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(54) **VIBROTACTILE CONTROL SYSTEMS AND METHODS**

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(56) **References Cited**

U.S. PATENT DOCUMENTS

5,290,964 A 3/1994 Nakada et al.
5,314,403 A 5/1994 Shaw
(Continued)

FOREIGN PATENT DOCUMENTS

CA 2982291 A1 4/2019
CN 203953629 U 11/2014
(Continued)

OTHER PUBLICATIONS

"Buttkicker Gamer2 for Simulation and Gaming"; The Guitammer Company; 2011; downloaded on May 15, 2015 from http://www.thebuttkicker.com/gaming/.
(Continued)

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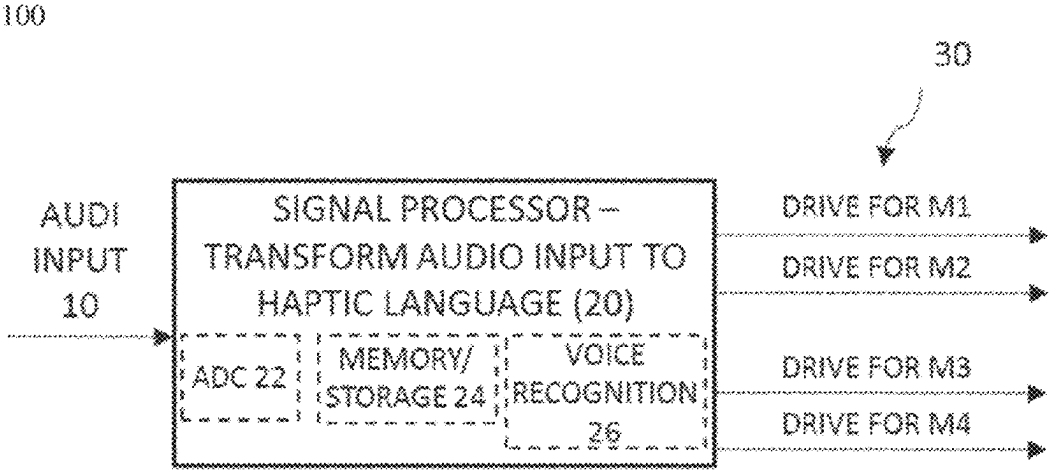
(57) **ABSTRACT**

Methods and systems are disclosed to facilitate creating the sensation of vibrotactile movement on the body of a user. Vibratory motors are used to generate a haptic language for music or other stimuli that is integrated into wearable technology. The disclosed system in certain embodiments enables the creation of a family of devices that allow people such as those with hearing impairments to experience sounds such as music or other input to the system. For example, a "sound vest" or other wearable array transforms musical input to haptic signals so that users can experience their favorite music in a unique way, and can also recognize auditory or other cues in the user's real or virtual reality environment and convey this information to the user using haptic signals.

20 Claims, 14 Drawing Sheets



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See application file for complete search history.

