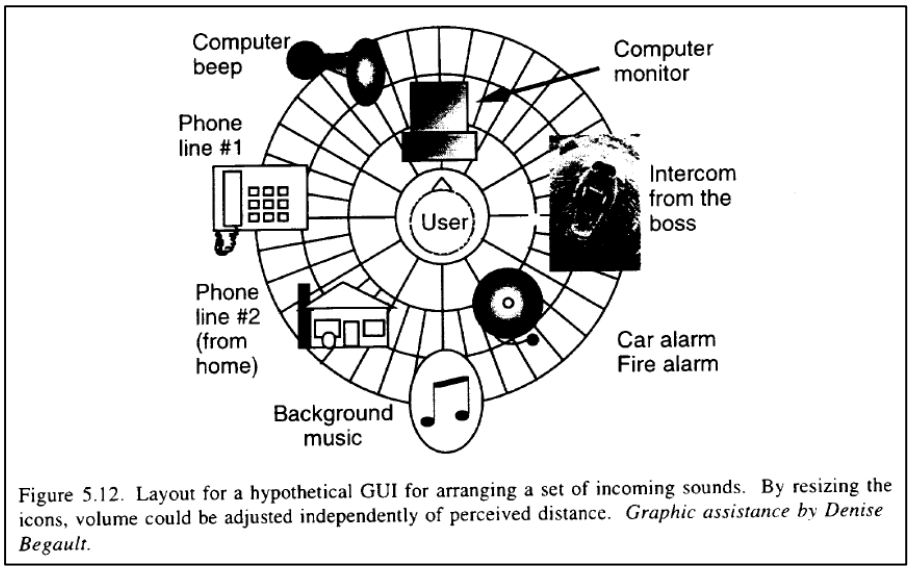


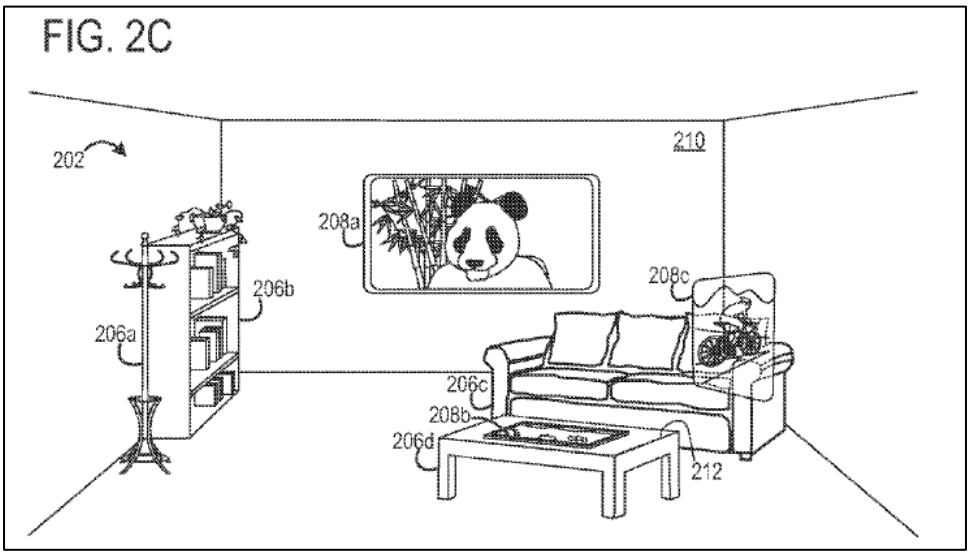
Figure 5.12. Layout for a hypothetical GUI for arranging a set of incoming sounds. By resizing the icons, volume could be adjusted independently of perceived distance. *Graphic assistance by Denise Begault.*

Begault (Ex.1007) at Fig. 5.12 (arrow indicating the direction of the user, and that the computer monitor is directly in front of the user, and within the user's field of view). As such, it would have been obvious that the virtual image of the monitor would appear in front of the user in the 3D environment, as displayed by Pedrotti's HMD.

353. I further note that, before June 2016, persons of ordinary skill in the art would have understood that virtual monitors were routinely presented in the field of view of a user in 3D virtual environments, to provide familiar "desktop" applications

and to display other information and media for the user. Surely, if a virtual monitor were intended to be used or presented as a menu, control panel, floating or virtual desktop, or UI element (e.g., if Begault's user interface were displayed to the user), it would have been obvious to display the virtual monitor in the field of view of the user.

354. For example, Mount 421 disclosed a virtual reality engine of an HMD "configured to cause the see-through display to visually present a virtual object ***in the form of a virtual monitor***," and that the "virtual monitor can simulate the appearance of a real world television, computer display, movie screen, and/or other monitor":



Mount 421 (Ex.1028) at [0011], Fig. 2C.

355. As another example, Akesson and Simsarian "use [a] monitor metaphor to describe the scenario where live video from [a] robot's working environment is

presented through a virtual monitor on top of the robot model in the virtual environment (see figure 1).").

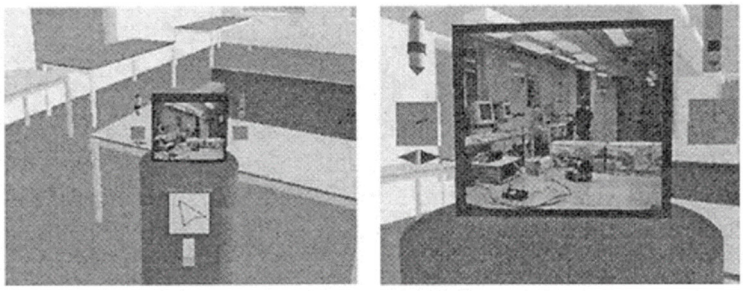


Figure 1. Monitor Metaphor. The left image shows an overview of the virtual environment with the robot and the monitor. The right image shows the operator's viewpoint when 'locked' to the robot. The operator then sees the video pan as the robot explores the space.

Akesson, *Reality Portals* (Ex.1133) at 1, Figure 1.

356. As yet another example, Martin disclosed displaying "media tags" that display media content in windows that appear in front of the user, similar to monitors displaying content:

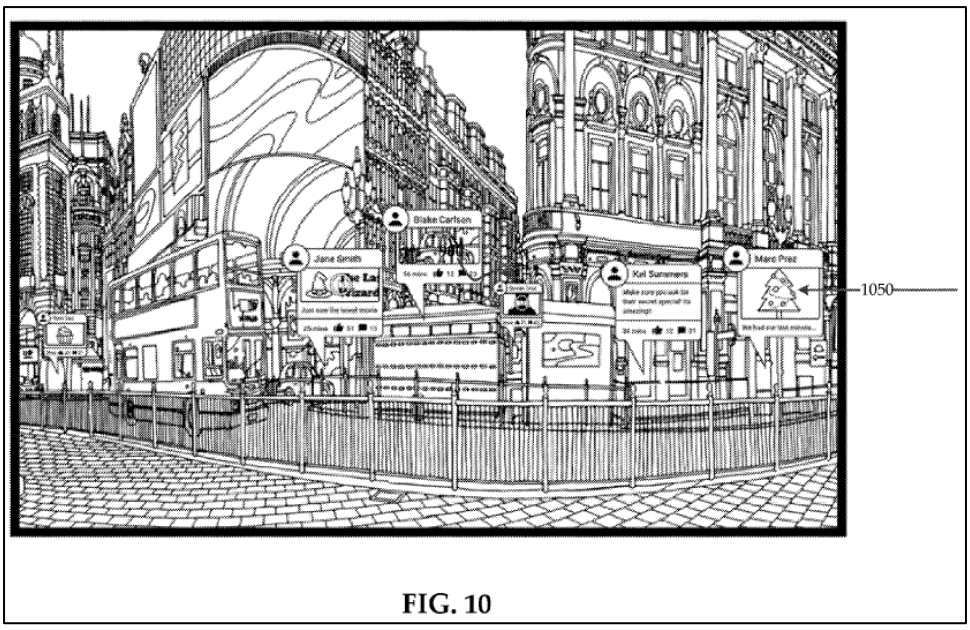


FIG. 10

Martin (Ex.1024) at [0009], [0014]-[0019], Fig. 10.

357. Other references disclosed virtual monitors displayed as floating screens, or monitors, in front of users:

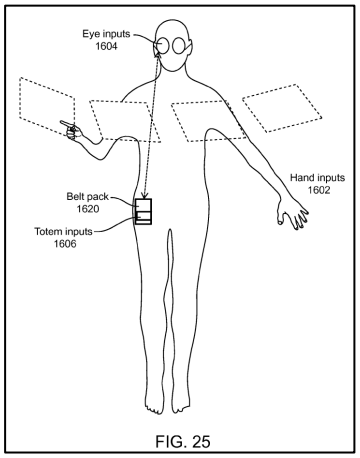


FIG. 25

Miller 652 (Ex.1025) at Fig. 25, [0422] ("virtual user interface" "may be a floating virtual screen"):

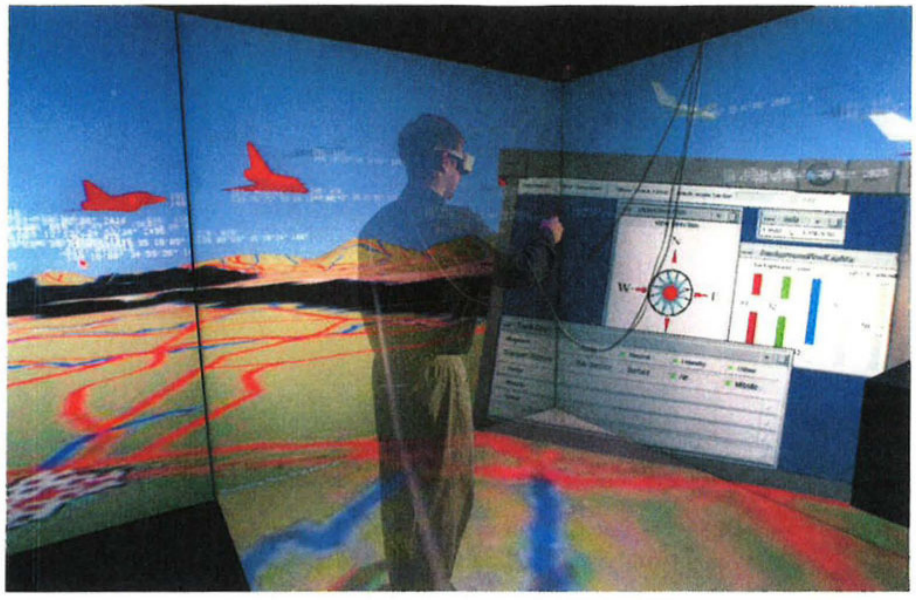


Figure 3.5 **The author interacting with desktop applications within the CABANA.** (From Jerald et al. (2001))

Jerald, THE VR BOOK (Ex.1063) at Fig. 3.5.

b. 6[b]: "processing, by the processor, the sound with the HRTFs to generate the binaural sound that originates from the virtual monitor; and"

358. For the same reasons that I discussed for limitations 1[b] and 1[d] regarding why it would have been obvious to process sound with HRTFs to generate binaural sound originating from a designated SLP and sound-generating VR objects, limitation 6[b] is obvious over Pedrotti in view of Jang, or Pedrotti in view of Jang and further in view of Begault. It would have been obvious to process sound with HRTFs to generate binaural sound that originates from the designated sound source, or SLP. *See* Sections X.C.3, X.C.5.

359. Furthermore, as I explained above for limitation 6[a], it would have been obvious that binaural sound originates from the virtual monitor, coming from in front of the user, because the user would have designated the virtual monitor to appear in front of the user in the user's field of view (*see* Begault (Ex.1007) at Fig. 5.12); as such, the sound associated with the virtual monitor would also have originated from that position in front of the user. *See* Sections X.D.5.a, VII.F (discussing other examples of where localized sound originates from a designated sound source).

c. 6[c]: "tracking, with the WED, head movements of the user to maintain the binaural sound originating from the virtual monitor as the head of the user moves."

360. Pedrotti teaches that its system, including the processor, can be "in the HMD," and also that the processor "track[s] the position and orientation of the HMD." Pedrotti (Ex.1005) at 4:4-11, 16:22-24. The "tracker" that provides the information regarding the HMD's position and orientation is "[a]ttached to or incorporated in the HMD." Pedrotti (Ex.1005) at 4:49-54 (providing an example of using a sensed magnetic field to derive position and information information); *see also* Pedrotti (Ex.1005) at 4:43-5:24 ("trackers, and the processors which determine the position and orientation of such trackers, are well known to those of skill in the art"), 12:31-39 ("processor knows where the user's head and hands are located"), 15:46-53 ("the user is wearing a HMD that may also have a tracker" and "the processor may also display a visual warning when the user's head approaches the boundary").

361. Additionally, as discussed for limitation 1[d], Jang discloses, or at a minimum renders obvious, the spatialization of binaural sound to particular SLPs and sound-generating VR objects. *See* Section X.C.5.

362. In view of these disclosures, persons of ordinary skill in the art implementing the teachings of Pedrotti and Jang would have known and been motivated to use Pedrotti's head tracking to provide the position and orientation of

the user, which in turn would be used to ensure the accurate localization of any generated binaural sound, e.g., sound originating from a virtual monitor.

363. It was known for years before 2016 that head movements, such as the rotation of a user's head, should be tracked and accounted for to facilitate better, more accurate binaural audio, e.g., to maintain proper locations for the origination of sound while a listener moves. *See* Section VII.E (discussing sound localization and binaural sound); *see, e.g.*, Jerald, THE VR BOOK (Ex.1063) at 156 ("Use binaural cues with head pose to give a sense of sound location"); Flaks (Ex.1009) at 10:5-8 ("FIG. 6 depicts a flow diagram of a process 600 of determining a listener's location and rotation in the room. For example, process 600 might be used to determine which way the user's head is rotated."), 11:25-43 ("In step 610, inertial sensors on the user collect data. In one embodiment, at least one inertial sensor is located on the user's head to allow tracking of the user's head. In step 612, the user's location in the room is determined based on tracking the model. In step 614, the rotation of the user's head is determined based on tracking the model. Process 600 may continue to track the user such that the location and rotation may be updated.").

364. Begault confirms this common knowledge of persons of ordinary skill in the art and further renders obvious limitation 6[c]. *See* Begault (Ex.1007) at 6 ("[I]f the sound source should stay in a single location in virtual space, then its location relative to the listener's head position will also need to be synthesized and

updated in real-time."), 12 ("trackers that allow updating the position of the virtual sound source in relation to the position of the head."), 99, 132-34 (discussing "a six degree-of-freedom tracker system" to facilitate "virtual sound images remain[ing] in virtual space independent of where one's head moves").

365. For example, Begault discloses that "[p]ositional data about the user's position in relationship to the source can then be obtained in terms of pitch, yaw, and roll, and *x*, *y*, and *z*," and describes "a commercially available 3-D sound system for real-time placement of a virtual source to a fixed position, independent of the listener's movement":

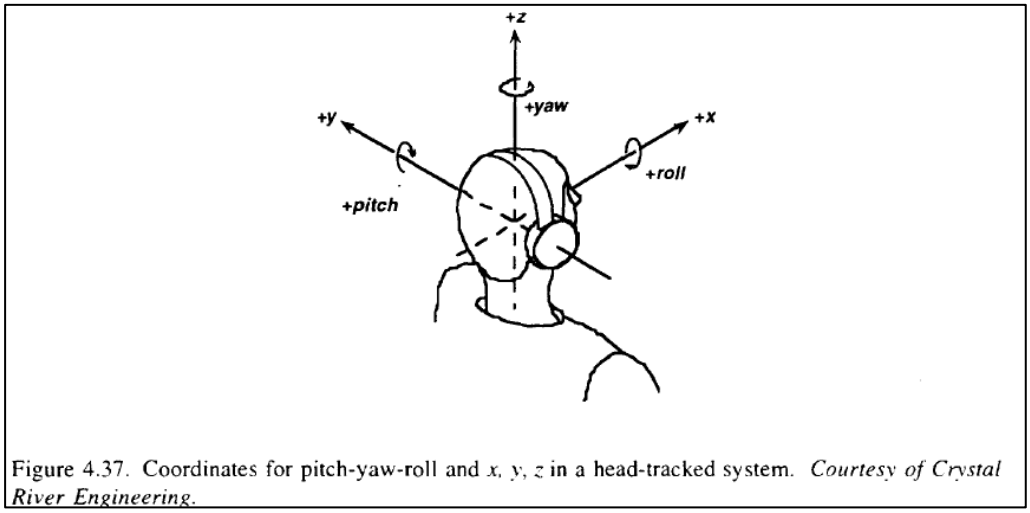


Figure 4.37. Coordinates for pitch-yaw-roll and *x*, *y*, *z* in a head-tracked system. *Courtesy of Crystal River Engineering.*

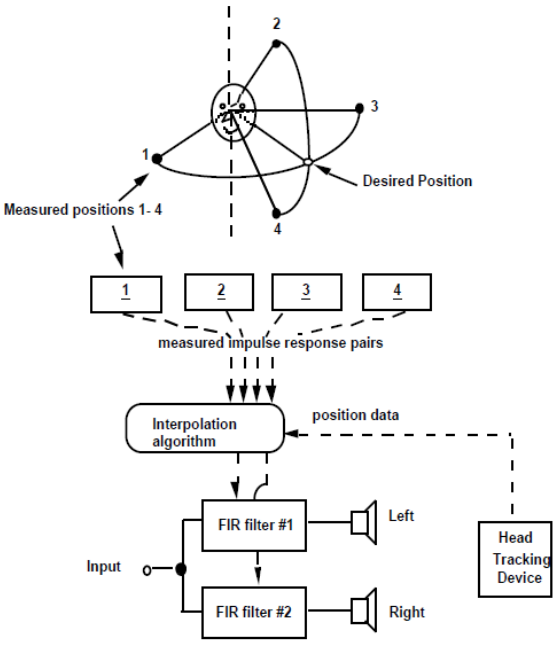


Figure 4.38. Interpolation procedure used to compensate for head movement of the listener. To simulate moving sound sources, the position data is obtained algorithmically instead of from a head tracker.

Begault (Ex.1007) at 132-34, Figs. 4.37-4.38.

6. Claim 7: "The method of claim 1, wherein the zone has a shape of a cylinder that extends from the physical floor and around the user, and the WED displays the cylinder to the user."

366. As previously explained, Pedrotti discloses that a user is able to define "a perimeter chosen by the user with one of the trackers," such as the boundary 1404 shown in Figure 14. Pedrotti (Ex.1005) at 14:56-62, Fig. 14.

367. Persons of ordinary skill in the art would have known and understood that a zone defined by a circular boundary for Pedrotti's "virtual fence," e.g., a

circular boundary drawn by a user, would have, or at a minimum obviously would have, the shape of an extruded cylinder extending from the floor and around the user.