(56) **References Cited**

U.S. PATENT DOCUMENTS

5,368,359	A	11/1994	Eakin	
5,553,148	A	9/1996	Werle	
6,093,164	A	7/2000	Davis et al.	
6,106,491	A	8/2000	Gianutsos	
6,132,392	A	10/2000	Stone	
6,284,962	B1	9/2001	Gardner et al.	
7,035,422	B1	4/2006	Wiener	
7,147,610	B2	12/2006	Maalouf	
7,152,345	B2	12/2006	Koenig	
7,582,066	B2	9/2009	Shimotori	
7,832,124	B2	11/2010	Blockton	
8,144,911	B2	3/2012	Chiang et al.	
8,343,066	B1	1/2013	Eagleman et al.	
8,398,571	B2	3/2013	Ellin	
8,582,789	B2	11/2013	Cheung et al.	
8,764,688	B1	7/2014	Nauman et al.	
8,795,210	B2	8/2014	Talish et al.	
9,318,940	B2	4/2016	Efrati	
9,336,795	B1	5/2016	Robertson et al.	
9,452,101	B2	9/2016	Tomlinson et al.	
9,461,529	B2	10/2016	Efrati	
9,679,546	B2	6/2017	Ebeling et al.	
9,786,201	B2	10/2017	Ebeling et al.	
9,924,251	B2	3/2018	Efrati	
10,016,615	B2	7/2018	Simon et al.	
10,022,511	B2	7/2018	Avni	
10,071,015	B2	9/2018	Seo et al.	
10,079,009	B2	9/2018	Efrati	
10,159,623	B2	12/2018	Leftly	
10,172,762	B1	1/2019	Branch et al.	
10,182,964	B2	1/2019	Snow	
10,245,208	B2	4/2019	MacGuinness	
10,362,830	B2	7/2019	Campbell	
10,617,597	B2	4/2020	Chawan et al.	
10,624,811	B2	4/2020	Mackey-Ponte	
10,632,040	B2	4/2020	Muench et al.	
10,695,263	B2	6/2020	Snow	
10,828,504	B2	11/2020	Blendermann	
10,905,628	B2	2/2021	Hodges	
10,925,803	B2	2/2021	Lattner	
10,964,179	B2	3/2021	Ebeling et al.	
11,009,948	B2	5/2021	Efrati	
11,026,824	B2	6/2021	Burnett et al.	
11,065,174	B2	7/2021	Lach et al.	
11,625,994	B2	4/2023	Ebeling et al.	
12,008,892	B2	6/2024	Ebeling et al.	
2002/0107556	A1	8/2002	McLoul et al.	
2002/0169398	A1	11/2002	Hancock	
2003/0144614	A1	7/2003	Cordo	
2003/0206642	A1	11/2003	Menzies	
2005/0020945	A1	1/2005	Tosaya et al.	
2005/0113167	A1	5/2005	Buchner et al.	
2006/0183964	A1	8/2006	Kehoe	
2007/0100262	A1	5/2007	Simos et al.	
2007/0203435	A1	8/2007	Novak	
2008/0027363	A1	1/2008	Brueckmann et al.	
2008/0143080	A1	6/2008	Burr	
2009/0005713	A1	1/2009	Podrazhansky et al.	
2009/0024183	A1*	1/2009	Fitchmun	A61N 1/36038 607/57
2009/0131165	A1	5/2009	Buchner et al.	
2009/0262967	A1	10/2009	Bryan	
2009/0270758	A1	10/2009	Eagleman et al.	
2010/0174217	A1	7/2010	Budnik et al.	
2010/0249637	A1	9/2010	Walter et al.	
2011/0021272	A1*	1/2011	Grant	A63F 13/10 463/30
2011/0040204	A1	2/2011	Ivorra et al.	
2011/0046687	A1	2/2011	Naschberger	
2011/0319796	A1	12/2011	Campdera	
2012/0059294	A1	3/2012	Schubert et al.	
2012/0130154	A1	5/2012	Sajan et al.	
2012/0238923	A1	9/2012	Yamashita et al.	
2012/0253236	A1	10/2012	Snow et al.	
2012/0260789	A1*	10/2012	Ur	G09B 19/0015 84/470 R
2013/0116606	A1	5/2013	Cordo	
2013/0204169	A1	8/2013	Poepperling et al.	
2013/0335209	A1*	12/2013	Cruz-Hernandez	G08B 6/00 340/407.1
2014/0005579	A1	1/2014	Drlik et al.	
2014/0012167	A1	1/2014	Devlieger et al.	
2014/0070957	A1	3/2014	Longinotti-Buitoni et al.	
2014/0100488	A1	4/2014	Simmons	
2014/0207033	A1	7/2014	Hillila	
2014/0276271	A1	9/2014	Stryker et al.	
2014/0318699	A1	10/2014	Longinotti-Buitoni et al.	
2015/0013111	A1	1/2015	White	
2015/0062959	A1	3/2015	Wilson	
2015/0097719	A1	4/2015	Balachandreswaran et al.	
2015/0119769	A1	4/2015	Golbin et al.	
2015/0161908	A1	6/2015	Ur et al.	
2015/0177939	A1	6/2015	Anderson et al.	
2015/0217121	A1	8/2015	Subramanian et al.	
2015/0224019	A1	8/2015	Barbera	
2015/0258302	A1	9/2015	Chandra et al.	
2015/0272815	A1	10/2015	Kitchens	
2015/0289034	A1	10/2015	Engman et al.	
2015/0290074	A1	10/2015	Koenig	
2015/0293590	A1	10/2015	Lehtiniemi et al.	
2015/0297445	A1	10/2015	Gordon et al.	
2015/0317910	A1	11/2015	Daniels	
2015/0324646	A1	11/2015	Kimia	
2015/0331488	A1	11/2015	Grant et al.	
2015/0332659	A1	11/2015	Ebeling et al.	
2015/0356889	A1	12/2015	Schwartz	
2015/0366504	A1	12/2015	Connor	

(56) **References Cited**

U.S. PATENT DOCUMENTS

2016/0012688	A1	1/2016	Eagleman et al.	
2016/0027338	A1	1/2016	Ebeling et al.	
2016/0030854	A1	2/2016	Shaanti	
2016/0129248	A1	5/2016	Creasey et al.	
2016/0133151	A1	5/2016	O'Dowd et al.	
2016/0166930	A1*	6/2016	Brav	G08B 21/02 463/30
2016/0228325	A1	8/2016	Kologrivov et al.	
2017/0079875	A1	3/2017	Qiao	
2017/0098350	A1	4/2017	Ebeling et al.	
2017/0119620	A1	5/2017	Trapp	
2017/0326024	A1	11/2017	Hernandez	
2017/0326025	A1	11/2017	Hernandez	
2018/0140503	A1	5/2018	Kim et al.	
2018/0356890	A1	12/2018	Zhang et al.	
2018/0369064	A1	12/2018	Baxter et al.	
2019/0001129	A1	1/2019	Rosenbluth et al.	
2019/0046794	A1	2/2019	Goodall et al.	
2019/0053968	A1	2/2019	Vergara et al.	
2019/0070057	A1	3/2019	Conner et al.	
2019/0151190	A1	5/2019	Burbank et al.	
2019/0151604	A1	5/2019	Harper et al.	
2019/0159953	A1	5/2019	Konczak et al.	
2019/0175895	A1	6/2019	Uryash et al.	
2019/0183724	A1	6/2019	Sifferlin	
2019/0298605	A1	10/2019	Rabolt et al.	
2019/0328610	A1	10/2019	Qiao	
2020/0171267	A1	6/2020	Millard et al.	
2020/0188210	A1	6/2020	Molina Trejo	
2020/0268602	A1	8/2020	Akaikine et al.	
2020/0286346	A1	9/2020	Ebeling et al.	
2020/0297067	A1	9/2020	Graham	
2020/0313536	A1	10/2020	Efrati	
2020/0323729	A1	10/2020	Arazi et al.	
2020/0345970	A1	11/2020	La Rovere et al.	
2021/0060287	A1	3/2021	Giacomini et al.	
2021/0060330	A1	3/2021	Chu et al.	
2021/0077343	A1	3/2021	Baxter et al.	
2021/0186801	A1	6/2021	Thomas et al.	
2021/0186803	A1	6/2021	Dimino	
2021/0213216	A1	7/2021	Smith et al.	
2021/0244316	A1	8/2021	Khaled	
2021/0251844	A1	8/2021	Radovic	
2021/0251848	A1	8/2021	Tracey et al.	
2021/0259579	A1	8/2021	Grant-Beuttler et al.	
2021/0259911	A1	8/2021	Earsley	
2021/0259914	A1	8/2021	Holbert	
2021/0275390	A1	9/2021	Hsueh et al.	
2021/0290482	A1	9/2021	Wang et al.	
2021/0330547	A1	10/2021	Moaddeb et al.	
2021/0338413	A1	11/2021	Haluska et al.	
2021/0366250	A1	11/2021	Ebeling et al.	
2022/0273173	A1	9/2022	Rodriguez Chapa et al.	
2023/0351868	A1	11/2023	Ebeling et al.	

FOREIGN PATENT DOCUMENTS

CN	207745244	U	8/2018
CN	111150635	A	5/2020
CN	211095931	U	7/2020
CN	212662235	U	3/2021
CN	112891183	A	6/2021
CN	113143734	A	7/2021
CN	213697860	U	7/2021
DE	102013111050	B4	5/2019
GB	251559	A	5/1926
GB	2515599	A	12/2014
JP	2020049179	A	4/2020
KR	20180036374	A	4/2018
KR	20180036379	A	4/2018
KR	20180116653	A	10/2018
KR	102047655	B1	11/2019
KR	20200102023	A	8/2020
KR	102175232	B1	11/2020
KR	20210079124	A	6/2021
KR	20210126424	A	10/2021
WO	9846189	A1	10/1998
WO	2004080528	A2	9/2004
WO	2006110545	A2	10/2006
WO	2006130559	A2	12/2006
WO	2006134999	A1	12/2006
WO	2009044400	A2	4/2009
WO	2010033086	A1	3/2010
WO	2017017681	A2	2/2017
WO	2017063071	A1	4/2017
WO	2017158583	A1	9/2017
WO	2019023467	A1	1/2019
WO	2020123789	A1	6/2020
WO	2020185601	A1	9/2020
WO	2020186274	A1	9/2020
WO	2020261225	A1	12/2020
WO	2021042976	A1	3/2021
WO	2021081189	A1	4/2021
WO	2021112922	A1	6/2021

OTHER PUBLICATIONS

Haptic Gaming SDK: Haptic Effects Library / UHL (Universal Haptic Layer); Immersion Corporation; 2015; downloaded on Dec. 18, 2015 from https://www.immersion.com.