368. Moreover, Pedrotti discloses that its "processor receives as an input information from which the processor can define a boundary surrounding a selected area, for example, one in which there are no physical obstacles," and "this information will typically be entered by a user or someone else, or may in part or whole be received from a tracker, and ***may be the radius and location of the center of a circle*** of a determined diameter that is clear of obstacles." Pedrotti (Ex.1005) at 15:13-22, Figs. 12-13 (depicting circular boundaries on floor). And Pedrotti discloses displaying a "cylindrical projection" of its "virtual fence." Pedrotti (Ex.1005) at 13:12-33.

* * *

369. For the reasons set out above, it is my opinion that every limitation of claims 2-7 of the '737 patent, and each of claims 2-7 as a whole, would have been obvious to persons of ordinary skill in the art over Pedrotti in view of Jang, and over Pedrotti in view of Jang and further in view of Begault.

E. Independent Claim 8

1. 8[pre]: "A method executed by one or more electronic devices, the method comprising:"

370. The preamble of claim 8 is identical to the preamble of claim 1 and would have been obvious. *See* Section X.C.1.

2. 8[a]: "tracking, with a wearable electronic device (WED) worn on a head of a user, a handheld portable electronic device (HPED) that moves to define a shape of a zone that extends from a physical floor and around the user holding the HPED in a hand;"

371. For the same reasons that I discussed for limitation 1[a], Pedrotti teaches, or at a minimum renders obvious, limitation 8[a]. *See* Section X.C.2.

372. Limitation 8[a] recites "defin[ing] a shape of a zone," whereas limitation 1[a] recites "defin[ing] a size and shape of a three-dimensional (3D) zone." Either way, this is taught by Pedrotti for reasons discussed. *See* Section X.C.2.

3. 8[b]: "designating, with the HPED held in the hand of the user, a sound localization point (SLP) for binaural sound at a location in empty space in the zone above the physical floor where the HPED is pointed;"

373. For the same reasons that I discussed for limitation 1[b], limitation 8[b] would have been obvious over Pedrotti in view of Jang, or over Pedrotti in view of Jang and further in view of Begault. *See* Section X.C.3. Limitation 8[b] additionally recites "where the HPED is pointed" in comparison to limitation 1[b].

374. Persons of ordinary skill in the art would have known and understood that it was common to use a handheld controller to select, move, and control virtual objects by pointing at them. *See* Section VII.D (discussing tracking handheld controllers); *see, e.g.*, Jerald, THE VR BOOK (Ex.1063) at 314-15 ("Tracked hand-held controllers are typically 6DoF devices (known as 'wands' in the VR research community where they have been used for decades) and can also contain functionality offered by non-tracked hand-held controllers. Tracked hand-held controllers are currently the best option for a majority of interactive VR applications. ***Tracked hand-held controllers are easy to use for many 3D tasks due to their natural, direct mapping to hand motion***.") (emphasis added), 327 ("[T]he Pointing Pattern is one of the most fundamental and often-used patterns for selection."); Ross (Ex.1125) at 22:17-29 ("[a] user, content creator, and/or other persons may create, customize, and/or adjust using a controller").

375. In view of the tracking capabilities of Pedrotti's HMD to determine the position and orientation of the handheld controller, and in view of what was conventional at the time, it would have been obvious to designate a SLP by pointing with the Pedrotti's handheld controller.

4. 8[c]: "tracking, with the WED worn on the head of the user, the HPED and where the HPED is pointed to provide the WED with the location in empty space in the zone above the physical floor that includes the SLP for the binaural sound;"

376. For the same reasons that I discussed for limitation 1[c], limitation 8[c] would have been obvious over Pedrotti in view of Jang, or over Pedrotti in view of Jang and further in view of Begault. *See* Section X.C.4. Limitation 8[c] additionally recites "where the HPED is pointed" in comparison to limitation 1[c].

377. As I explained in discussing limitation 8[b], immediately above, persons of ordinary skill in the art would have known and been motivated to use and implement pointing as claimed, because that well-known and commonly used in the industry. *See* Section X.E.3.

5. 8[d]: "processing, by a processor, sound with head-related transfer functions (HRTFs) to produce the binaural sound that originates at the SLP at the location in empty space in the zone above the physical floor; and"

378. For the same reasons that I discussed for limitation 1[d], limitation 8[d] would have been obvious over Pedrotti in view of Jang, or over Pedrotti in view of Jang and further in view of Begault. *See* Section X.C.5

379. Limitation 8[d] recites "to produce the binaural sound that originates at the SLP" whereas limitation 1[d] recites "to generate binaural sound that externally localizes to the user at the location of the SLP."

380. Persons of ordinary skill in the art would have understood that these refer to the same effect—namely, that the user hears binaural sound as if it is coming from the location of the SLP, which is consistent with skilled artisans' understanding of localized sound, and specifically binaural sound. *See* Section VII.E (discussing localization of sound and binaural sound).

6. 8[e]: "displaying, with the WED worn on the head of the user, a virtual image at the location in empty space in the zone above the physical floor from where the binaural sound originates at the SLP to the user."

381. Limitation 8[e] would have been obvious for the same reasons as limitation 1[e] over Pedrotti in view of Jang, or over Pedrotti in view of Jang and further in view of Begault. *See* Section X.C.6.

* * *

382. For the reasons set out above, it is my opinion that every limitation of claim 8 of the '737 patent, and claim 8 as a whole, would have been obvious to persons of ordinary skill in the art over Pedrotti in view of Jang, and over Pedrotti in view of Jang and further in view of Begault.

F. Dependent Claims 9-13

383. I understand that claims 9-13 depend on independent claim 8.

384. Thus, it is my opinion that each of dependent claims 9-13 would have been obvious to persons of ordinary skill in the art for the same reasons as

independent claim 8 (*see* Section X.E), and additionally for the reasons I discuss in the following subsections.

1. Claim 9: "The method of claim 8 further comprising: providing a voice as the binaural sound that externally localizes at the virtual image at the location in empty space in the zone above the physical floor, wherein the voice originates from a character in a virtual reality (VR) game that the user plays."

385. For the same reasons that I discussed for claim 2, claim 9 would have been obvious over Pedrotti in view of Jang, or over Pedrotti in view of Jang and further in view of Begault. *See* Section X.D.1.

386. Claim 9 recites "externally localizes at the virtual image at the location in empty space," instead of "externally localizes to the user at the VR character that is at the location of the SLP" as recited in limitation 2[b]. But as discussed for limitations 1[b] and 1[e], persons of ordinary skill in the art would have found it obvious to have the sound and image for a virtual object, e.g., a VR character, stay and move together. *See* Sections X.C.3, X.C.6.

2. Claim 10: "The method of claim 8 further comprising: displaying, with the WED, a boundary of the zone with virtual lines to alert the user when the user conflicts with the boundary of the zone while the user plays a virtual reality (VR) game."

387. For the same reasons that I discussed for claims 2 and 4, Pedrotti discloses, or at a minimum renders obvious, claim 10. *See* Sections X.D.1

(discussing application in a virtual reality (VR) game), X.D.3 (discussing other limitations present in claim 10); *see also* Pedrotti (Ex.1005) at 11:48-52 (describing application to when "a user is physically located in the user's living room and playing a game within a virtual world"), 15:46-55 (presenting "a visual warning in the form of grid lines or a virtual fence").

3. Claim 11: "The method of claim 8 further comprising: displaying the zone as a customized three-dimensional (3D) shape drawn by the user with the HPED held in the hand of the user."

388. For the same reasons that I discussed for limitation 1[a] and claim 5 (and specifically limitation 5[b]), Pedrotti discloses, or at a minimum renders obvious, claim 11. *See* Sections X.C.2, X.D.4 (discussing Pedrotti's customized safe area zones).

4. Claim 12: "The method of claim 8 further comprising: tracking, with the WED, a location where the HPED is pointed as the HPED moves the SLP and the virtual image from one location where the HPED is pointed to another location where the HPED is pointed."

389. For the same reasons that I discussed for claims 3 and 8 (and specifically limitation 8[c]), claim 12 would have been obvious over Pedrotti in view of Jang, or over Pedrotti in view of Jang and further in view of Begault. *See* Sections X.D.2 (discussing tracking), X.E.4 (discussing "where the HPED is pointed"). As discussed for limitations 1[b] and 1[e], persons of ordinary skill in the

art would have certainly expected and found it straightforward and basic (and, of course, obvious) to have the sound and image of a virtual object move together with the SLP, including when a user moves such objects with a VR controller by pointing at and moving them. *See* Sections X.C.3, X.C.6; *see also* Section VII.C (discussing selection and manipulation of virtual objects with handheld controllers).

5. Claim 13: "The method of claim 8 further comprising: improving performance of the processor processing the sound by storing the HRTFs in a cache memory in the WED, wherein the processor is a digital signal processor (DSP) located in the WED."

390. For the same reasons that I discussed for claim 8 (and in particular limitation 8[d]), claim 13 would have been obvious over Pedrotti in view of Jang, or over Pedrotti in view of Jang and further in view of Begault. *See* Section X.E.5.

391. Begault discloses how sound is processed with HRTFs to generate binaural sound, and further discloses that "[w]ithin a virtual reality or multimedia application, 3-D sound processing is almost always best accomplished digitally, using audio DSP chips to manipulate signal sources." Begault (Ex.1007) at 100-01, 105-06 ("The basis of 3-D sound processing lies in imitation of the spatial cues present in natural spatial hearing, where the binaural HRTF imposes spatially dependent spectral modifications and time delays on an incoming wavefront to the hearing system. ***In virtual spatial hearing, it is possible to imitate these modifications using a DSP as a digital filter***.") (emphasis added). Begault discloses

that "[t]he 3-D audio component of an integrated audio subsystem … can contain anywhere from one to as many DSPs as can be accommodated," and provides examples using DSPs to spatialize sound sources. Begault (Ex.1007) at 101; *see* Section IX.C (overview of Begault discussing use of DSPs in the context of HRTF processing).

392. Persons of ordinary skill in the art would have been motivated to use DSPs as the processor for HRTF processing, as Begault teaches, because DSPs are fast and excel specifically at signal processing tasks such as HRTF processing and generating binaural sound. Begault (Ex.1007) at 100 ("[a]udio DSP chips typically are designed to perform a limited set of digital DSP instructions *very quickly*—i.e., in real time"), 101 ("[a] single DSP can perform the equivalent filtering operation for both the left and right pinnae"). As DSPs are designed to perform complex operations including processing real-time signals, this speed furthers the general principle of enhancing realism and immersivity by providing spatialized audio quickly (e.g., as the user changes pose, the sound the user hears will also alter accordingly).

393. DSPs are also reconfigurable, and thus removes the need to replace the hardware entirely when implementing a change in the system, thus creating more flexible systems. They are also appropriately sized for use in a system like Pedrotti's. *See, e.g.*, Begault (Ex.1007) at 20 ("The technological context for

implementing 3-D sound is directly tied to both the evolution of digital signal processing (DSP)… Changing the character of an input signal in the digital domain to create virtual spatial hearing experiences has been greatly facilitated by the development of DSP chips, particularly since they can be configured as filters that modify sound in the same way as in natural spatial hearing. Other advantages of DSP include relatively smaller hardware size, greater predictability of noise, and ease of reconfiguration—one can write different software specifications to the signal processor, rather than resoldering hardware components."); Qualcomm, *Mobile Processors 101: Why Smartphones are Smarter with an All-In-One Processor* (Jun. 12, 2013) (Ex.1082) at 1-3 (describing the DSP in Qualcomm's Snapdragon processor as being small enough to be incorporated into a smartphone).

394. Further, because DSPs are able to more efficiently process signals, they consume less power. This benefits the user in that the user does not need to charge an HMD incorporating a DSP as frequently. Qualcomm, *What's So Special About The Digital Signal Processor* (Dec. 5, 2013) (Ex.1081) at 1-3 ("Many of these experiences—such as sound and image enhancements as well as advanced camera and sensor capabilities—include signal-processing tasks that the DSP excels in executing at low power. And saving power not only extends the battery life of the mobile device, it also keeps your phone cooler and provides a better user experience."). For these reasons, persons of ordinary skill in the art would have

known and been motivated to use DSPs, as Begault teaches, for the audio processing required in a Pedrotti-Jang system.

395. I further note that DSPs were commonly incorporated into HMDs for more dedicated and efficient processing for years before June 2016. *See, e.g.*, Balachandreswaran (Ex.1045) at [0111] ("the processor may comprise a CPU, ***a digital signal processor (DSP)***, a graphics processing unit (GPU), an image signal processor (ISP), and a near-field communication unit") (emphasis added), [0130] ("the HMD may comprise an embedded digital signal processor (DSP) having system-on-a-chip (SOC)"); Ashkenazi (Ex.1044) at 12:33-56 ("System 1100 includes an audio object memory 1102," "an HRTF memory 1116," and "a digital signal processor 1118"), Fig. 2.

396. These examples demonstrate that, not only would persons of ordinary skill in the art have been motivated to use a DSP, as Begault teaches, in a Pedrotti-Jang system, such skilled artisans would have reasonably expected to succeed in incorporating a DSP and that such a processor would improve performance.

397. Furthermore, persons of ordinary skill in the art would have known and understood that sound processing performance could and would be improved by storing the HRTFs in a cache memory in the HMD (or WED). Storing HRTFs in cache memory was a common technique used, for example, in instances where a user's customized HRTF is retrieved from a larger database containing customized

HRTFs for different users. *See, e.g.*, U.S. Patent No. 9,544,706 ("Hirst") (Ex.1017) at 8:13-23 ("The applications 560, 536, which may be executed on client devices 516a and 516n, respectively, may send a communication to the computing device(s) 502 via the communications network 514 providing information identifying the user and requesting the customized HRTF associated with the user's profile. The computing device(s) 502 may then send a communication with the customized HRTF data to the client devices 516a and 516n via the communications network 514. ***The client devices 516a and 516n may store the customized HRTF in an HRTF cache 550, 554.***") (emphasis added), Fig. 5; U. S. Patent No. 10,070,239 ("Romigh") (Ex.1035) at cl. 1 (claiming "[a] system for generating a personalized Head-Related Transfer Function"), 6:52-56 ("the memory 36 may include one or more levels of data, instruction, and/or combination caches, ***with caches serving the individual processing unit*** or multiple processing units (not shown) as is well known in the art.") (emphasis added). Moreover, it was well known to persons of ordinary skill in the art before June 2016 that processing speed and efficiency can be improved by leveraging cache locality and keeping data needed for pertinent computations (e.g., HRTFs for processing binaural sound) readily available. *See, e.g.*, Foster, Cornell University, *Data Structures and Functional Programming, Lecture 25: Memory and Locality* (2012) ("Foster") (Ex.1059) at 2 ("The primary (L1) cache is the fastest cache, usually right on the processor chip and able to serve

memory requests in one-three cycles"; "caches improve performance when memory accesses exhibit locality."); Jiménez, Texas A&M University, *Computer Architecture Lecture 7: Caches* (2007) (Ex.1064) at 1 ("The basic idea is to have a small, expensive cache memory hold frequently used values from the larger, cheap main memory. This way, access to data and instructions is significantly faster than it would be with just the main memory."); Hennessy & Patterson, COMPUTER ARCHITECTURE: A QUANTITATIVE APPROACH ("Hennessy") (Ex.1061) at 130 ("the extension of caches to multiple levels" "have helped keep the memory wall at bay"). That would have been known to any person of ordinary skill in the art with basic training in computer science. *See, e.g.*, Hennessy (Ex.1061) at 129-30 ("Virtual memory was introduced in research computers in the early 1960s and into IBM mainframes in the 1970s. Caches appeared around the same time."); Foster (Ex.1059) at 1-2 ("A cache keeps track of the contents of memory locations recently requested by the processor. If the processor asks for one of these locations, the cache gives the answer instead."); *see also* Paragraph 128 (above) (discussing Seligman).

* * *

398. For the reasons set out above, it is my opinion that every limitation of claims 9-13 of the '737 patent, and each of claims 9-13 as a whole, would have been obvious to persons of ordinary skill in the art over Pedrotti in view of Jang, and over Pedrotti in view of Jang and further in view of Begault.

G. Independent Claim 14

1. 14[pre]: "An electronic system, comprising:"

399. Claim 14's preamble would have been obvious for the same reasons the preambles of claims 1 and 8 would have been obvious. *See* Sections X.C.1, X.E.1.

2. 14[a]: "a portable electronic device (PED) that moves to define a boundary of a three-dimensional (3D) zone extending from a physical floor on which a user holding the PED stands and around the user and that designates a sound localization point (SLP) in empty space inside the 3D zone; and"

400. For the same reasons that I discussed for limitations 1[a]-1[b] and 8[a]-8[b], limitation 14[a] would have been obvious over Pedrotti in view of Jang, or over Pedrotti in view of Jang and further in view of Begault. *See* Sections X.C.2-X.C.3, X.E.2-X.E.3.

401. Limitation 14[a] recites "a portable electronic device" and "a user holding [a] PED," which encompasses a "handheld portable electronic device (HPED)" as recited in limitations 1[a] and 8[a]. Put another way, Pedrotti's handheld controller is both the "PED" recited in claim 14, and the "HPED" ("handheld" PED) recited in claims 1 and 8.

402. Additionally, limitation 14[a] recites that the user stands on the physical floor. This would have been obvious to persons of ordinary skill in the art (indeed, to any user of an AR or VR device), including in view of Pedrotti, which depicts the

floor on which a user stands. *See, e.g.*, Pedrotti (Ex.1005) at Fig. 10 (item 1010), 12:16-22 ("floor 1010").

3. 14[b]: "a wearable electronic device (WED) that is worn on a head of the user, tracks movement of the PED to determine the boundary of the 3D zone that extends from the physical floor and around the user,"

403. For the same reasons that I discussed for limitations 1[a] and 8[a], Pedrotti teaches, or at a minimum renders obvious, limitation 14[b]. *See* Sections X.C.2, X.E.2.

4. 14[c]: "includes a processor that processes sound with head-related transfer functions (HRTFs) so sound externally localizes as binaural sound to the user at the SLP in empty space inside the 3D zone defined by movement of the PED, and"

404. For the same reasons that I discussed for limitations 1[d] and 8[d], limitation 14[c] would have been obvious over Pedrotti in view of Jang, or over Pedrotti in view of Jang and further in view of Begault. *See* Sections X.C.5, X.E.5.

5. 14[d]: "displays a virtual image at the SLP in empty space inside the 3D zone, and displays a 3D virtual image that shows the boundary of the 3D zone that extends from the physical floor and around the user."

405. For the same reasons that I discussed for limitations 1[e], 4[b], 5[a], and 8[e], limitation 14[d] would have been obvious over Pedrotti in view of Jang, or over Pedrotti in view of Jang and further in view of Begault. *See* Sections X.C.6, X.D.3.b,

X.D.4.a, X.E.6. This is the case under 8K's apparent interpretation, and as taught by the '737 patent.

406. Limitation 14[d] additionally recites that the virtual image is "3D" in comparison to limitations 1[e] and 8[e]. Persons of ordinary skill in the art would have understood that the virtual images displaying boundaries in Pedrotti's HMD (e.g., the image of Pedrotti's "virtual fence") are, or at a minimum obviously would be, 3D virtual images. *See also* Section VII.G (discussing prior art safety and chaperone systems, including systems displaying 3D virtual images). Indeed, there would be no way to display a "virtual image that shows the boundary of the 3D zone that extends from the physical floor and around the user" other than doing so in 3D.

* * *

407. For the reasons set out above, it is my opinion that every limitation of claim 14 of the '737 patent, and claim 14 as a whole, would have been obvious to persons of ordinary skill in the art over Pedrotti in view of Jang, and over Pedrotti in view of Jang and further in view of Begault.

H. Dependent Claims 15-20

408. I understand that claims 15-20 depend on independent claim 14.

409. Thus, it is my opinion that each of dependent claims 15-20 would have been obvious to persons of ordinary skill in the art for the same reasons as

independent claim 14 (*see* Section X.G), and additionally for the reasons I discuss in the following subsections.

1. Claim 15: "The electronic system of claim 14, wherein the 3D zone has a customized size and shape defined by movement of the PED while held in a hand of the user."

410. For the same reasons that I discussed for claim 5 (and in particular limitation 5[b]), Pedrotti discloses, or at a minimum renders obvious, claim 15. *See* Section X.D.4.

411. Claim 15 recites "customized size and shape defined by movement of the PED" whereas limitation 5[b] recites "customized shape drawn by the user of the HPED." As explained above, persons of ordinary skill in the art would have understood that Pedrotti's method that allows a user to define a boundary of a customized size and shape via movement of Pedrotti's controller (the PED), since the user is able to mark a "sampling point" anywhere—leading to a safe area zone of a customized size and shape. Pedrotti (Ex.1005) at 14:56-65.

2. Claim 16

a. 16[a]: "The electronic system of claim 14, wherein the WED tracks the PED to determine when the PED is at the boundary of the 3D zone, and"

412. For the same reasons that I discussed for limitations 1[c] and 4[a], Pedrotti discloses, or at a minimum renders obvious, limitation 16[a]. *See* Sections X.C.4, X.D.3.a.

413. Limitation 16[a] recites "when the PED is at the boundary," whereas limitation 4[a] recites "when a location of the user conflicts with a boundary of the zone." Persons of ordinary skill in the art would have understood that determining when a PED is "at" a boundary requires substantially the same steps as determining when the location of the PED (which is held by the user) or the location of the user "conflicts" with a boundary. That is, persons of ordinary skill in the art would have known that both require comparing the location of the PED or user with that of Pedrotti's boundary. Both are disclosed, or at least obvious over Pedrotti, for the same reasons.

414. Pedrotti discloses that its system determines when the user's hand, which is holding the controller, is within a preselected distance of the boundary. Pedrotti (Ex.1005) at 12:40-47, 12:51-13:10 ("the user 1002 is holding a controller with a tracker in the hand … since the hand of the user 1002 is within the preselected distance of the boundary of the selected area, the processor generates instructions to the HMD to generate the visual warning"). Pedrotti also discloses that "[i]f the user's head or hands go beyond the boundary as determined by the trackers, the processor can provide additional messaging or warning, such as text or auditory warnings, or an additional visual warning, that persists until the user returns to the selected area within the boundary." Pedrotti (Ex.1005) at 12:60-66, 13:63-67.

415. Persons of ordinary skill in the art thus would have understood that Pedrotti's system determines (or would obviously determine) when a PED is at the boundary of a 3D zone.

b. 16[b]: "the WED automatically displays the 3D virtual image that shows the boundary of the 3D zone to alert the user that the PED is at the boundary of the 3D zone."

416. For the same reasons that I discussed for limitations 4[b] and 16[a], Pedrotti discloses, or at a minimum renders obvious, limitation 16[b]. *See* Sections X.D.3.b, X.H.2.a.

417. Limitation 16[b] additionally recites "automatically displays" whereas limitation 4[b] recites "displaying." Persons of ordinary skill in the art would have understood that Pedrotti's system in fact automatically displays the virtual fence once the condition that the PED is at the boundary of the 3D zone is met. Pedrotti (Ex.1005) at 16:4-58, Fig. 15.[9]

[9] *See also* '737 8K Infringement Contentions (Ex.1121) at 21 (contending that displaying a 3D virtual image, just like Pedrotti discloses, demonstrates that "the WED automatically displays the 3D virtual image" as claimed).

3. Claim 17

a. 17[a]: "The electronic system of claim 14, wherein the WED tracks the user to determine when the user is at the boundary of the 3D zone, and"

418. For the same reasons that I discussed for limitations 1[c] and 4[a], Pedrotti discloses, or at a minimum renders obvious, limitation 17[a]. *See* Sections X.C.4, X.D.3.a; Pedrotti (Ex.1005) at 4:37-44 ("[t]he processor similarly tracks the position and orientation of the HMD tracker"), 12:40-47 ("when the user's head and/or hand approaches to within the preselected distance").

b. 17[b]: "the WED automatically displays the 3D virtual image that shows the boundary of the 3D zone to alert the user that the user is at the boundary of the 3D zone."

419. For the same reasons that I discussed for limitations 4[b] and 17[a], Pedrotti discloses, or at a minimum renders obvious, limitation 17[b]. *See* Sections X.D.3.b, X.H.3.a.

420. Limitation 17[b] additionally recites "automatically displays" whereas limitation 4[b] recites "displaying." As noted, persons of ordinary skill in the art would have understood that Pedrotti's system in fact automatically displays the virtual fence when the condition that the PED is at the boundary of the 3D zone is met. Pedrotti (Ex.1005) at 16:4-58, Fig. 15; *see also* Section X.H.2.b (limitation 16[b]).

4. Claim 18

a. 18[a]: "The electronic system of claim 14, wherein the WED determines a location of the user,"

421. For the same reasons that I discussed for limitations 4[a] and 17[a], Pedrotti discloses, or at a minimum renders obvious, limitation 18[a]. *See* Sections X.D.3.b, X.H.3.a.

422. Persons of ordinary skill in the art would have known that in order to carry out the method Pedrotti describes that assesses the location of the user's head and hands in comparison to a boundary, the processor, which is in the HMD, must first determine a location of the user's head and hands—i.e., the location of the user. Pedrotti (Ex.1005) at 4:37-44 ("[t]he processor similarly tracks the position and orientation of the HMD tracker"), 12:40-47 ("when the user's head and/or hand approaches to within the preselected distance").

b. 18[b]: "stores the 3D zone for the location, and"

423. For the same reasons that I discussed for limitation 5[b], limitation 18[b] would have been obvious over Pedrotti in view of Jang. *See* Section X.D.4.b.

424. Limitation 18[b] recites "stor[ing] the 3D zone for the location," whereas limitation 5[b] recites "stor[ing] coordinate locations of the customized shape."

425. Persons of ordinary skill in the art would have understood that storing the coordinate locations, or "sampling points" identified by the user, also provides

the pertinent information regarding the user's safe area zone, and thus stores the 3D zone for the user's location as claimed. Pedrotti (Ex.1005) at 14:56-65.

426. Moreover, persons of ordinary skill in the art would have found it obvious to store 3D zones for particular locations (i) as part of the process of a user defining a boundary since the 3D zone is associated with the user being at a location that is within that boundary, and (ii) because, if a user switches locations (e.g., playing a game in a different room or moving toward a different part of a large room), physical obstacles a boundary is intended to guard against are different. Pedrotti (Ex.1005) at 11:43-55.

c. 18[c]: "displays the 3D virtual image that shows the boundary of the 3D zone in response to determining that the user is at the location."

427. For the same reasons that I discussed for limitation 4[b] and 17[a]-17[b], Pedrotti discloses, or at a minimum renders obvious, limitation 18[c]. *See* Sections X.D.3.b, X.H.3.a-X.H.3.b.

428. Persons of ordinary skill in the art would have understood that it would have been advantageous to display the 3D virtual image that shows the boundary of the 3D zone as the user is defining a boundary according to Pedrotti's method. As Pedrotti explains, the user "moves around [a] chosen perimeter" to define the boundary. Pedrotti (Ex.1005) at 14:62-65. During this process, the user is at a location, or locations, corresponding to the zone the user is defining (and is to be

stored). Pedrotti (Ex.1005) at 4:49-51 ("[a]ttached to or incorporated in the HMD 106 is a tracker 108, which can be used to determine the position and orientation of the headset 104, and thus the head of user 103"). And, during this process, persons of ordinary skill in the art would have known to display the 3D virtual image in order to provide the user with feedback about the boundary as they are creating it, just as one would do when creating or drawing any object in a virtual reality scene.

429. For example, as discussed in Ross, a user interface for "creation, customization, and/or adjustment of the fields of view [and], the view boundaries" can include a "view 500 [] presented to the user and/or the content creator in the virtual space (e.g., in three dimensions)," which displays 3D virtual images showing the boundary of a 3D zone. Ross (Ex.1125) at 22:3-11, 22:12-29 ("[t]he user may virtually reach out and grab and/or move the fields and/or objects in the fields to make changes"). And, as Ross further explains, a content creation preview field can be provided and configured to "present a user with a preview of system 10 that simulates the created, customized, and/or adjusted" "characteristics of system 10," to displays to users 3D virtual images previewing and showing the boundary of a 3D zone. Ross (Ex.1125) at 23:14-21.

430. Persons of ordinary skill would have known that the display of the 3D virtual image would occur in response to a determination that the user is at the

location, which is a determination that is made when the user is defining the boundary.

431. Furthermore, since Pedrotti teaches triggering a display of the boundary when the user is within a preselected distance, persons of ordinary skill in the art would have found it obvious to likewise condition displaying the boundary when the user is at a particular location, which can be at any location (at any "preselected distance" from a boundary) in accordance with Pedrotti's teachings. Pedrotti (Ex.1005) at 12:40-47 ("when the user's head and/or hand approaches to within a preselected distance, for example, one foot (again, either preprogrammed into the processor or user selectable), of the boundary of the selected area the processor generates a warning that the use is close to the boundary so that the user can take action to avoid the boundary and thus potential collision with physical objects").

5. Claim 19

a. 19[a]: "The electronic system of claim 14, wherein the WED includes one or more sensors that track a light source in the PED to determine a location of the PED as the PED moves to define the boundary of the 3D zone,"

432. For reasons discussed for limitation 1[a], Pedrotti's WED tracks a handheld PED as the PED moves to define the boundary of the 3D zone. *See* Section X.C.2.

433. Additionally, Pedrotti discloses that trackers used in its system, including in its handheld controllers, may be "light-emitting trackers which can be seen by, and therefore provide position and orientation information to, a camera mounted on [a] base station or elsewhere." Pedrotti (Ex.1005) at 5:8-11, 4:59-61 ("trackers, and the processors which determine the position and orientation of such trackers, are well known to those of skill in the art"); *see also* Section X.C.4 (discussing HMD tracking of the handheld controller). Using such trackers to determine a location of Pedrotti's handheld controllers is consistent with Pedrotti's teachings, specifically that "[t]he processor determines the position of the tracker at a number of sampling points as the user moves around the chosen perimeter" when defining "an irregularly shaped area." Pedrotti (Ex.1005) at 14:62-65.

434. Furthermore, using sensors to sense light-emitting trackers in handheld controllers was a known technique in the art, and Pedrotti expressly references tracking and sensing methods known to persons of ordinary skill in the art. *See* Pedrotti (Ex.1005) at 5:11-24 ("As would be understood by one of ordinary skill in the art in light of the teachings herein, essentially any type of tracker (e.g., magnetic, optical, electrical, sonar, radar, ultrasonic, or any combination thereof) which can provide information regarding its position (and, in some cases, orientation, if needed or desired) can be used in the present approach.").

435. As at least the following references show, the technique of tracking a light source emitted from a PED to determine its location was well-known in the art before June 2016. *See, e.g.*, Wan (Ex.1040) at 4:29-35 ("The VR controller 136 can, e.g., emit and/or reflect infrared (IR) or any other type(s) of light that can be detected by one or more of the cameras 113 and 114 to help determine positions of, for example, the user's hands."); Koseki (Ex.1020) at 9:25-34 ("the posture … of the game controller 1200 can be detected from the size, the tilt, and the deformation of each of the light-emitting markers 1202 within the image captured by the color image sensor 1104 …"); Kobayashi (Ex.1019) at 1:46-52 ("in a case of an optical sensor, a light emitting unit employing a device, e.g., a light emitting diode (LED), emits light by controlling of a sensor controller, then a photoreceptive unit, e.g., a camera, a line sensor or the like, receives the light from the light emitting unit, and the viewpoint position and/or orientation of the measuring target are determined based on the received light data"); *see also* Section VII.D (discussing tracked handheld controllers). As was known in the art, HMDs incorporated "light-based sensors such as cameras and/or active sensors which may emit light." Miller 466 (Ex.1026) at 23:65-24:3.

436. Furthermore, it was known that receiver units that sense light emitted from controllers are incorporated into HMDs such that HMDs track the light-emitting controllers. For example, in Wan, the HMD incorporates cameras that

detect light in order to track the controllers. As Wan explains, the virtual reality head-mounted display (V-HMD) includes functions such as "tracking a VR controller or other device held by a user." Wan (Ex.1040) at 2:32-45. "The VR controller 136 can, e.g., emit and/or reflect infrared (IR) or any other type(s) of light that can be detected by one or more of the cameras 113 and 114 to help determine positions of, for example, the user's hands." Wan (Ex.1040) at 4:29-32. The cameras 113 and 114 are in/on the V-HMD:

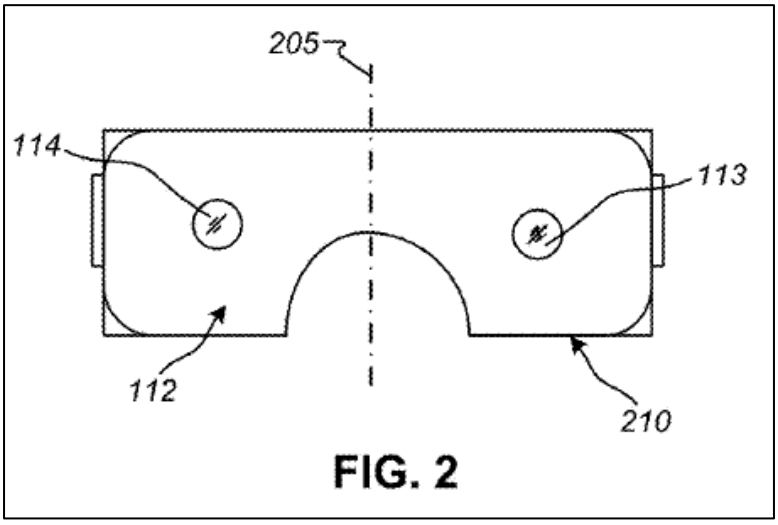


Fig. 2 (showing placement of cameras 113 and 114). The cameras 113 and 114 include a number of color "sensing pixels" and "infrared (IR) sensing pixels." Wan (Ex.1040) at 5:39-60 ("the imaging sensors of the cameras 113, 114 are RGBIR sensors").

b. 19[b]: "the WED displays a virtual monitor at the SLP in empty space inside the 3D zone, and"

437. For the same reasons that I discussed for limitations 6[a] and 6[b], limitation 19[b] would have been obvious over Pedrotti in view of Jang, or over Pedrotti in view of Jang and further in view of Begault. *See* Sections X.D.5.a-X.D.5.b.

c. 19[c]: "the binaural sound continues originates to the user at the virtual monitor as the head of the user rotates to different orientations with respect to the virtual monitor."

438. For the same reasons that I discussed for limitations 6[b] and 6[c], limitation 19[c] would have been obvious over Pedrotti in view of Jang, or over Pedrotti in view of Jang and further in view of Begault. *See* Sections X.D.5.b-X.D.5.c.

6. Claim 20: "The electronic system of claim 14, wherein the WED displays the 3D virtual image that shows the boundary of the 3D zone as lines to enable the user to determine the boundary of the 3D zone."

439. For the same reasons that I discussed for claims 4, 10, and 14 (and in particular limitation 14[d]), Pedrotti discloses, or at a minimum renders obvious, claim 20. *See* Sections X.D.3, X.F.2, X.G.5.

440. Persons of ordinary skill in the art would have known and understood that by displaying a 3D virtual image showing the boundary of the 3D zone,

Pedrotti's system allows a user to determine the boundary of the 3D zone, from the visual cue.

* * *

441. For the reasons set out above, it is my opinion that every limitation of claims 15-20 of the '737 patent, and each of claims 15-20 as a whole, would have been obvious to persons of ordinary skill in the art over Pedrotti in view of Jang, and over Pedrotti in view of Jang and further in view of Begault.

XI. Ground 2: Claims 1-20 Are Unpatentable Over McCulloch In View Of Pedrotti, And Further In View Of Flaks

442. In this section, I explain why every limitation of claims 1-20 of the '737 patent, and each of claims 1-20 as a whole, would have been obvious to persons of ordinary skill in the art over McCulloch in view of Pedrotti, and further in view of Flaks.

A. Reasons Persons Of Ordinary Skill In The Art Would Combine McCulloch and Pedrotti

443. Persons of ordinary skill in the art would have been motivated to combine McCulloch's system Pedrotti's systems and methods for implementing safety boundaries that define a user's playspace.

444. First, McCulloch and Pedrotti are analogous art. McCulloch is a system for "controlling a virtual object displayed by a near-eye, augmented reality display with a real controller device." McCulloch (Ex.1008) at 1:18-21, 1:46-48, Fig. 5.

Persons of ordinary skill in the art would have known that Pedrotti's systems and methods—which are aimed at preventing "collisions with surrounding physical objects" and "remain[ing] in a safe area"—also apply to AR systems because Pedrotti expressly encourages persons of ordinary skill in the art to use boundaries with AR and VR display devices alike (e.g., WEDs or HMDs), including see-through HMDs, such as Google Glass, and systems where a portion of the user's perception of real objects is occluded:



Phys.org, *Google Glass Available in US as of April 15* (Apr. 10, 2014) (Ex.1078) at 1; Pedrotti (Ex.1005) at 2:4-12 ("when using a HMD the user is unable to see those nearby objects while in the virtual world"), 16:10-19 ("[V]arious embodiments may be applicable to HMDs that block the user's view of all or only part of the physical world. Even some uses of a device such as Google Glass, which obscures only a small portion of the user's field of vision of the physical world, may benefit from some embodiments described herein."); Jerald, THE VR BOOK (Ex.1063) at 32-33

(describing non-see-through HMDs, video see-through HMDs, and optical-see-through HMDs as existing on a spectrum), Fig. 3.1 (similarly describing AR and VR on a continuum); *see also* Section VII.G (discussing how AR systems also benefit from safety or chaperone systems).