"Woojer—FEEL the Sound!"; Kickstarter, Inc. Manhattan, NY; Dec. 2013; downloaded on Dec. 17, 2015 from https://www.kickstarter.com/projects/1382889335/woojer-feel-the-sound.

Abstract of Branje, C et al.: "Playing vibrotactile music: A comparison between the Vibrochord and a piano keyboard"; Int J Hum-Comput St; Apr. 2014; pp. 431-439; vol. 72 Issue 4.

Abstract of Darrow, A.A et al.; "The Effect of Vibrotactile Stimuli via the SOMATRON™ on the Identification of Rhythmic Concepts by Hearing Impaired Children"; J Music Ther; 1989; pp. 115-124; vol. 26 No.3.

Abstract of Darrow, A.A.; "The Effect of Frequency Adjustment on the Vocal Reproduction Accuracy of Hearing Impaired Children": J Music Ther; 1990; pp. 24-33; vol. 27 No. 1.

Abstract of Darrow, A.A; "The Effect of Vibrotactile Stimuli via the SOMATRON on the Identification of Pitch Change by Hearing Impaired Children"; J Music Ther; 1992; pp. 103-112; vol. 29 No.2.

Abstract of Gu, C. et al.; "Vibrotactile thresholds at the sole of the foot: effect of vibration frequency and contact location"; Somatosens Mot Res; Nov. 25, 2011; pp. 86-93; vol. 28 No. 3-4.

Abstract of Hayes, L. et al.; "Imposing a Networked Vibrotactile Communication System for Improvisational Suggestion"; Organized Sound; Apr. 2012; pp. 36-44; vol. 17, Issue 1.

Abstract of Ideguchi, T. et al.; "Influence of the Sensation of Vibration on Perception and Sensibility while Listening to Music"; Int J Innov Comput I; Mar. 2009; pp. 631-640; vol. 5 No. 5.

Alan Cross; "This is New: Vibrotactile Music"; A Journal of Musical Things; Jun. 20, 2012; downloaded Dec. 18, 2015 from http://ajournalofmusicalthings.com/this-is-new-vibrotactile-music/.

Beaufait, M. et al.; "Soundless Music"; Electrical and Computer Engineering University of Michigan, EECS 452: Digital Signal Processing Design Laboratory; Winter 2012; accessed Dec. 17, 2015 from http://www.eecs.umich.edu.

Birnbaum, D. et al.; "A Systematic Approach to Musical Vibrotactile Feedback"; International Computer Music Association; 2007; pp. 397-404; vol. 2007.

Bobier, David; "VibraFusionLab"; VibraFusionLab; 2015; downloaded on Dec. 18, 2015 from http:/www.vibrafusionlab.com/.

Carmen Branje; "Feeling the Music: Vibrotactile music is the latest example of technology enabling the emergence of new art forms."; Jul. 15, 2011.

Chafe, C.; "Tactile Audio Feedback"; Proc. Intl. Computer Music Conf.; Sep. 1993: pp. 76-79; Tokio, Japan.

Choi, S. et al.; "Vibrotactile Display: Perception, Technology, and Applications"; Proc. IEEE; Sep. 2013; pp. 2093-2104; vol. 101, No. 9.

Copper,R; "Beethoven, Music and The Deaf: A Brief Consideration of the Works and Struggles of Ludwig Van Beethoven"; Lifeprint.

(56) **References Cited**

OTHER PUBLICATIONS

com; May 14, 2007; USA; downloaded Dec. 17, 2015 from http://www. lifeprint.com/asl101/topics/beethoven02. htm.

D. Richard Ternes; "Building Large Set of Haptic Icons: rhythm as a design parameter, and between-subjects MDS for evaluation"; Thesis submitted Aug. 2007; pp. 1-263; The University of British Columbia; Canada.