445. In fact, McCulloch expressly discloses that "a gaming application may receive user input identifying boundaries for a playspace in which virtual objects can be positioned." McCulloch (Ex.1008) at 20:11-13. Persons of ordinary skill in the art would have recognized that Pedrotti's "safe area" serves the same function of McCulloch's boundaries, which are part of McCulloch's "virtual environment rules" that "provide fallback rules or alternative rules based on the real objects and real features mapped in the user environment" and are "a factor in the execution of a game." McCulloch (Ex.1008) at 20:22-25, 20:4-11 ("applications store adaptive virtual environment rules [] for effecting the placement and display of one or more virtual objects in a 3D mapping of an environment"). For instance, Pedrotti's boundaries help "the user [to] remain within a selected area," or virtual environment, "if there are physical objects in the vicinity of the user." Pedrotti (Ex.1005) at 1:57-63, 11:44-52 (describing the user "physically located in the user's living room and playing a game within a virtual world").

446. Second, persons of ordinary skill in the art would have implemented Pedrotti's boundary system to prevent injury and property damage, which is a problem in both AR and VR environments. In such environments, the user risks personal injury and property damage from collisions, tripping hazards, etc. For example, if a user of McCulloch's system is flying a virtual helicopter, the user can be focused on the virtual helicopter and trip over a sofa. *See, e.g.*, McCulloch (Ex.1008) at 12:51-54 (describing a virtual remote control helicopter as the "current object of focus in a display field of view"), 26:12-15 (explaining the user's divided attention, e.g., "[t]he user gets distracted and does not change the path [of the helicopter] via user input"); Pedrotti (Ex.1005) at 13:34-45 (visual warning appropriate "when the user is not looking in the direction" he is walking). As another example, if a user is battling virtual monsters that are occluding the user's view of a bookshelf, and the user thrusts his hand to attack a monster, the user risks injuring his hand on the bookshelf. *See, e.g.*, U.S. Patent Application No. 13/288,350 ("Mount 350") (Ex.1027) (incorporated by reference in McCulloch (Ex.1008) at 20:60-63), [0042] (describing virtual monsters). Persons of ordinary skill would have understood that Pedrotti's methods allow the user to stay within boundaries, which protect the user physically and help the user avoid these physical collisions, without disrupting immersivity of the user's experience.

447. Even as an Augmented Reality (AR) system, McCulloch's system is susceptible to safety issues stemming from the user's impeded ability to sense the real, physical environment, which necessitates Pedrotti's "safe area" or boundaries. Persons of ordinary skill in the art would have known and understood that virtual objects and effects in an AR paradigm can occlude the user's view of the real world—indeed such occlusions are intentional. For example, in his widely cited and well-known article titled "A Survey of Augmented Reality," Ron Azuma defines AR as "allow[ing] the user to see the real world, with virtual objects superimposed upon or composited with the real world." Azuma, *A Survey of Augmented Reality* (1997) ("Azuma") (Ex.1112) at 356.

448. Persons of ordinary skill in the art would be very familiar with this fundamental concept of AR, and also understand that occlusion concerns are independent of the see-through technology (e.g., optical see-through" displays and "video see-through" ("video-see") displays), both of which are disclosed in McCulloch. McCulloch (Ex.1008) at 3:56–4:1, 9:38–45 (explaining how optical see-through systems overlay virtual imagery on the user's view of the real world). McCulloch also teaches this, as McCulloch explains the see-through nature of optical see-through displays. McCulloch (Ex.1008) at 3:56–61 ("a user wearing a see-through, augmented reality display device system actually sees with his or her

natural sight a real object, which is not occluded by image data of a virtual object or virtual effects, in a display field of view of the see-through display, hence the names see-through display and optical see-through display").

449. Further, persons of ordinary skill in the art would have understood that determining real-virtual object occlusion relationships, such as carried out by McCulloch's occlusion engine 302, is an essential aspect of AR. When describing the function of the occlusion engine 302, McCulloch teaches that virtual objects shown in the HMD may occlude portions of the user's view of the physical world. McCulloch (Ex.1008) at 20:64–21:4 (introducing the occlusion engine 302), 21:4–12 ("In the case of complete occlusion of a virtual object by a real object, the occlusion engine can notify the virtual data engine to not display the virtual object. In the case of complete occlusion of the real object by the virtual object, the virtual object or its parts can be sized to completely cover the real object and its parts. For partial occlusions, the display is updated to show part of the virtual object and part of the real object."), Fig. 4A.

450. Persons of ordinary skill in the art would therefore understand that both optical see-through and video see-through ("video-see") AR displays are susceptible to the same safety issues that VR displays are, stemming from the user's inability to see real world objects that are partially or fully occluded by virtual objects in the

see-through AR display. For example, if an AR system user with a see-through display was attacking a virtual monster standing in front of (and visually occluding) a real (physical) chair in the room, and thrusting their hand holding the controller at the virtual monster, the user is unable to sense that chair's presence and would strike it with their hand (and the controller), thus hurting themselves. Persons of ordinary skill in the art would therefore be motivated to incorporate Pedrotti's "safe area" or boundaries. Pedrotti (Ex.1005) at 11:43-65 (identifying the need for warnings "[s]ince the display in the HMD blocks the user's view of the physical world, the physical objects are not visible to the user").

451. Third, McCulloch's system is directed to creating an immersive experience for the user, which causes the user to "unintentionally ignore the hazards of navigating in the real world," an effect that is compounded because AR is intended to blend real and virtual objects into one environment. McCulloch (Ex.1008) at 21:21-28 (providing localized sound for a more immersive experience), 23:39-42 (McCulloch's display "position[s] virtual objects so that they appear realistically at 3D locations determined for them in the display"), 26:7-19 (describing localized sound of a virtual helicopter crash because "[t]he user gets distracted and does not change the path via user input"); Sabelman (Ex.1088) at 49, 52 (AR wearables like Microsoft HoloLens increase the risk of injury because they use "the central visual

field to display objects integrated into the real world" with "detailed, full-color, realistic objects."). As Sabelman explains, avatars and game characters are particularly distracting. Sabelman (Ex.1088) at 52 ("AR will win the struggle for attention" in these contexts). Other effects detrimental to a user's safety when using an AR device include reduced depth of focus, distance and speed perception, and reaction time. Sabelman (Ex.1088) at 51. As Azuma explains, "[a]fter the basic problems with AR are solved, the ultimate goal will be to generate virtual objects that are so realistic that they are virtually indistinguishable from the real environment." Azuma (Ex. 1112) at 380.

452. Implementing a "safe area" or boundaries in McCulloch's AR environment would allow a user to more fully enjoy the immersive experience while counteracting the user's compromised ability to sense physical surroundings. In fact, in line with McCulloch's aim to deliver an immersive experience, Pedrotti's system also aims to maintain immersion by minimizing disruption of the game experience by automatically detecting the user's location in relation to the zone boundaries and displaying a virtual fence only when the user is a specified distance from the boundaries. Pedrotti (Ex.1005) at 11:66-12:3 (describing display of a virtual fence as the user gets closer to the boundary, all "without distracting the user from the immersive virtual world"); McCulloch (Ex.1008) at 26:35-48 (managing

interaction between real and virtual objects "for more realism"), 20:28-29 (users "expect a certain quality of experience whenever an application is executed"), 23:39-51 (HMD should "position virtual objects so that they appear realistically at 3D locations"). Further, persons of ordinary skill in the art would have known and understood that immersion is a goal for both AR and VR systems. Jerald, THE VR BOOK (Ex.1063) at 29 (noting that, for AR, "ideally the human mind would not be able to distinguish between computer-generated stimuli and the real world"), 30 (noting that, for VR, "[t]he goal of virtual environments is to completely engage a user in an experience so that she feels as if she is present (Chapter 4) in another world").

453. Finally, because the systems of McCulloch and Pedrotti have essentially the same underlying functionality, including HMDs and full position and orientation tracking, persons of ordinary skill in the art would have understood that there was a reasonable expectation of success for applying Pedrotti's "safe area" to McCulloch's system. Both McCulloch's and Pedrotti's systems use 6DoF head and controller tracking that allows the user to physically walk around and interact with virtual objects. McCulloch (Ex.1008) at 4:25-31 (describing "a handheld inertial motion unit (IMU)" as an example of a real controller device), 8:17-39 (describing an "inertial sensing unit" and a "location sensing unit" in the HMD); Pedrotti

(Ex.1005) at 1:21-29 (disclosing an HMD (WED), such as "the Oculus Rift from Oculus VR, now owned by Facebook"), 1:40-45 (disclosing a handheld controller (HPED)), 4:37-44 ("the processor similarly tracks the position and orientation of the HMD tracker, and possibly the position and orientation of one or more trackers in the physical controllers"), 16:20-24 ("processor may be located … in the HMD"); *see also* Jerald, THE VR BOOK (Ex.1063) at 484 ("the convergence of AR and VR is not new from a research perspective"; "the same hardware might be used for both"). As such, persons of ordinary skill in the art would have reasonably expected to implement Pedrotti's method of using the movement of an HPED to define a size and a shape of a three-dimensional (3D) zone with McCulloch's system.

454. Persons of ordinary skill in the art also would have known that McCulloch's HMD can and does capture and store playspace boundaries, and that McCulloch's system is able to store physical properties of virtual objects and display those objects. McCulloch (Ex.1008) at 20:4-27; *see also* McCulloch (Ex.1008) at 8:17-46 (describing inertial sensing unit 132 and image generation unit 120), 19:8-62 (describing storing virtual object properties), 23:25-38 (describing virtual data engine 195). Consequently, implementing Pedrotti's virtual fence for a safe area (i.e., a virtual object depicting a playspace's boundaries) with McCulloch's system and methods would have been routine, straightforward, and well within the skill of

persons of ordinary skill in the art. Persons of ordinary skill in the art also would have been motivated to implement Pedrotti's virtual fence for at least the reasons I discuss in Section VII.G. I further address skilled artisans' reasonable expectation of success in additional detail below, e.g., in discussing the challenged claims.

B. Reasons Persons Of Ordinary Skill In The Art Would Combine McCulloch, Pedrotti, And Flaks

455. McCulloch expressly incorporates Flaks by reference into its specification, and does so specifically for Flaks' "positional 3D audio engine." McCulloch (Ex.1008) at 21:21-38; *see* Section IX.D (overview of McCulloch). Thus, Flaks is a constituent part of McCulloch's disclosures and, at a minimum, persons of ordinary skill in the art reading McCulloch and its description of a computing environment 54 comprising a 3D audio engine 304 (McCulloch (Ex.1008) at 21:21-39, Fig. 4A) would have known to look to Flaks for implementation details for 3D audio, including details concerning how the positional 3D engine uses HRTFs to produce 3D localized audio, i.e., binaural sound. *See, e.g.*, Flaks (Ex.1009) at 1:9-12 ("Humans estimate the location of a source by taking cues derived from one ear, and by comparing cues received at both ears (difference cues or ***binaural*** cues).") (emphasis added), 1:40-46 ("[o]ne possible use of 3D audio is in augmented reality scenarios," "[f]or example, a user should be able to accurately localize a sound as coming from a virtual sound source"), 7:15-16 ("an HRTF for

the listener is applied to form the 3D audio signal," where the HRTF may be "determined based on sensor determined characteristics" or selected from "a library of HRTFs"); 9:65-10:4 (similarly describing applying the listener's HRTF to generate the 3D audio signal), 14:32-39 ("the 3D audio signal is constantly being updated for the changing user position" and it is also possible to "update[e] the HRTF for the user in real time").[10]

456. Persons of ordinary skill in the art would have expected to succeed in implementing Flaks' 3D audio processing methods with McCulloch's system because McCulloch tells skilled artisans to use Flaks' teachings and because HRTFs have long been used to generate localized, binaural sound in HMDs. *See* Section VII.E; *see also*, *e.g.*, Srinivasan (Ex.1038) at 2:3-23, 11:48-12:1, Figs. 3, 7; Najaf-

[10] As was well known in the art, binaural sound reflects sound generated from audio cues accounting for sound perceived by each of a person's ears. *See* Jerald, THE VR BOOK (Ex.1063) at 100-01 ("Binaural cues (also known as stereophonic cues) are two different audio cues, one for each ear, that help to determine the position of sounds. Each ear hears a slightly different sound—different in time and different in level."); Begault at 41 ("binaural HRTF" is "terminology for referring to both left- and right-ear HRTFs").

Zadeh (Ex.1030) at 4:55-5:26, Fig. 4; Agevik (Ex.1042)at [0034]-[0038], Figs. 1A-1B; Romigh (Ex.1035) at 1:22-48, 2:25-47.

C. Independent Claim 1

1. 1[pre]: "A method executed by one or more electronic devices, the method comprising:"

457. McCulloch teaches the preamble of claim 1. At a minimum, McCulloch renders the preamble obvious.

458. McCulloch discloses methods executed by one or more electronic devices, such as McCulloch's HMD ("head mounted display device 2") and tracked HPEDs ("real controller device(s) 21"). McCulloch (Ex.1008) at 4:49-55 (discussing HMD), 6:55-61 (discussing HPEDs), 7:4-9 (describing communication over networks 50), 12:41-48 ("requested actions indicated by real controller device commands being applied and displayed from the user perspective" in the "display field of view").

459. Pedrotti also teaches, or at a minimum, renders obvious the preamble of claim 1. *See* Section X.C.1; *see, e.g.*, Pedrotti (Ex.1005) at 2:27-59.

2. 1[a]: "tracking, with a wearable electronic device (WED) worn on a head of a user, movement of a handheld portable electronic device (HPED) held in a hand of the user such that the movement of the HPED defines a size and a shape of a three-dimensional (3D) zone that extends from a physical floor and around the user;"

460. McCulloch in view of Pedrotti renders limitation 1[a] obvious.

461. McCulloch discloses a "head mounted display device 2," which is a WED worn on a head of a user:

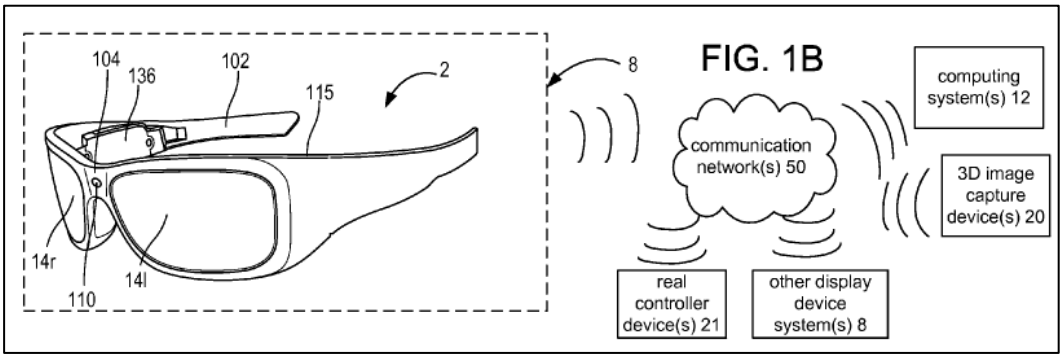


FIG. 1B

McCulloch (Ex.1008) at Fig. 1B; *see also* McCulloch (Ex.1008) at 4:49-55, 8:1-46 (describing control circuity 136 of the display device 2 and sensors, including an inertial sensing unit 132 and location or proximity sensors).

462. McCulloch's HMD has "[c]ontrol circuitry 136" including a "processing unit 210," which "may comprise one or more processors including a central processing unit (CPU) and a graphics processing unit (GPU)" and "memory 244":

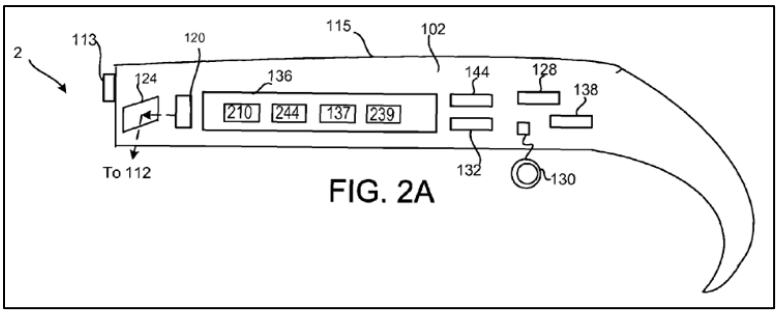


FIG. 2A

McCulloch (Ex.1008) at Fig. 2A, 8:1-16; *see also* McCulloch (Ex.1008) at 5:32-35 ("the functionality of companion processing module 4 may be integrated in software

and hardware components of the display device 2 as in FIG. 1B"), Fig. 1B, 7:4-23. And the "computing environment" for McCulloch's "display device system 8," which includes the HMD, comprises an "image and audio processing engine 191" that "processes image data… and audio data." McCulloch (Ex.1008) at Fig. 4A, 13:52-18:7 (depicting and describing "computing environment 54" for McCulloch's HMD).

463. McCulloch further discloses "handheld IMU controller[s]," i.e., HPEDs held in the user's hands. McCulloch (Ex.1008) at 4:25-31 (describing variants of controllers), 28:63-66 ("Joe is holding a handheld IMU real controller device 19 in this example"). "[C]hanges in position and orientation of [a] handheld controller cause its inertial motion unit to generate one or more signals which are converted by the handheld IMU real controller device 19 to be user input requesting display of an action by [a] virtual object," such as a virtual basketball. McCulloch (Ex.1008) at 29:4-11.

464. McCulloch also discloses, or at a minimum renders obvious, tracking the movement of its real controller device with its HMD because its HMD receives inertial and positional data associated with the real controller device. McCulloch discloses tracking the translation and rotation of the handheld controller, e.g., the handheld IMU real controller device 19, via its inertial sensors. McCulloch

(Ex.1008) at 29:4-36 ("changes in position and orientation of the handheld controller causes its inertial motion unit to generate one or more signals which are converted by the handheld IMU real controller device 19 to be user input requesting display of an action by the virtual object 30_2"), 29:36-63 ("Inertial motion sensors ['IMU'] in the handheld real controller device 19 identify parameters like speed, acceleration and direction of motion of the device 19 which is sent as data to the display device system 8."), 29:6-12 (similar), 24:28-35 (describing real controller device interface software 188), Figs. 8B, 8D; *see also* McCulloch (Ex.1008) at 28:63-66 (explaining that the "handheld IMU real controller device 19" "establishe[s] communication with [] display device system 8 (e.g., 2 and 4)"); 25:25-28. ("In other examples, non-NUI input like moving a displayed selection arrow with the real controller device may be used to identify a user selected object for control or force feedback as discussed below.").

465. Furthermore, persons of ordinary skill in the art would have understood that determining the handheld IMU device was being moved "in the direction of the television 16 [such] that the virtual basketball 303 collides with the display of the television" as disclosed by McCulloch (Ex.1008 at 29:44-46) would require the dynamic determination of the position and orientation of the handheld IMU device relative to the McCulloch's HMD and the world. McCulloch teaches this relative

position and orientation tracking as well because McCulloch's HMD is also tracked by the HMD itself, and the HMD provides image and depth data to track objects in front of the user, including the user's hands and controllers held in the user's hands.

466. McCulloch's HMD includes absolute position and orientation tracking of the HMD through various sensors and transceivers. *See, e.g.*, McCulloch (Ex.1008) at 8:17-30 ("Inside, or mounted to temple 102, are an earphone of a set of earphones 130, an inertial sensing unit 132 including one or more inertial sensors, a location sensing unit 144 including one or more location or proximity sensors, some examples of which are a GPS transceiver, an infrared (IR) transceiver, or a radio frequency transceiver for processing RFID data. Optional electrical impulse sensing unit 128 detects commands via eye movements. In one embodiment, inertial sensing unit 132 includes as sensors a three axis magnetometer, a three axis gyro, and a three axis accelerometer. The inertial sensors are for sensing position, orientation, and sudden accelerations of head mounted display device 2. From these movements, head position, and thus orientation of the display device, may also be determined."), Fig. 2A.

467. McCulloch's HMD also includes front-facing cameras to develop image and depth data to track objects in front of the user, including the user's hands and controllers held in the user's hands. McCulloch (Ex.1008) at 12:18-21 ("the

front facing capture devices 113 capture and provide image and depth data from which real objects are identified as well as their positions and often orientations relative to the display portion of the device"), 7:57-59 ("capture devices 113 are also referred to as outward facing capture devices meaning facing outward from the user's head"), 7:34-37 ("the capture devices 113 may also be depth sensitive, for example, they may be depth sensitive cameras which transmit and detect infrared light from which depth data may be determined"), 22:4-8 ("gesture recognition engine 193 can identify actions performed by a user indicating a control or command to an executing application," including actions "performed by a body part of a user, e.g. a hand or finger"), 28:5-11 ("the capture devices 113 can capture data of the user's hand and finger pointing to different objects and identifying them as a control object or a force feedback object or both, and the image and depth data is processed by the gesture recognition engine 193 for identifying a pointing selection gesture").

468. Persons of ordinary skill in the art would have understood that the camera-based absolute position and orientation of the handheld IMU real controller device 19 (held in the user's hand) supplements the IMU information about velocities and accelerations received from the IMU real controller device. As I discussed above, a "hybrid method of integrating multiple technologies together (sensor fusion)" can "provide both high precision and accuracy." Jerald, THE VR

BOOK (Ex.1063) at 315. As such, persons of ordinary skill in the art would have known, or at minimum found it obvious, to use sensor fusion methods to combine the camera-based absolute position and orientation of the handheld IMU real controller device 19 (held in the user's hand) with the IMU-based derivative signals (e.g., velocities and accelerations) from the IMU real controller device 19.

469. Tracking the controller takes places entirely within McCulloch's HMD. The computing environment 54 is contained within the HMD, or device display system 8, which includes head mounted display device 2 and companion processing module 4. *See, e.g.*, McCulloch (Ex.1008) at 28:63-66 (referring to "display device system 8 (e.g., 2 and 4)"), 5:32-36 ("the functionality of the companion processing module 4 may be integrated in software and hardware components of the display device 2 as in FIG. 1B"), 7:14-16 ("control circuitry 136 of the display device 2 incorporates the functionality which a companion processing module provides in FIG. 1A"); 13:56-60 ("Fig. 4A illustrates a computing environment embodiment 54 from a software perspective which may be implemented by a system like display device system 8"); Fig. 4A (arrow showing item 8 pointing to computing environment 54).

470. The HMD, which contains the companion processing module, is in communication with the real controller devices in order to track the real controller

devices and receive user input, as described above. *See* McCulloch (Ex.1008) at 5:19-36 ("[t]he companion processing module 4 may communicate wired or wirelessly" with "one or more real controller devices"), 24:28-30 (explaining that real controller device interface software 188, which is part of the computing environment 54 of the HMD, "communicates over a network 50 with the device interface software 189 of a real controller device 21"). And, as noted above, the changes in position and orientation of the handheld controller, which are "user input requesting display of an action," is the input data is provided to the real controller device interface software 188, which is part of the HMD's computing environment. McCulloch (Ex.1008) at 29:6-11, 25:29-33 ("the real controller device interface software 188 receives user input data from a real controller device"), 24:47-54 ("real controller device interface software 188 identifies a virtual object for control" and "applies the user input from the controller 21 requesting an action to be performed from the user perspective by indicating display instructions to the virtual data engine 195 or the application 166").

471. In addition to receiving information provided by the real controller devices, the computing environment 54 also receives device data 198, which includes data from the HMD itself, e.g., "data from sensors or sensing units" such as "the orientation sensors in inertial sensing unit 132" and "location and proximity

transceivers in location sensing unit 144." McCulloch (Ex.1008) at 24:14-21. Additionally, the computing environment 54 of McCulloch's HMD includes image and audio processing engine 191, which displays a user's actions (e.g., controlling a virtual object by real controller device 21) on the HMD. McCulloch (Ex.1008) at 13:64-14:11, 24:47-54 ("real controller device interface software 188 identifies a virtual object for control … applies the user input from the controller 21 requesting an action to be performed from the user perspective by indicating display instructions to the virtual data engine 195 or the application 166"); *see* Section IX.D (overview of McCulloch).

472. Also, persons of ordinary skill in the art would have known that McCulloch's HMD tracks (or at a minimum would obviously track) its controllers because, as I have explained, this was a common setup, particularly for gaming applications. *See* Section VII.D (discussing tracking). And, as discussed, several commercially available HMDs tracked controllers before June 2016. *See* Section VII.A (summary of brief history).

473. Furthermore, limitation 1[a] would have been obvious to persons of ordinary skill in the art reading McCulloch in view of Pedrotti. As explained above in Section X.C.2, Pedrotti discloses a WED worn on a head of a user and a handheld portable electronic device (HPED) held in a hand of the user, and also teaches

tracking, with a WED, movement of an HPED. Pedrotti further teaches using the movement of the WED-tracked HPED to define a size and shape of a 3D zone extending from a physical floor and around a user, and that the resulting zone extends from a physical floor and around the user.

474. Further, persons of ordinary skill in the art would have used Pedrotti's method of defining a boundary for a safe area (a 3D zone) with McCulloch's system for reasons I explained in Section XI.A (reasons to combine McCulloch and Pedrotti). McCulloch discloses that "a gaming application may receive user input identifying boundaries for a playspace," but offered one example of user input—gaze tracking with voice command. McCulloch (Ex.1008) at 20:11-18. Persons of ordinary skill in the art would have known and understood that Pedrotti's method, which uses HMD-tracked handheld controllers to draw a boundary, is advantageous, efficient, and accurate, including in comparison to other known tracking and/or boundary-drawing methods, such as gaze tracking and voice commands, and thus would have been motivated to use it. With a handheld controller, as taught in Pedrotti, the user can more readily and accurately ensure that hazardous conditions are sufficiently outside the boundaries by a simple action of pointing or moving the controller along the desired boundaries. Jerald, THE VR BOOK (Ex.1063) at 282 ("hand-tracked devices work well … for pointing"), 327 ("[p]ointing is faster when

speed of remote selection is important, but is also often used for precisely selecting close objects") (internal citations omitted). In comparison, skilled artisans would have understood that gaze tracking is resource-intensive and imprecise when used alone. Jerald, THE VR BOOK (Ex.1063) at 318-19 ("Interacting via eye tracking alone is usually not a good idea—eye tracking works better with multimodal input."), 319 ("Gaze data is noisy."), 328 ("eye gaze selection is typically not a good selection technique"). Furthermore, even if gaze tracking were supplemented with voice commands for demarcating boundary points for better precision, persons of ordinary skill in the art would have been motivated to pursue a simpler approach, especially when McCulloch's HMD already tracks the controller using the real controller device or IMU, with comparable hardware as disclosed in Pedrotti and consistent with how boundaries were defined in many safety and chaperone systems before June 2016. *See* Section XI.A (discussing McCulloch's and Pedrotti's HMDs and controllers among reasons to combine McCulloch and Pedrotti); Section VII.G (summary of safety and chaperone systems).

3. 1[b]: "designating, with the HPED held in the hand of the user, a sound localization point (SLP) in empty space in the

zone above the physical floor from where binaural sound originates to the user;"

475. Limitation 1[b] would have been obvious to persons of ordinary skill in the art over McCulloch in view of Pedrotti, including based on the Pedrotti disclosures discussed in Section X.C.3 (Ground 1, limitation 1[b]).

476. Additionally, limitation 1[b]—which, as discussed, 8K contends requires only moving sound-producing virtual objects (*see* Section X.C.3; '737 8K Infringement Contentions (Ex.1121) at 4)—would have been obvious over McCulloch in view of Pedrotti, and over McCulloch in view of Pedrotti and further in view of Flaks, for the following reasons.

477. McCulloch discloses multiple examples in which movement of a handheld controller moves a virtual object. McCulloch (Ex.1008) at 12:49-13:51 ("FIGS. 3A and 3B illustrate a contextual example of a virtual object being controlled with a real controller device from a user perspective."), 25:6-26:34 (describing the process by which a user is able to control a virtual object using the real controller device); 25:25-27 (describing other inputs for controlling objects), 29:4-17 ("FIG. 8B illustrates an example of a virtual object representation of the user selected real object being controlled with the real controller device …."), Figs. 3A-3E, 8B. And, with respect to Figure 8B, McCulloch explains controlling virtual objects with movement of the controller, including changes in its position and

orientation: "[t]he changes in position and orientation of the handheld controller causes its inertial motion unit to generate one or more signals which are converted by the handheld IMU real controller device 19 to be user input." McCulloch (Ex.1008) at 29:6-9.

478. As a concrete use example, McCulloch discloses that "the movement of the real controller device 19 up by the user has translated into an up action to be applied to the basketball virtual object 30_2, which the user sees from his perspective as he is looking straight at the virtual basketball 30_2":

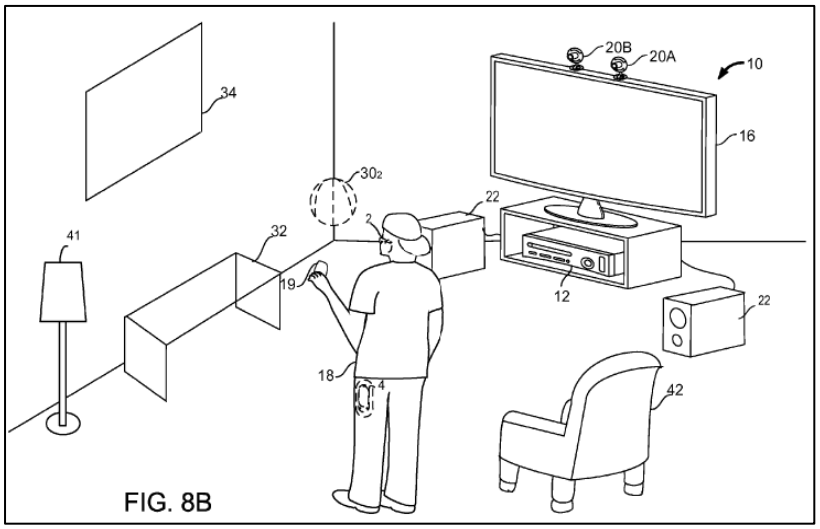


FIG. 8B

McCulloch (Ex.1008) at 29:12-16, Fig. 8B. And persons of ordinary skill in the art would have known and understood that sound associated with a virtual object moves with the object. Thus, with respect to McCulloch's example, sound associated with the virtual basketball moves with the basketball (e.g., the ball bouncing on the floor or whooshing through the air). As McCulloch explains, "the 3D audio engine 304

plays audio data for the virtual object projected from a 3D space position of the virtual object relative to a 3D space position and orientation identified for the display device which is used to approximate the position and orientation of the user's head supporting the display device." McCulloch (Ex.1008) at 26:7-12. In another of McCulloch's example concerning a virtual helicopter, the user's input using the controller "caus[es] the display to show the tail rotors going down and the pulling effect this has on the rest of the helicopter"; and, when the user is not paying attention and the helicopter crashes into a wall behind the user, "the 3D audio engine 304 plays the audio of the virtual crash to project from a position of the wall behind the user." McCulloch (Ex.1008) at 13:24-48, 26:12-19. *See also* Section X.C.3 (Ground 1, limitation 1[b] providing additional examples of sound associated with a virtual object moving with the object). Persons of ordinary skill in the art would have known that such sounds could and would be implemented in any of McCulloch's examples. McCulloch (Ex.1008) at 24:58-25:5 ("The technology may be embodied in other specific forms without departing from the spirit or essential characteristics thereof … the method embodiments are not limited to operating in the system embodiments described" and "may be implemented in other system embodiments.").

479. Persons of ordinary skill in the art would know this is how McCulloch's system works because McCulloch discloses storing input audio data with respect to

virtual objects, and incorporates by reference Flaks' disclosure of a positional 3D audio engine. McCulloch (Ex.1008) at 21:21-38 (incorporating Flaks), 14:21–22 ("sound effects for an application from the 3D audio engine 304 to be output to the user via earphones 130"), 14:53-67 (scene mapping engine 305 combines information regarding position and movement of virtual objects with the image and audio processing engine 191). And, as I have explained, it was well known, straightforward, and basic (and, of course, obvious) that virtual characters or objects, including characters and objects that can be controlled and moved by a handheld controller, are programmed to be associated with their sounds in AR and VR settings, such that sounds emanate from the locations for the virtual characters' and objects' images. *See* Section X.C.3.

480. Moreover, McCulloch's 3D audio engine uses data "identifying from which direction or position to make the sound seem to come from," and outputs that data to earphones to generate sound "as if [it is] coming from the direction of the virtual object projected into the display field of view." McCulloch (Ex.1008) at 14:53-67 (scene mapping engine 305 combines information regarding position and movement of virtual objects with the image and audio processing engine 191), 16:58-63 (similar), 21:21-54.

481. McCulloch, in fact, provides several examples of localized sound emanating from virtual objects controlled by "real controller device[s]." McCulloch (Ex.1008) at 26:7-19 (flying helicopter that crashes into wall), 29:3-30:3 (bouncing basketball that crashes into television), 25:6-26:34, Fig. 5 (describing a process for "controlling a virtual object" "with a real controller device" that includes "play[ing] audio for the virtual object projected from a 3D space position of the virtual object"), Figs. 8A-8D, 24:67-25:3.

482. Furthermore, McCulloch incorporates by reference Flaks' disclosure of a positional 3D audio engine, which demonstrates to persons of ordinary skill in the art that McCulloch discloses a virtual environment where virtual objects are associated with their localized, binaural sounds. McCulloch (Ex.1008) at 21:29-34; Flaks (Ex.1009) at 1:9-11 (explaining "[h]umans estimate the location of a source by taking cues derived from one ear, and by comparing cues received at both ears (difference cues or binaural cues)"), 1:44-46 (disclosing HRTF processing to "localize a sound as coming from a virtual sound source"), 1:62-67 (indicating that Flaks' invention is directed to binaural sound because "[a] realistic 3D audio signal may be generated based on the data collected from sensors," where the data "describes physical characteristics of the listener (e.g., head and pinna shape and size) in order to determine a suitable HRTF for that listener"), 13:55-14:4. As further

evidence that Flaks' audio engine generates binaural sound, Flaks discloses that, as part of its "process 600 of determining a listener's location and rotation in the room," the model of the human target "include[s] information that describes the rotation of the user's head such that the orientation of the user's ears is known." Flaks (Ex.1009) at 10:5-9, 11:22-24. As part of Flaks' process of determining HRTFs for a particular listener, Flaks explains "if the system was expecting data for a right ear, then the system determines whether the data matches what is expected for a right ear." Flaks (Ex.1009) at 11:61-65. Because binaural sound accounts for both ears, persons of ordinary skill in the art would have understood these express statements to show that Flaks' 3D audio engine generates binaural sound. *See also* Section VII.E (discussing background for binaural sound).

483. Persons of ordinary skill in the art would have understood from McCulloch's (and Flaks') disclosures that binaural sound for McCulloch's bouncing (and crashing) basketball will (or at a minimum will obviously) track the basketball's virtual image, e.g., for "realistic 3D audio" improving a user's experience. McCulloch (Ex.1008) at 1:62-64.

484. Additionally, persons of ordinary skill in the art would have known that the location from which sound for McCulloch's virtual basketball (or another virtual object) emanates is, or at a minimum obviously would be, in "empty space in the

zone above the physical floor." As discussed, McCulloch discloses a "playspace," "in which virtual objects can be positioned." McCulloch (Ex.1008) at 20:11-13. And those virtual objects would be in Pedrotti's "safe area" (the claimed zone), which extends from the physical floor, as well as above the physical floor. McCulloch's Figure 8B, for example, shows a virtual basketball 30_2 floating in the air in a room, which is, or at a minimum obviously would have been, within Pedrotti's "safe area" boundary and virtual fence (i.e., "in empty space in zone"). McCulloch (Ex.1008) at Fig. 8B. And per McCulloch's and Flaks' teachings, e.g., Flaks' disclosure that its 3D audio engine "creates the illusion that sound is coming from a location in 3D space" (Flaks (Ex.1009) at 1:26-28), persons of ordinary skill in the art would have known and understood that binaural sound would originate from the locations of the images of user-controlled virtual objects that McCulloch's system displays.

4. 1[c]: "tracking, with the WED worn on the head of the user, the HPED held in the hand of the user such that the HPED provides a location to the WED of the SLP in empty space in the zone above the physical floor from where the binaural sound originates to the user;"

485. Limitation 1[c] would have been obvious to persons of ordinary skill in the art over McCulloch in view of Pedrotti, including based on the Pedrotti disclosures discussed in Section X.C.4 (Ground 1, limitation 1[c]).

486. Additionally, limitation 1[c]—which, as discussed, 8K contends requires only moving sound-producing virtual objects, such as characters (*see* Section X.C.4; '737 8K Infringement Contentions (Ex.1121) at 6)—would have been obvious over McCulloch in view of Pedrotti, and over McCulloch in view of Pedrotti and further in view of Flaks, for the following reasons.

487. For the reasons that I discussed for limitations 1[a] and 1[b], McCulloch teaches tracking a HPED held in the hand of a user with a WED worn on a user's head, and McCulloch's HMD-tracked handheld controllers move virtual objects and the locations from which those virtual objects' sounds emanate. *See* Sections XI.C.2-XI.C.3; *see also* McCulloch (Ex.1008) at 28:63-66, 29:4-17.