Dr. Stefano Papetti; "AHMI Audio-Haptic modalities in Musical Interfaces": Institute for Computer Music and Sound Technology; Mar. 1, 2014; Zurich, Switzerland; downloaded Dec. 18, 2015 from https://www.zhdk.ch/index.php?id=icst_ahmi_ e.

Emanuele. Mahzoun; "Good Vibrations: A vibrotactile aid toward music sensation aiming at helping deaf people"; Thesis presented as part of Degree of Master of Science in Electrical Engineering with emphasis on Signal Processing BTH; May 2013; pp. 61.

Eric Gunther; "Skinscape: A Tool for Composition in the Tactile Modality"; Thesis Submitted to the Department of Electrical Engineering and Computer Science MIT; May 23, 2001; pp. 118.

Fontana, F et al.; "Perception of Interactive Vibrotactile Cues on the Acoustic Grand and Upright Piano"; Proceedings ICMC SMC 2014, Sep. 14-20, 2014; pp. 948-953; Athens, Greece.

Giordano et al.; "Perceptual and Technological Issues in the Design of Vibrotactile Augmented Interfaces for Music Technology and Media": Haptic and Audio Interaction Design; vol. 7989, Lecture Notes in Computer Science; pp. 89-98; HAID 2013, LNCS 7989.

Good, A.; "Compensatory Plasticity in the Deaf Brain: Effects on Perception of Music"; 2014; Brain Sci; pp. 560-574; vol. 4.

Gunther, E. et al. "Cutaneous Grooves: Composing for the Sense of Touch"; Journal of New Music Research; 2002; pp. 1-13; vol. 31 No. 1.

Hakon Knutzen; "Haptics in the Air—Exploring Vibrotactile Feedback for Digital Musical Instruments with Open Air Controllers"; Department of Musicology University of Oslo; Oct. 2013; pp. 1-106; Oslo Notway.

Hoggan, E. et al.; "Audio or tactile feedback: which modality when?"; CHI'09 Proceedings of the SIGCHI Conference on Human Factors in Computing Systems; Apr. 9, 2009; pp. 2253-2256; New York, NY, USA.

Inwook Hwang; "Perceptual Analysis of Vibrotactile Stimuli and Its Application to Vibrotactile Rendering of Music"; Department of Computer Science and Engineering Pohang University of Science and Technology; Jun. 24, 2013; pp. 1-116; Pohang, South Korea.

Israr, A. et al.; "Tactile Brush: Drawing on Skin with a Tactile Grid Display"; CHI 2011 . Session: Touch 1: Tactile & Haptics; May 7-12, 2011; pp. 2019-2028; Vancouver, BC, Canada.

Jack Loftus; "Music For Deaf People Headphones Produce "Sound" Through Synesthesia"; GIZMODO; May 5, 2010; downloaded Dec. 17, 2015 from http://gizmodo.com/5551200/music-for-deaf-people-headphones-produce-sound-through-synesthesia.

Jack. R. et al.; "Designing Tactile Musical Devices with and for Deaf Users: a Case Study"; Proceedings of the International Conference on the Multimodal Experience of Music 2015; Mar. 23-25, 2015; pp. 001-007; University of Sheffield, UK.

Jacob Siegal; "Good Vibrations: A Musical Glove That Improves Motor Skills"; PCWorld; Jul. 17, 2012; downloaded Dec. 17, 2015 from http://www.pcworld.com.

Kalan,J; "Why have so few innovations for deaf people actually made it to market?. . . "; BBC Future: Jul. 31, 2013; downloaded Dec. 17, 2015, http://v11ww.bbc.com/future/story/20130731-helping-the--deaf-to-see-sound.

Karam, M.; "Designing and Experiencing Audio-Tactile Displays"; eTELEMED 2010; Feb. 10-16, 2010; St Maarten, Netherlands Antilles; downloaded Dec. 18, 2015 from http://www.iaria.org/conferences2010/fileseTELEMED10/AudioTactileDisplays.pdf.

Kirn, Peter; "On Apple Watch, Sound Design Translates into Haptic Feel"; cdm; Apr. 7, 2015; downloaded on Dec. 18, 2015 from http://cdm.link/2015/04/apple-watch-sound-design-translates-haptic-feel/.

Lasane, Andrew; "This Futuristic Headband Vibrates Music Through Your Skull"; mental_floss; 2015; downloaded on Dec. 17, 2015 from http://mentalfloss.com/article/68760/futuristic-headband-vibrates-music-through-your-skull.