488. Further, and continuing with McCulloch's basketball example, McCulloch's Figure 8D depicts "a collision with [a] virtual object representation" when the user "has moved the handheld IMU device with such an intensity in the direction of the television 16 that the virtual basketball 30_3 collides with the display of the television":

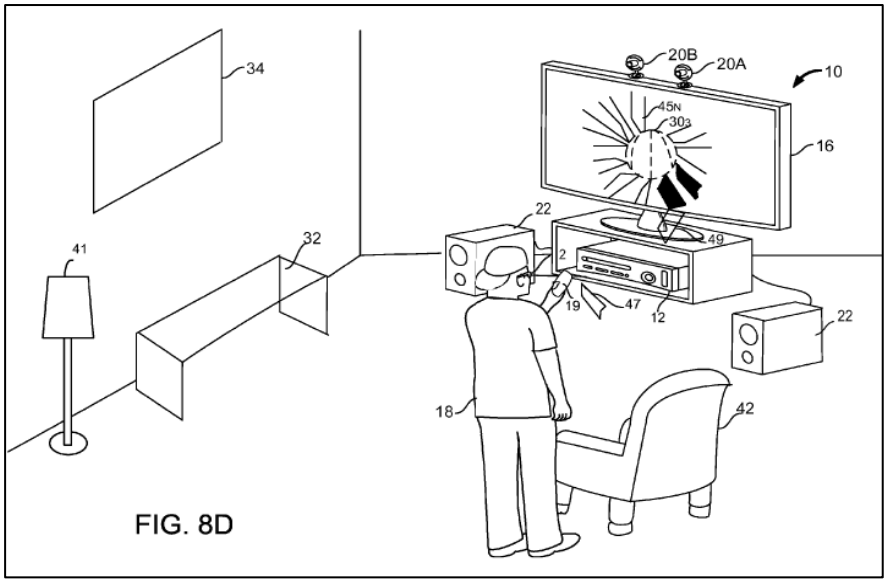


FIG. 8D

McCulloch (Ex.1008) at 29:36-3:30, Fig. 8D; *see also* McCulloch (Ex.1008) at Figs. 8B-8C.

489. Persons of ordinary skill in the art would have known and understood from McCulloch that this collision emits a crash sound from the location of the basketball 30_3, which is produced as binaural sound, e.g., with the Flaks-McCulloch positional 3D audio engine. McCulloch (Ex.1008) at 21:34-38 ("Audio data from a sound library 312 may be associated with one or more collisions … so that the 3D audio engine 304 will play the audio data during display of one or more collisions or actions.").

490. Persons of ordinary skill in the art also would have known and understood that, for the binaural sound associated with the collision to be localized properly, McCulloch's HMD receives, or obviously would receive, the location of

the crash from the sensory information obtained from its HMD-tracked real controller device(s). *See* Section X.C.4.

491. Also, as discussed for limitation 1[b], McCulloch's figures show that McCulloch's virtual objects, e.g., the basketball, and those objects' associated sounds' locations (their SLPs) are in, or at a minimum obviously are in, empty space in a zone above a physical floor, e.g., in McCulloch's "playspace" within a Pedrotti "safe zone" boundary and virtual fence. *See* Section XI.C.3. And, as discussed for limitation 1[b], McCulloch, including the expressly incorporated Flaks, or in view of Flaks, discloses or at a minimum renders obvious binaural sound originating to a user from an SLP. *See* Section XI.C.3.

5. 1[d]: "processing, by a processor, sound with head-related transfer functions (HRTFs) to generate the binaural sound that externally localizes to the user at the location of the SLP in empty space in the zone above the physical floor; and"

492. Limitation 1[d] would have been obvious to persons of ordinary skill in the art over McCulloch in view of Pedrotti, including based on the Pedrotti disclosures discussed in Section X.C.5 (Ground 1, limitation 1[d]).

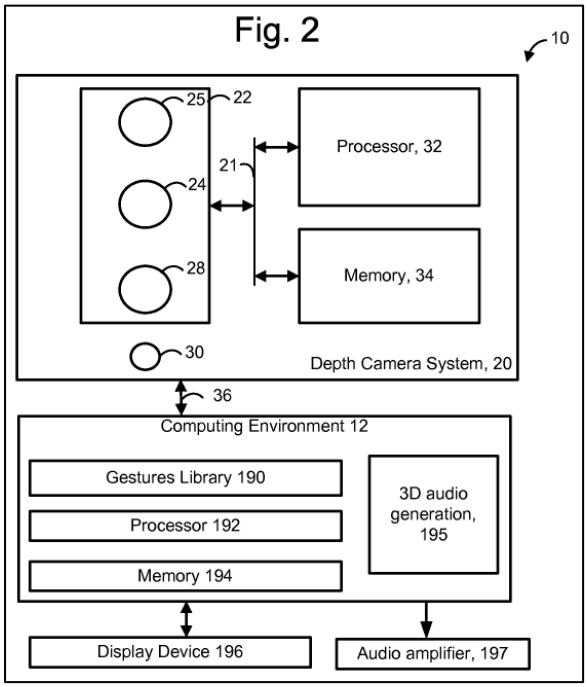
493. Additionally, limitation 1[d]—which, as discussed, 8K contends is satisfied by any sound processing with HRTFs (*see* Section X.C.5; '737 8K Infringement Contentions (Ex.1121) at 8)—would have been obvious over

McCulloch in view of Pedrotti, and over McCulloch in view of Pedrotti and further in view of Flaks, for the following reasons.

494. As discussed, McCulloch's HMD includes an image and audio processing engine 191 that incorporates a positional 3D audio engine 304 to produce "audio data for the virtual object projected from a 3D space position of the virtual object." *See* McCulloch (Ex.1008) at 25:60-26:19; *see also* Sections IX.D (overview of McCulloch); XI.C.1-XI.C.4 (limitations 1[a]-1[c]). McCulloch incorporates Flaks for implementation details regarding the positional 3D audio engine. McCulloch (Ex.1008) at 21:21-38. And Flaks discloses that 3D audio is generated with a processor processing HRTFs. Flaks (Ex.1009) at 2:6-20 ("The processor applies a head related transfer function (HRTF) for the listener to each of the components of the 3D audio signal, and provides the 3D audio signal."), 3:38-42 (describing HRTF library), 5:5-19 (describing Figure 2, which is a block diagram of Flaks' 3D audio system), 11:44-55 (deriving HRTF from sensor input).

495. Flaks further discloses that a 3D audio signal is associated with a virtual sound source location (i.e., an SLP). Flaks (Ex.1009) at 3:23-28 ("audio signal may represent a 'virtual sound' that represents a sound coming from some specific location in 3D space"), 9:8-12 (similar).

496. Flaks further discloses that a "processor applies a head related transfer function (HRTF) for the listener to each of the components of the 3D audio signal, and provides the 3D audio signal":



Flaks (Ex.1009) at 2:6-20, 5:5-19, Fig. 2 (processor 192 in relation to 3D audio generation 195).

497. Accordingly, persons of ordinary skill in the art would have known and understood that McCulloch's (and Flaks') 3D audio engine used a processor to process sound with HRTFs to generate binaural sound as claimed.

498. Furthermore, even without McCulloch's and Flaks' express teachings, persons of ordinary skill in the art would have known and been motivated to process HRTFs with a processor to generate binaural sound as claimed with a system like

McCulloch's. As I have explained, such processing was routinely used in the industry for spatializing audio, specifically binaural audio. *See* Section VII.E (discussing sound localization and binaural sound); Begault (Ex.1007) at 41, 99, 105-06, 118, 139-40, 170 (discussing processing HRTFs to produce spatialized audio and binaural audio).

499. As discussed for limitation 1[b], McCulloch's figures show that McCulloch's virtual objects, e.g., the basketball, and those objects' associated sounds' locations (their SLPs) are in, or at a minimum obviously are in, empty space in a zone above a physical floor, e.g., in McCulloch's "playspace" within a Pedrotti "safe zone" boundary and virtual fence. *See* Section XI.C.3.

6. 1[e]: "displaying, with the WED worn on the head of the user a virtual image at the location of the SLP in empty space in the zone above the physical floor from where the binaural sound originates to the user."

500. Limitation 1[e] would have been obvious to persons of ordinary skill in the art over McCulloch in view of Pedrotti, including based on the Pedrotti disclosures discussed in Section X.C.6 (Ground 1, limitation 1[e]).

501. Additionally, limitation 1[e]—which, as discussed, 8K contends requires only the presentation of sound-producing virtual objects, such as characters (*see* Section X.C.6; '737 8K Infringement Contentions (Ex.1121) at 9)—would have

been obvious over McCulloch in view of Pedrotti, and over McCulloch in view of Pedrotti and further in view of Flaks, for the following reasons.

502. As discussed for limitation 1[a], McCulloch discloses an HMD that displays virtual images. *See* Section XI.C.2. For example, as noted, McCulloch's HMD displays a virtual basketball to the user. McCulloch (Ex.1008) at Fig. 8B-8D.

503. Furthermore, McCulloch discloses a scene mapping engine 306 that "identifies the position and tracks the movement of real and virtual objects in [a] volumetric space," and McCulloch's HMD's image generation unit 120 "display[s] a virtual object" such that it appears "at a designated depth location in a field of view to provide a realistic, in-focus three dimensional display of a virtual object." McCulloch (Ex.1008) at 8:40-46, 16:58-63, 13:52-14:5 (describing associated software components), Fig. 4A. McCulloch also teaches linking visual and audio data, e.g., with collision-related events:

> The sound library … may also store audio data for sound effects to be played by the 3D audio engine 304 and which may be linked with different simulated actions, pre-collision events and collision events. Similarly, a visual effects library may store routines for animations, highlighting, and other types of visual enhancements which may also be associated with particular actions, pre-collision events and collision effects … An application can register virtual objects and pre-collision

> events and the associated visual effects, sound effects, and collision effects …

McCulloch (Ex.1008) at 22:66-23:20.

504. Additionally, Flaks discloses that "[a]s one example, the virtual sound source 29a could be an object being displayed on the display 196." Flaks (Ex.1009) at 4:10-20, 1:17-28 (similar).

505. Persons of ordinary skill in the art would have understood that the virtual image that is displayed by McCulloch's HMD is displayed "at the location of the SLP in empty space," as required by limitation 1[e]. This would have been obvious over McCulloch, including because it expressly incorporates Flaks or in view of Flaks, since both McCulloch and Flaks disclose associating the audio data from a virtual object with the display of the virtual object or sound source, i.e., SLP. *See, e.g.*, McCulloch (Ex.1008) at 21:25-28 ("Audio data for virtual objects generated by an application can be output to the earphones to sound as if coming from the direction of the virtual object projected into the display field of view."); Flaks (Ex.1009) at 4:10-3 ("the sound in the 3D audio signal may appear to be originating from some virtual sound source," which "could be an object being displayed on the display"). For example, if the basketball crashed into the monitor, persons of ordinary skill in the art would have known, including based on McCulloch's and Flaks' disclosures, that sound for that crash should be perceived

to originate from the point of the collision, not from any other object in the room. McCulloch (Ex.1008) at 29:46-55 ("[t]he physics engine 308 models the collision and the virtual data engine 195 displays a collision effect"), 21:35-38 ("Audio data from a sound library 312 may be associated with one or more collisions or actions" "so that the 3D audio engine 304 will play the audio data during display of one or more collisions or actions.").

* * *

506. For the reasons set out above, it is my opinion that every limitation of claim 1 of the '737 patent, and claim 1 as a whole, would have been obvious to persons of ordinary skill in the art over McCulloch in view of Pedrotti, and over McCulloch in view of Pedrotti and further in view of Flaks.

D. Dependent Claims 2-7

507. I understand that claims 2-7 depend from claim 1.

508. Thus, it is my opinion that each of dependent claims 2-7 would have been obvious to persons of ordinary skill in the art for the same reasons as independent claim 1 (*see* Section XI.C), and additionally for the reasons I discuss in the following subsections.

1. Claim 2

a. 2[a]: "The method of claim 1, wherein the binaural sound is a voice of a virtual reality (VR) character that talks to the user while the user plays a VR game,"

509. Limitation 2[a] would have been obvious to persons of ordinary skill in the art over McCulloch, including because it expressly incorporates Flaks or in view of Flaks.

510. It would have been obvious to persons of ordinary skill in the art to use McCulloch's inventions in a VR environment, including VR games. As discussed, AR and VR share similarities, with AR technologies almost always the more complex of the two since AR can be thought of as supplementing reality with virtual objects. *See, e.g.*, Azuma (Ex.1112) at 355-56 ("Augmented reality (AR) is a variation of virtual environments (VE), or virtual reality as it is more commonly called. VE technologies completely immerse a user inside a synthetic environment. While immersed, the user cannot see the real world around him. In contrast, AR allows the user to see the real world, with virtual objects super-imposed upon or composited with the real world. Therefore, AR supplements reality, rather than completely replacing it.") (emphasis in original omitted); Jerald, THE VR BOOK (Ex.1063) at 32-33 (functionalities and qualities associated with an HMD, such as "accurate tracking, low latency, and careful calibration" apply equally to all HMDs), 484 ("[a]ugmented reality and virtual reality" have "many similarities and the two

will likely converge," including because "the same hardware might be used for both"; "the convergence of AR and VR is not new from a research perspective"); U.S. Patent No. 8,884,984 ("Flaks 984") (Ex.1013) at Background ("One of the harder problems to solve with augmented reality is the ability to overlay virtual objects on top of real objects.") (incorporated by reference as U.S. Patent Application No. 12/905,952 in McCulloch (Ex.1008) at 10:66-11:2); Billinghurst 2015 (Ex.1049) at 80-81 ("[a]s more or less virtual content is added to the AR scene the interface moves closer or further away from the VE [virtual environment] or RE [real environment]").

511. Thus, persons of ordinary skill in the art would have known AR systems and methods are frequently, and at a minimum obviously, applicable in a VR context. *See* Balachandreswaran (Ex.1045) at [0002] ("AR and VR exist on a continuum of mixed reality (MR) visualization."); Zhou at 1006-09 (describing an exemplary game where two users occupying the same physical 3-meter by 3-meter region explore a virtual land augmented on the physical ground, which then transitions into a completely virtual scene when the players have located a virtual princess), Figs. 9-11; Billinghurst, *The MagicBook – Moving Seamlessly Between Reality and Virtuality* (2001) ("Billinghurst 2001") (Ex.1123) at 6 (users turning the physical pages of MagicBook "can fly into the page and experience the story as an

immersive virtual environment"), 7 ("[w]he users see an augmented reality scene they wish to explore, flicking the switch on the handle will transition them into the immersive environment" where "[t]he real world is no longer visible"), Figs. 2A-2C (showing how to "us[e] the MagicBook interface to move between reality and virtual reality); Billinghurst 2015 (Ex.1049) at 227 (describing another system where users "[w]earing see-through HMDs" and "using a 3D wand [] can also pull the content off the screen and see it as a 3D AR object floating in space in front of them").

512. Indeed, this is also the case for McCulloch. As discussed above, a video see-through AR system, which McCulloch discloses, could and would easily be used for VR. The only difference is the content, as AR would encompass video with computer-generated virtual objects and portions of the real environment, whereas VR would primarily encompass only the former. McCulloch (Ex.1008) at 26:31-34 ("If the near-eye AR display device system includes a video-see display or is operating in a video-see mode, a virtual object representation of the real object may already exist."). Notably, the real objects in McCulloch's video-see mode are rendered as image data in the video displayed to the user. *See* McCulloch (Ex.1008) at 3:61-67 (providing background on video-see display); Jerald, THE VR BOOK (Ex.1063) at 32-33 (similar). McCulloch specifically describes examples of this, such as replacing a physical basketball with a virtual one, or replacing characteristics

of the real environment with those of a virtual game environment through sound modeling. McCulloch (Ex.1008) at 29:4-16 ("FIG. 8B illustrates an example of a virtual object representation of the user selected real object being controlled with the real controller device … The real basketball 30 has been erased in this example."); *see also* Flaks (Ex.1009) at 8:35-40 ("However, instead of using actual materials of the real objects, virtual characteristics may be used. For example, instead of an actual thick carpet, a cement floor could be modeled."). Thus, persons of ordinary skill in the art would have known and been motivated to apply McCulloch's teachings in VR. Persons of ordinary skill in the art would have understood that any display intended to be used for AR can be used for VR by filling the field of view (FOV) with virtual imagery or virtual objects, as was done with the MagicBook I describe above.

513. Moreover, McCulloch teaches that its inventions are useful for controlling virtual objects for virtual games. McCulloch (Ex.1008) at Title, 4:25-31 (controllers "associated with gaming consoles or game applications"), 6:12-14 ("The user and his friends may be wearing their display device systems for playing a game which takes place throughout the house."), 6:29-33 (display of "virtual objects" for "a game application"); Mount 350, [0003] (user "may walk around a real-world environment and play a virtual game"), [0024].

514. Additionally, as discussed in Section XI.D.1.a (Ground 1, limitation 2[a]), persons of ordinary skill in the art would have known that VR games would include VR characters as a typical (and obvious) virtual object that would talk in those games. For example, Mount 350 discloses the display of virtual monsters and characters. Mount 350 (Ex.1027) at [0042], [0049].

515. And, as discussed for limitation 1[e], persons of ordinary skill in the art would have known and been motivated to use 3D audio, e.g., through Flaks' binaural sound processing, to match sounds and voices of characters with their visual representations such that "binaural sound is a voice of a virtual reality (VR) character," as the claim requires. *See* Sections X.C.6 (Ground 1, limitation 1[e]), XI.C.6 (Ground 2, limitation 1[e]).

b. 2[b]: "and the voice externally localizes to the user at the VR character that is at the location of the SLP in empty space in the zone above the physical floor."

516. Limitation 2[a] would have been obvious to persons of ordinary skill in the art over McCulloch, including because it expressly incorporates Flaks or in view of Flaks.

517. Persons of ordinary skill in the art would have found obvious externally localizing to the user the voice of the VR character at the location of the VR character, i.e., at the location of the SLP, because this is the concept behind 3D audio, and specifically binaural sound—localizing sound at the sound source to the listener.

See Section X.D.1.b (Ground 1, limitation 2[b]), XI.C.3-XI.C.5 (Ground 2, limitations 1[b]-1[d]). Indeed, such localization is the driving concept behind 3D audio and binaural sound.

518. Persons of ordinary skill in the art would have known and been motivated to spatialize audio in a VR setting, for example, through commonly known HRTF processing techniques (such as those taught in Flaks), to provide a more immersive VR experience to a user, which would obviously include associating any virtual object's sound with that object's location. As I have explained, long before June 2016, persons of ordinary skill in the art knew that a VR character's voice should not appear to originate from a location distinct from that VR character. For example, a user should not hear a robot displayed to the front of a user as if the robot is speaking (or beeping) from behind the user.

2. Claim 3

a. 3[a]: "The method of claim 1 further comprising: tracking, with the WED worn on the head of the user, the HPED held in the hand of the user as the HPED moves in a trajectory having a shape of an arc;"

519. Limitation 3[a] would have been obvious to persons of ordinary skill in the art over McCulloch in view of Pedrotti, including based on the Pedrotti disclosures discussed in Section X.D.2.a (Ground 1, limitation 3[a]).

520. Additionally, limitation 3[a] would have been obvious over McCulloch in view of Pedrotti for the following reasons.

521. McCulloch discloses examples where the movement of the real controller device would result in the real controller device moving in an arc. McCulloch (Ex.1008) at 29:11-16 ("movement of the real controller device 19" as "translated into an [] action to be applied to" the virtual object), 27:55-64 (describing physics engine for controller's force feedback applicable to swinging, hitting, and throwing virtual objects, e.g., McCulloch's virtual basketball, actions that would necessitate or obviously encompass moving a controller in an arc); *see also* Pedrotti (Ex.1005) at 9:29-52, 16:33-42, Fig. 8 (showing Pedrotti's virtual sword). And McCulloch discloses, including through the Mount reference it incorporates, games in which the user would move the real controller device in a trajectory having a shape of an arc based on the nature of the object controlled by the movement of the real controller device. *See, e.g.*, Mount 350 (Ex.1027) at [0024] ("The gaming application may include one of any number of different gaming applications such as … action games including first person shooting games.").

b. 3[b]: "processing, by the processor and with the HRTFs, the sound to generate SLPs of the binaural

sound that moves through the empty space along the trajectory having the shape of the arc; and"

522. Limitation 3[b] would have been obvious to persons of ordinary skill in the art over McCulloch in view of Pedrotti, including based on the Pedrotti disclosures discussed in Section X.D.2.b (Ground 1, limitation 3[b]).

523. Additionally, McCulloch, including because it expressly incorporates Flaks or in view of Flaks, discloses, or at a minimum renders obvious, limitation 3[b].

524. As discussed for limitations 1[b]-1[d], McCulloch's real controller device provides a location to an HMD so a 3D audio engine can generate binaural sound associated with virtual objects. McCulloch (Ex.1008) at 21:21-38; Flaks (Ex.1009) at 1:44-46. Persons of ordinary skill in the art would have known and been motivated to keep together visual elements moving in an arc and their associated sound sources, such that binaural sound, generated using McCulloch's 3D audio engine, originates from visual elements moving in an arc. *See* Sections XI.C.3-XI.C.5.

c. 3[c]: "displaying, with the WED worn on the head of the user, virtual images that follow the trajectory having the shape of the arc that shows the user the

trajectory of the SLPs of the binaural sound moving through the empty space."

525. Limitation 3[c] would have been obvious to persons of ordinary skill in the art over McCulloch in view of Pedrotti, including based on the Pedrotti disclosures discussed in Section X.D.2.c (Ground 1, limitation 3[c]).

526. Additionally, limitation 3[c] would have been obvious over McCulloch in view of Pedrotti, and over McCulloch in view of Pedrotti and further in view of Flaks for the reasons discussed for limitations 3[a] and 3[b]. *See* Sections XI.D.2.a, XI.D.2.b. Persons of ordinary skill in the art would have known and been motivated to move sound associated with one of McCulloch's or Pedrotti's virtual objects in the same arc trajectory of those objects. And as such objects move in an arc, they show the user the trajectory of their associated binaural sounds.

3. Claim 4

a. 4[a]: "The method of claim 1 further comprising: determining, with the WED worn on the head of the user, when a location of the user conflicts with a boundary of the zone; and"

527. Limitation 4[a] would have been obvious to persons of ordinary skill in the art over McCulloch in view of Pedrotti, including based on the Pedrotti disclosures discussed in Section X.D.3.a (Ground 1, limitation 4[a]).

528. Additionally, limitation 4[a] would have been obvious over McCulloch in view of Pedrotti for the following reasons.

529. McCulloch discloses defining boundaries for a zone, or "playspace." McCulloch (Ex.1008) at 20:11-13 ("a gaming application may receive user input identifying boundaries for a playspace in which virtual objects can be positioned"), 15:48-16:41 (using a scene mapping engine to compare the location of tracked objects against stored data of a zone based on a common coordinate system), Fig. 4A.

530. Persons of ordinary skill in the art would have known that these boundaries described in McCulloch apply to the user's playspace as well, and not just virtual objects. This is because, given either a VR or AR environment, there are safety concerns for the user who is focused on the game. *See, e.g.*, Sabelman (Ex.1088) (discussing dangers of AR because of the user's focus, even if the user is able to visually perceive the surrounding physical environment); Jerald, THE VR BOOK (Ex.1063) at 220 (with respect to safety, "[c]onsider forcing users to stay within safe areas"). Accordingly, persons of ordinary skill in the art would have been motivated by McCulloch's teachings, e.g., its disclosure of boundaries for a playspace, to implement the rules and methods Pedrotti discloses for determining when a user's location conflicts with the boundary of a safe area for gameplay.

b. 4[b]: "displaying, with the WED, the boundary of the zone to alert the user that the location of the user conflicts with the boundary of the zone."

531. Limitation 4[b]—which, as discussed, 8K contends in district court requires only the display of a virtual fence to "alert" a user (*see* Section X.D.3.b; '737 8K Infringement Contentions (Ex.1121) at 21)—would have been obvious to persons of ordinary skill in the art over McCulloch in view of Pedrotti based on the Pedrotti disclosures discussed in Section X.D.3.b (Ground 1, limitation 4[b]).

4. Claim 5

a. 5[a]: "The method of claim 1 further comprising: displaying, with the WED worn on the head of the user, a virtual image of the zone as lines that extends from the physical floor and around the user,"

532. Limitation 5[a] would have been obvious to persons of ordinary skill in the art over McCulloch in view of Pedrotti, including based on the Pedrotti disclosures discussed in Section X.D.4.a (Ground 1, limitation 5[a]).

533. Additionally, limitation 5[a]—which, as discussed, 8K contends in district court requires only the display of two walls to show a "boundary of the 3D zone that extends from the physical floor and around the user" (*see* Section X.D.4.a; '737 8K Infringement Contentions (Ex.1121) at 18)—would have been obvious over McCulloch in view of Pedrotti for the following reasons.

534. Persons of ordinary skill in the art would have known that McCulloch's system could and would generate, store, and display Pedrotti's virtual fence because McCulloch discloses an HMD with a virtual data engine that displays virtual objects and further discloses that object data can include "[a] polygon mesh… to represent [an] object's boundary." McCulloch (Ex.1008) at 17:47-48, 23:25-38, Fig. 4A.

b. 5[b]: "wherein the zone has a customized shape drawn by user with the HPED, and the WED stores coordinate locations of the customized shape."

535. Limitation 5[b] would have been obvious to persons of ordinary skill in the art over McCulloch in view of Pedrotti, including based on the Pedrotti disclosures discussed in Section X.D.4.b (Ground 1, limitation 5[b]).

536. Additionally, limitation 5[b]—which, as discussed, 8K contends in district court requires only moving an HPED along a desired boundary (*see* Section X.D.4.b; '737 8K Infringement Contentions (Ex.1121) at 20)—would have been obvious over McCulloch in view of Pedrotti for the following reasons.

537. Persons of ordinary skill in the art would have known that McCulloch's playspace boundaries, which are identified via "user input," could and would be any shape drawn by a user. McCulloch (Ex.1008) at 20:11-13 ("a gaming application may receive user input identifying boundaries for a playspace in which virtual objects can be positioned"), 20:13-18 (discussing "gaze data captured while the user is gazing at boundary points"); Section VII.C (discussing handheld controllers and

how they were used for drawing any kinds of curves and shapes). Persons of ordinary skill in the art thus would have understood from McCulloch that boundaries are chosen and drawn by the user, which is consistent with the implementation details provided by Pedrotti.

538. Further, it would have been obvious to persons of ordinary skill in the art to store coordinate locations of a customized zone in an HMD based on McCulloch's disclosure of a scene mapping engine, which handles "3D mapping," including "3D space positions or position volumes for objects" with a shared coordinate system. McCulloch (Ex.1008) at 15:6-8, 15:16-29. McCulloch's "map can be stored … and retrieve from memory and be updated over time as one or more users enter or re-enter the environment." For example, "[w]hen a user enters an environment, the scene mapping engine 306 may first search for a pre-generated 3D map identifying 3D space positions and identification data of objects stored locally." McCulloch (Ex.1008) at 15:63-67.

539. In view of these McCulloch teachings, persons of ordinary skill in the art would have found it obvious to store coordinate locations of a customized zone along with maps, particularly because a zone can be considered its own object with a 3D space position and position volume. It would have been obvious to skilled artisans to compare, for example, the location of a tracked controller against stored

data of a zone based on McCulloch's disclosure of common coordinates for its maps. Furthermore, storing data, including in HMDs, was known in the art and disclosed by McCulloch. McCulloch (Ex.1008) at 8:1-11, Figs. 2A ("memory 244" in HMD 2), 4A.

5. Claim 6

a. 6[a]: "The method of claim 1 further comprising: displaying, with the WED, a virtual monitor in a field of view (FOV) of the user;"

540. McCulloch discloses, or at a minimum renders obvious, limitation 6[a].

541. McCulloch discloses displaying virtual objects using its image and audio processing engine and updating tracked virtual objects in a user's field of view. McCulloch (Ex.1008) at 12:29-32 ("A virtual object is generated by an application and is displayed at a position and orientation in the view dependent coordinate system as the user would see it if it were a real object."), 12:3-16 ("In some examples, virtual objects are tracked in the display field of view and real objects are ignored … The display of the virtual object is updated so as to be seen in accordance with the updated user perspective … The positions of both real and virtual objects are tracked in the display field of view."). McCulloch further discloses a virtual monitor that shatters when a virtual basketball hits it. McCulloch (Ex.1008) at 29:36-63, Figs. 8B-8D.

542. Furthermore, persons of ordinary skill in the art would have known and understood that a virtual monitor is just an example virtual object that McCulloch's system could and would display, particularly because it was common to display virtual monitors in AR and VR environments, e.g., as a way to provide content to users. *See* Section X.D.5.a (Ground 1, limitation 6[a]) (discussing references displaying virtual monitors, including Jang, Begault, Mount 421, Martin, Miller 652, and THE VR BOOK).

b. 6[b]: "processing, by the processor, the sound with the HRTFs to generate the binaural sound that originates from the virtual monitor; and"

543. McCulloch discloses, or at a minimum renders obvious, limitation 6[b], including because it expressly incorporates Flaks or in view of Flaks.

544. Persons of ordinary skill in the art would have known that many existing AR and VR systems displayed virtual monitors. *See* Sections X.D.5.a, XI.D.5.a).

545. Persons of ordinary skill in the art also would have known that sound associated with such monitors should be processed to originate from the virtual monitors' locations. For the same reasons it would have been obvious to process sound with HRTFs to generate binaural sound originating from a designated SLP and sound-generating VR objects, which I discussed above in the context of limitations 1[b] and 1[d], it would have been obvious to process sound with HRTFs

to generate binaural sound from a virtual monitor using McCulloch's 3D audio engine (the details of which are provided in Flaks), such as before or when the monitor is shattered by a basketball, as McCulloch describes. *See* Sections XI.C.3, XI.C.5.

c. 6[c]: "tracking, with the WED, head movements of the user to maintain the binaural sound originating from the virtual monitor as the head of the user moves."

546. McCulloch discloses, or at a minimum renders obvious, limitation 6[b], including because it expressly incorporates Flaks or in view of Flaks.

547. McCulloch discloses that its HMD tracks a user's "movements, head position, and thus orientation." McCulloch (Ex.1008) at 8:17-39. Relatedly, Flaks describes processing and producing 3D audio, i.e., binaural sound, accounting for the position and orientation tracking of a user's head. *See* Sections XI.C.3 and XI.C.5 (limitations 1[b] and 1[d]). Specifically, Flaks explains that its "process 600 might be used to determine which way the user's head is rotated," and that there are sensors used for tracking on the user's head. Flaks (Ex.1009) at 10:5-8, 11:25-43 ("[A]t least one inertial sensor is located on the user's head to allow tracking of the user's head … In step 612, the user's location in the room is determined based on tracking the model. In step 614, the rotation of the user's head is determined based on tracking the model. Process 600 may continue to track the user such that the location and rotation may be updated.").

548. Persons of ordinary skill in the art thus would have known and been motivated to process binaural sound originating from a virtual monitor, and to update that sound to maintain its position as the user (and the user's head) moves. *See* Section X.D.5.c (Ground 1, limitation 6[c]) (discussing Begault and how well known it was to process sound for virtual objects with HRTFs while accounting for a user's head position).

6. Claim 7: "The method of claim 1, wherein the zone has a shape of a cylinder that extends from the physical floor and around the user, and the WED displays the cylinder to the user."

549. Claim 7 would have been obvious to persons of ordinary skill in the art over McCulloch in view of Pedrotti, including based on the Pedrotti disclosures discussed in Section X.D.6 (Ground 1, claim 7).

550. Additionally, for the same reasons that I discussed for claims 1, 4, and 5, claim 7 would have been obvious over McCulloh in view of Pedrotti and further in view of Flaks. *See* Sections XI.C, XI.D.3, XI.D.4.

* * *

551. For the reasons set out above, it is my opinion that every limitation of claims 2-7 of the '737 patent, and each of claims 2-7 as a whole, would have been obvious to persons of ordinary skill in the art over McCulloch in view of Pedrotti, and over McCulloch in view of Pedrotti and further in view of Flaks.

E. Independent Claim 8

1. 8[pre]: "A method executed by one or more electronic devices, the method comprising:"

552. The preamble of claim 8 is identical to the preamble of claim 1 and would have been obvious. *See* Section XI.C.1.

2. 8[a]: "tracking, with a wearable electronic device (WED) worn on a head of a user, a handheld portable electronic device (HPED) that moves to define a shape of a zone that extends from a physical floor and around the user holding the HPED in a hand;"

553. For the same reasons that I discussed for limitation 1[a], limitation 8[a] would have been obvious over McCulloch in view of Pedrotti. *See* Section XI.C.2.

554. Limitation 8[a] recites "defin[ing] a shape of a zone," whereas limitation 1[a] recites "defin[ing] a size and shape of a three-dimensional (3D) zone." Either way, this is taught by Pedrotti for reasons discussed. *See* Section X.C.2 (Ground 1, limitation 1[a]).

3. 8[b]: "designating, with the HPED held in the hand of the user, a sound localization point (SLP) for binaural sound at a location in empty space in the zone above the physical floor where the HPED is pointed;"

555. For the same reasons that I discussed for limitation 1[b], limitation 8[b] would have been obvious over McCulloch in view of Pedrotti, or over McCulloch in view of Pedrotti and further in view of Flaks. *See* Section XI.C.3.

556. Limitation 8[b] additionally recites "where the HPED is pointed" in comparison to limitation 1[b].

557. Persons of ordinary skill in the art would have known and understood that it was common to use a handheld controller to select, move, and control virtual objects by pointing at them. *See* Section X.E.3 (Ground 1, limitation 8[b]). Additionally, McCulloch discloses a controller that is used to point. McCulloch (Ex.1008) at 4:25-33, 6:61-66, 25:25-28 ("In other examples, non-NUI input like moving a displayed selection arrow," a type of pointer, "with the real controller device may be used to identify a user selected object for control or force feedback as discussed below"), cl. 12.

4. 8[c]: "tracking, with the WED worn on the head of the user, the HPED and where the HPED is pointed to provide the WED with the location in empty space in the zone above the physical floor that includes the SLP for the binaural sound;"

558. For the same reasons that I discussed for limitation 1[c], limitation 8[c] would have been obvious over McCulloch in view of Pedrotti, or over McCulloch in view of Pedrotti and further in view of Flaks. *See* Section XI.C.4.

559. Limitation 8[c] additionally recites "where the HPED is pointed" in comparison to limitation 1[c].

560. For the same reasons that I discussed for limitation 8[b], persons of ordinary skill in the art would have found it obvious that the handheld controller is

pointed at the SLP since tracking where handheld controllers are pointed was well-known and commonly used in the art. *See* Section XI.E.3.

5. 8[d]: "processing, by a processor, sound with head-related transfer functions (HRTFs) to produce the binaural sound that originates at the SLP at the location in empty space in the zone above the physical floor; and"

561. For the same reasons that I discussed for limitation 1[d], limitation 8[d] would have been obvious over McCulloch in view of Pedrotti, and over McCulloch in view of Pedrotti and further in view of Flaks. *See* Section XI.C.5.

562. Limitation 8[d] recites "to produce the binaural sound that originates at the SLP" whereas limitation 1[d] recites "to generate binaural sound that externally localizes to the user at the location of the SLP."

563. Persons of ordinary skill in the art would have understood that these refer to the same effect—namely, processing sound so a user hears it as if it is coming from the location of an external location in space (the SLP), which is consistent with skilled artisans' understanding of localized sound, and specifically 3D or binaural sound. *See* Section VII.E (discussing localization of sound and binaural sound).

6. 8[e]: "displaying, with the WED worn on the head of the user, a virtual image at the location in empty space in the zone above the physical floor from where the binaural sound originates at the SLP to the user."

564. For the same reasons that I discussed for limitation 1[e], limitation 8[e] would have been obvious over McCulloch in view of Pedrotti, or over McCulloch in view of Pedrotti and further in view of Flaks. *See* Section XI.C.6.

* * *

565. For the reasons set out above, it is my opinion that every limitation of claim 8 of the '737 patent, and claim 8 as a whole, would have been obvious to persons of ordinary skill in the art over McCulloch in view of Pedrotti, and over McCulloch in view of Pedrotti and further in view of Flaks.

F. Dependent Claims 9-13

566. I understand that claims 9-13 depend on independent claim 8.

567. Thus, it is my opinion that each of dependent claims 9-13 would have been obvious to persons of ordinary skill in the art for the same reasons as independent claim 8 (*see* Section XI.E), and additionally for the reasons I discuss in the following subsections.

1. Claim 9: "The method of claim 8 further comprising: providing a voice as the binaural sound that externally localizes at the virtual image at the location in empty space in the zone above the physical floor, wherein the voice originates from a character in a virtual reality (VR) game that the user plays."

568. For the same reasons that I discussed for claim 2, claim 9 would have been obvious to persons of ordinary skill in the art over McCulloch, including because it expressly incorporates Flaks or in view of Flaks. *See* Section XI.D.1.

569. Claim 9 recites "externally localizes at the virtual image at the location in empty space," instead of "externally localizes to the user at the VR character that is at the location of the SLP" as recited in limitation 2[b]. But as discussed for limitations 1[b] and 1[e], persons of ordinary skill in the art would have found it obvious to have the sound and image of the virtual object, e.g., a VR character, stay and move together. *See* Sections XI.C.3 and XI.C.6.

2. Claim 10: "The method of claim 8 further comprising: displaying, with the WED, a boundary of the zone with virtual lines to alert the user when the user conflicts with the boundary of the zone while the user plays a virtual reality (VR) game."

570. For the same reasons that I discussed for claims 2 and 4, claim 10 would have been obvious over McCulloch in view of Pedrotti. *See* Sections XI.D.1 (discussing McCulloch's application to a virtual reality (VR) game), XI.D.3 (discussing other limitations present in claim 10).

3. Claim 11: "The method of claim 8 further comprising: displaying the zone as a customized three-dimensional (3D) shape drawn by the user with the HPED held in the hand of the user."

571. For the same reasons that I discussed for limitation 1[a] and claim 5 (and specifically limitation 5[b]), claim 11 would have been obvious over McCulloch in view of Pedrotti. *See* Sections XI.C.2 (discussing that the zone is 3D), XI.D.4 (discussing customized shape).

4. Claim 12: "The method of claim 8 further comprising: tracking, with the WED, a location where the HPED is pointed as the HPED moves the SLP and the virtual image from one location where the HPED is pointed to another location where the HPED is pointed."

572. Claim 12 would have been obvious to persons of ordinary skill in the art over McCulloch in view of Pedrotti, including based on the Pedrotti disclosures discussed in Section X.F.4 (Ground 1, claim 12).

573. Additionally, claim 12 would have been obvious over McCulloch in view of Pedrotti for the following reasons.

574. McCulloch discloses the claimed scenario of moving the SLP and virtual image from one location to another in its basketball example:

> FIG. 8D illustrates an example of a simulated effect on a physical state of the user selected force feedback object due to a collision with the virtual object representation of the user selected control real object in the continuing example of FIGS. 8A, 8B and 8C. ***Inertial motion***

> ***sensors (not shown) in the handheld real controller device 19 identify parameters like speed, acceleration and direction of motion of the device 19 which is sent as data to the display device system 8.*** Joe has moved the handheld IMU device with such an intensity in the direction of the television 16 that the virtual basketball 303 collides with the display of the television.

McCulloch (Ex.1008) at 29:36-46 (emphasis added).

575. Also, for the same reasons that I discussed for claims 3 and 8 (and specifically limitation 8[c]), claim 12 would have been obvious. *See* Sections XI.D.2 (discussing tracking), XI.E.4 (discussing "where the HPED is pointed"). And as discussed for limitations 1[b] and 1[e], persons of ordinary skill in the art would have certainly expected and found it straightforward and basic (and, of course, obvious) to have the sound and image of a virtual object move together with the SLP, including when a user moves such objects with a VR controller by pointing at and moving them. *See* Sections XI.C.3 and XI.C.6; *see also* Section VII.C (discussing selection and manipulation of virtual objects with handheld controllers).

5. Claim 13: "The method of claim 8 further comprising: improving performance of the processor processing the sound by storing the HRTFs in a cache memory in the WED,

wherein the processor is a digital signal processor (DSP) located in the WED."

576. For the same reasons that I discussed for claim 8 (and in particular limitation 8[d]), claim 13 would have been obvious to persons of ordinary skill in the art over McCulloch, including because it expressly incorporates Flaks or in view of Flaks. *See* Section XI.E.5.

577. McCulloch discloses an HMD with "one or more processors," including "digital processing unit 210" and an audio processing engine. McCulloch (Ex.1008) at 8:1-16, 8:30-39 ("each of the devices processing an analog signal in its operation include control circuitry which interfaces digitally with the digital processing unit 210 and memory 244 and which produces or converts analog signals, or both produces and converts analog signals, for its respective device").

578. McCulloch further discloses use of Flaks' audio engine to generate sound, which is a component of the computing environment 54 of McCulloch's HMD. McCulloch (Ex.1008) at 10:66-11:2, Fig. 4 (showing 3D audio engine 304 within the image and audio processing engine 191, which in turn is within the computing environment 54 of display device 8).

579. McCulloch also discloses using cache memory of the CPU to improve performance, and specifically, using cache for the generation of 3D audio, through incorporation of Flaks, which provides: "The multimedia console 100 has a central

processing unit (CPU) 101 having a level 1 cache 102, a level 2 cache 104, and a flash ROM (Read Only Memory) 106. The level 1 cache 102 and a level 2 cache 104 temporarily store data and hence reduce the number of memory access cycles, thereby improving processing speed and throughput. The CPU 101 may be provided having more than one core, and thus, additional level 1 and level 2 caches 102 and 104." Flaks (Ex.1009) at 14:60-67.

580. Furthermore, persons of ordinary skill in the art would have known and been motivated to implement McCulloch's audio processing with a DSP and to store HRTFs in cache memory for the reasons I explained in the context of claim 13 in Ground 1. *See* Section X.F.5 (Ground 1, claim 13).

* * *

581. For the reasons set out above, it is my opinion that every limitation of claims 9-13 of the '737 patent, and each of claims 9-13 as a whole, would have been obvious to persons of ordinary skill in the art over McCulloch in view of Pedrotti, and over McCulloch in view of Pedrotti and further in view of Flaks.

G. Independent Claim 14

1. 14[pre]: "An electronic system, comprising:"

582. Claim 14's preamble would have been obvious for the same reasons the preambles of claims 1 and 8 would have been obvious. *See* Sections XI.C.1, XI.E.1.

2. 14[a]: "a portable electronic device (PED) that moves to define a boundary of a three-dimensional (3D) zone extending from a physical floor on which a user holding the PED stands and around the user and that designates a sound localization point (SLP) in empty space inside the 3D zone; and"

583. For the same reasons that I discussed for limitations 1[a]-1[b] and 8[a]-8[b], limitation 14[a] would have been obvious over McCulloch in view of Pedrotti, or over McCulloch in view of Pedrotti and further in view of Flaks. *See* Sections XI.C.2-XI.C.3, XI.E.2-XI.E.3.

584. Limitation 14[a] recites "a portable electronic device" and "a user holding [a] PED," which encompasses the "handheld portable electronic device (HPED)" recited in limitations 1[a] and 8[a]. Put another way, McCulloch's or Pedrotti's handheld controller is both the "PED" recited in claim 14, and the "HPED" (the "handheld" PED) recited in claims 1 and 8.

585. Additionally, limitation 14[a] recites that the user stands on the physical floor. This would have been obvious to persons of ordinary skill in the art (indeed, to any user of an AR or VR device), including in view of McCulloch or Pedrotti, the latter of which depicts the floor on which a user stands. *See, e.g.*, McCulloch (Ex.1008) at Figs. 8B-8D (showing the user standing on the floor); Pedrotti (Ex.1005) at Fig. 10 (item 1010), 12:16-22 ("floor 1010").

3. 14[b]: "a wearable electronic device (WED) that is worn on a head of the user, tracks movement of the PED to determine

the boundary of the 3D zone that extends from the physical floor and around the user,"

586. For the same reasons that I discussed for limitations 1[a] and 8[a], limitation 14[b] would have been obvious over McCulloch in view of Pedrotti. *See* Sections XI.C.5, XI.E.5.

4. 14[c]: "includes a processor that processes sound with head-related transfer functions (HRTFs) so sound externally localizes as binaural sound to the user at the SLP in empty space inside the 3D zone defined by movement of the PED, and"

587. For the same reasons that I discussed for limitations 1[d] and 8[d], limitation 14[c] would have been obvious over McCulloch in view of Pedrotti, and over McCulloch in view of Pedrotti and further in view of Flaks. *See* Sections XI.C.5, XI.E.5.

5. 14[d]: "displays a virtual image at the SLP in empty space inside the 3D zone, and displays a 3D virtual image that shows the boundary of the 3D zone that extends from the physical floor and around the user."

588. For the same reasons that I discussed for limitations 1[e], 4[b], 5[a], and 8[e], limitation 14[d] would have been obvious over McCulloch in view of Pedrotti. *See* Sections XI.C.6, XI.D.3.b, XI.D.4.a, XI.E.6.

589. Limitation 14[d] additionally recites that the virtual image is "3D" in comparison to limitations 1[e] and 8[e]. Persons of ordinary skill in the art would have understood that the virtual images displaying boundaries in Pedrotti's HMD

(e.g., the image of Pedrotti's "virtual fence") are, or at a minimum obviously would be, 3D virtual images. *See also* Section VII.G (discussing prior art safety and chaperone systems, including systems displaying 3D virtual images). Indeed, there would be no way to display a "virtual image that shows the boundary of the 3D zone that extends from the physical floor and around the user" other than doing so in 3D.

* * *

590. For the reasons set out above, it is my opinion that every limitation of claim 14 of the '737 patent, and claim 14 as a whole, would have been obvious to persons of ordinary skill in the art over McCulloch in view of Pedrotti, and over McCulloch in view of Pedrotti and further in view of Flaks.

H. Dependent Claims 15-20

591. I understand that claims 15-20 depend from independent claim 14.

592. Thus, it is my opinion that each of dependent claims 15-20 would have been obvious to persons of ordinary skill in the art for the same reasons as independent claim 14 (*see* Section XI.G), and additionally for the reasons I discuss in the following subsections.

1. Claim 15: "The electronic system of claim 14, wherein the 3D zone has a customized size and shape defined by movement of the PED while held in a hand of the user."

593. For the same reasons that I discussed for claim 5 (and in particular limitation 5[b]), claim 15 would have been obvious over McCulloch in view of

Pedrotti, including based on the Pedrotti disclosures discussed in Section X.H.1 (Ground 1, claim 15). *See* Section XI.D.4.b.

594. Claim 15 recites "customized size and shape defined by movement of the PED" whereas limitation 5[b] recites "customized shape drawn by the user of the HPED."

595. As explained above, persons of ordinary skill in the art would have known and understood that Pedrotti's "safe area" method allows a user to define a boundary of a customized size and shape via movement of Pedrotti's controller (the PED), since the user is able to mark a "sampling point" anywhere—leading to a safe area zone of a customized size and shape. Pedrotti (Ex.1005) at 14:56-65.

2. Claim 16

a. 16[a]: "The electronic system of claim 14, wherein the WED tracks the PED to determine when the PED is at the boundary of the 3D zone, and"

596. For the same reasons that I discussed for limitations 1[c] and 4[a], limitation 16[a] would have been obvious over McCulloch in view of Pedrotti, including based on the Pedrotti disclosures discussed in Section X.H.2.a (Ground 1, limitation 16[a]). *See* Sections XI.C.4, XI.D.3.a.

597. Limitation 16[a] recites "when the PED is at the boundary," whereas limitation 4[a] recites "when a location of the user conflicts with a boundary of the zone."

598. Persons of ordinary skill in the art thus would have understood that Pedrotti's system determines (or would obviously determine) when a PED is at the boundary of a 3D zone. *See* Section X.H.2.a (Ground 1, limitation 16[a]).

b. 16[b]: "the WED automatically displays the 3D virtual image that shows the boundary of the 3D zone to alert the user that the PED is at the boundary of the 3D zone."

599. For the same reasons that I discussed for limitations 4[b] and 16[a], limitation 16[b]—which, as discussed, 8K contends in district court requires only displaying a 3D virtual image (*see* Section X.H.2.b; '737 8K Infringement Contentions (Ex.1121) at 21)—would have been obvious over McCulloch in view of Pedrotti, including based on the Pedrotti disclosures discussed in Section X.H.2.b (Ground 1, limitation 16[b]). *See* Sections XI.D.3.b, XI.H.2.a.

600. Limitation 16[b] additionally recites "automatically displays" whereas limitation 4[b] recites "displaying." Persons of ordinary skill in the art would have understood that Pedrotti's system in fact automatically displays the virtual fence when the condition that the PED is at the boundary of the 3D zone is met. *See* Pedrotti (Ex.1005) at 16:4-58, Fig. 15; *see also* Section X.H.2.b (Ground 1, limitation 16[b]).

3. Claim 17

a. 17[a]: "The electronic system of claim 14, wherein the WED tracks the user to determine when the user is at the boundary of the 3D zone, and"

601. For the same reasons that I discussed for limitations 1[c] and 4[a], limitation 17[a] would have been obvious over McCulloch in view of Pedrotti, including based on the Pedrotti disclosures discussed in Section X.H.3.a (Ground 1, limitation 17[a]). *See* Sections XI.C.4, XI.D.3.a.

b. 17[b]: "the WED automatically displays the 3D virtual image that shows the boundary of the 3D zone to alert the user that the user is at the boundary of the 3D zone."

602. For the same reasons that I discussed for limitations 4[b] and 17[a], limitation 17[b] would have been obvious over McCulloch in view of Pedrotti, including based on the Pedrotti disclosures discussed in Section X.H.3.b (Ground 1, limitation 17[b]). *See* Sections XI.D.3.b, XI.H.3.a.

603. Limitation 17[b] additionally recites "automatically displays" whereas limitation 4[b] recites "displaying." As noted, persons of ordinary skill in the art would have understood that Pedrotti's system in fact automatically displays the virtual fence when the condition that the PED is at the boundary of the 3D zone is met. Pedrotti (Ex.1005) at 16:4-58, Fig. 15; *see also* Section X.H.2.b (Ground 1, limitation 16[b]).

4. Claim 18

a. 18[a]: "The electronic system of claim 14, wherein the WED determines a location of the user,"

604. Limitation 18[a] would have been obvious to persons of ordinary skill in the art over McCulloch in view of Pedrotti, including based on the Pedrotti disclosures discussed in Section X.H.4.b (Ground 1, limitation 18[a]).

605. Additionally, for the same reasons that I discussed for limitations 4[a] and 17[a], limitation 18[a] would have been obvious over McCulloch in view of Pedrotti, or McCulloch in view of Pedrotti and further in view of Flaks, and for the following reasons. *See* Sections XI.D.3.a, XI.H.3.a.

606. McCulloch discloses that its HMD determines a location of the user. McCulloch (Ex.1008) at 8:17-30 ("a location sensing unit 144 including one or more location or proximity sensors").

607. Flaks also teaches tracking the user's location as a functionality of its 3D audio engine. Flaks (Ex.1009) at 7:33-34 (further indicating that the listener's location is "carefully tracked"), 9:18-20 ("system may track the physical location of the user"), 11:32-38 ("known technique for tracking movements of one or more persons can be used"); McCulloch (Ex.1008) at 21:21-38 (incorporating Flaks).

b. 18[b]: "stores the 3D zone for the location, and"

608. For the same reasons that I discussed for limitation 5[b], limitation 18[b] would have been obvious over McCulloch in view of Pedrotti, including based on the Pedrotti disclosures discussed in Section X.H.4.b (Ground 1, limitation 18[b]). *See* Section XI.D.4.b.

609. Limitation 18[b] recites "stor[ing] the 3D zone for the location," whereas limitation 5[b] recites "stor[ing] coordinate locations of the customized shape."

610. McCulloch discloses storing a 3D zone because it teaches generating and storing 3D maps of environments, and it would have been obvious to store 3D zones in relation to the mapped environments. *See* McCulloch (Ex.1008) at 15:48-54 ("The scene mapping engine 306 can also use a view independent coordinate system for 3D mapping. ***The map can be stored in the view independent coordinate system in a storage location (e.g. 324)*** accessible as well by other display device systems 8, other computer systems 12 or both, ***be retrieved from memory and be updated over time*** as one or more users enter or ***re-enter the environment***.") (emphasis added), 15:63-67 ("When a user enters an environment, the scene mapping engine 306 may first search for a pre-generated 3D map identifying 3D space positions and identification data of objects stored locally or accessible from another display device system 8 or a network accessible computer system 12."). For

example, if a user enters a new environment (e.g., moves into a different room or a different part of the room), persons of ordinary skill in the art would have understood to retrieve the stored 3D map and the associated boundary in order to apply the appropriate or updated boundary for that user's location. As McCulloch indicates, location information can be based not only on a relative coordinate system, but also an absolute location, such as based on GPS information retrieved from the HMD's sensors. McCulloch (Ex.1008) at 8:17-22.

c. 18[c]: "displays the 3D virtual image that shows the boundary of the 3D zone in response to determining that the user is at the location."

611. For the same reasons that I discussed for limitation 4[b] and 17[a]-17[b], limitation 18[c] would have been obvious over McCulloch in view of Pedrotti based on the Pedrotti disclosures discussed in Section X.H.4.c (Ground 1, limitation 18[c]). *See* Sections XI.D.3.b, XI.H.3.a- XI.H.3.b.

612. Furthermore, in view of McCulloch's disclosure regarding storing 3D maps for when users enter or re-enter an environment, persons of ordinary skill in the art would have found it obvious to display the boundary when a user first enters an environment to obtain a general sense of the boundary of that particular environment. McCulloch (Ex.1008) at 15:48-54; 15:63-67.

5. Claim 19

a. 19[a]: "The electronic system of claim 14, wherein the WED includes one or more sensors that track a light source in the PED to determine a location of the PED as the PED moves to define the boundary of the 3D zone,"

613. McCulloch and Pedrotti each discloses, or at a minimum renders obvious, limitation 19[a]. *See* Section X.H.5.a (Ground 1, limitation 19[a]) (discussing pertinent Pedrotti disclosures).

614. McCulloch discloses using capture devices (e.g., cameras) as well as infrared ("IR") transceivers in an HMD to detect and track infrared light, which may be emitted by a controller. McCulloch (Ex.1008) at 7:34-40 (capture devices), 8:7-39 (IR transceivers), 5:19-36 (companion processing module 4, which may be in the HMD, communicates via infrared with controller devices 21). And, the technique of tracking a light source emitted from a PED to determine its location was well-known in the art. *See* Section X.H.5.a. Furthermore, persons of ordinary skill in the art would have known that optical tracking systems can offer advantages, such as "accurate measurements of both position and orientation over relatively large working volumes, without many of the problems inherent in magnetic or acoustic tracking systems." Welch 1995 (Ex.1119) at 1 (also discussing disadvantages of mechanical tracking systems and acoustic tracking systems).

b. 19[b]: "the WED displays a virtual monitor at the SLP in empty space inside the 3D zone, and"

615. For the same reasons that I discussed for limitations 6[a] and 6[b], limitation 19[b] would have been obvious over McCulloch in view of Pedrotti. *See* Sections XI.D.5.a-XI.D.5.b.

c. 19[c]: "the binaural sound continues originates to the user at the virtual monitor as the head of the user rotates to different orientations with respect to the virtual monitor."

616. For the same reasons that I discussed for limitations 6[b] and 6[c], limitation 19[c] would have been obvious over McCulloch in view of Pedrotti, or McCulloch in view of Pedrotti and further in view of Flaks. *See* Sections XI.D.5.b-XI.D.5.c.

6. Claim 20: "The electronic system of claim 14, wherein the WED displays the 3D virtual image that shows the boundary of the 3D zone as lines to enable the user to determine the boundary of the 3D zone."

617. For the same reasons that I discussed for claims 4, 10, and 14 (and in particular limitation 14[d], claim 20 would have been obvious over McCulloch in view of Pedrotti. *See* Sections XI.D.3, XI.F.2, XI.G.5.

618. Persons of ordinary skill in the art would have understood that by displaying a 3D virtual image showing the boundary of the 3D zone, the user is able to determine the boundary of the 3D zone in light of the visual cue.

* * *

619. For the reasons set out above, it is my opinion that every limitation of claims 15-20 of the ’737 patent, and each of claims 15-20 as a whole, would have been obvious to persons of ordinary skill in the art over McCulloch in view of Pedrotti, and over McCulloch in view of Pedrotti and further in view of Flaks.

XII. Conclusion

620. For the foregoing reasons, it is my opinion that claims 1-20 of the '737 patent are unpatentable under 35 U.S.C. § 103.

621. All statements made herein of my own knowledge are true, and all statements made on information and belief are believed to be true. Further, I am aware that these statements are 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. I declare under penalty of perjury that the foregoing is true and correct.

Executed on June 8, 2023 in Longwood, Florida.



Dr. Gregory F. Welch