Lauren Sarah Hayes; "Skin Music: an audio-haptic composition"; Cycling '74: Tools for Sound, Graphics, and Interactivity Project #1065; 2012; Edinburg, Scotland; downloaded Dec. 18, 2015 from https://cycling74.com.

Lee, K. "Mouth-Mounted MP3 Player lets You Hear Beats Through Your Teeth"; PCWorld; Jun. 1, 2012; downloaded Dec. 17, 2015 from http://www.techhive.com/article/256652/ mouth _ mounted _ mp3 _player _Jets _ _you_hear_ beats_Jhrough _ _your_Jeeth.html.

Malloch, Joseph; "Vibrotactile feedback for the T-Stick DMI"; wordpress.com; Feb. 6, 2008; downloaded on Dec. 18, 2015 from https://josephmalloch.word press.com/2008/02/06/vibrotactile-feedback-for-the-t-stick-d mi/.

Manresa-Yee, C.; "A Vibrotactile Interface to Motivate Movement for Children with Severe to Profound Disabilities" Proceedings of the XV International Conference on Human Computer Interaction 2014; pp. 69-72; downloaded on Dec. 18, 2015 from vbn.aau.dk.

Mario Enriquez: "A Study of Haptic Icons"; The Faculty of Graduate Studies Department of Computer Science University of British Columbia; Oct. 2002; pp. 1-88; Vancouver, British Columbia, Canada.

Marshall, M.T. et al.; "Vibrotactile Feedback in Digital Musical Instruments"; Proceedings of the 2006 Conference on New Interfaces for Musical Expression; Jan. 2006; pp. 1-4; Paris, France; downloaded Dec. 18, 2015 from http://recherche.iream.fr.

MAT 200C, Spring 2014 downloaded on Dec. 20, 2015 from http://mat200c-2014-tumblr.com/.

Matt Kramer; "Vibro Acoustic"; Jul. 22, 2009; Orlando Florida; downloaded Dec. 18, 2015 from http://mattkramersoundhealing.com/.

McGuire, J. et al.; "Vibrotactile Device for Optimizing Skin Response to Vibration"; UW-BEM Design; Oct. 26, 2011; p. 25: Madison, WI; downloaded Mar. 3, 2016 from http://bmedesign.engr.wisc.edu/projects/file/?fid=2148.

Merlo, J.L et al.; "Communicating Through the Use of Vibrotactile Displays for Dismounted and Mounted Soldiers"; 25th Army Science Conference; Nov. 2006; pp. 7; Orlando, FL.

Miga Motor Company; "DM01 Linear Shape Memory Alloy Actuator with Basic Stamp Microcontroller Kit"; Miga Motors; Mar. 1, 2007; downloaded Mar. 29, 2016 from http://www.migamotors.com/Media/DM01-BOE-App-Notes.pdf.

Morley, J.W.; "Perceived Pitch of Vibrotactile Stimuli: Effects of Vibration Amplitude, and implications for Vibration Frequency Coding." J. Physiol.; May 9, 1990; pp. 403-416; vol. 431; Great Britain.

Nanayakkara, S.C. et al.; "Enhancing Musical Experience for the Hearing-impaired using Visual and Haptic Displays"; Jan. 2012; pp. 1-42; Human-Computer Interaction; vol. 28 No.2.

Papetii, S et al.; "Multi-point vibrotactile feedback. for an expressive musical interface"; Proceedings of the International Conference on New Interfaces for Musical Expression; May 31-Jun. 3, 2015; pp. 235-240; Baton Rouge, LA, USA.

Ridden, Paul; "Review: The Woojer wearable woofer"; New Atlas; Nov. 13, 2014; downloaded on Dec. 17, 2015 from http://newatlas.com/woojer-review/34750/.

Russo, F. A. et al.; "Vibrotactile Discrimination of Musical Timbre"; J Exp Psychol Hum Percept Perform; 2012; pp. 822-826; vol. 38 No. 4.

Saba, M. P. et al.; "Hey yaa: a Haptic Warning Wearable to Support Deaf People Communication"; Collaboration and technology; 2011; pp. 215-223; vol. 6969.

Satoshi Morita; "Sonic art for intersensory listening experience"; Proceedings of the Electroacoustic Music Studies Network Conference, Electroacoustic Music Beyond Performance; Jun. 2014; pp. 1-11; Berlin, Germany.

Saul Mate-Cid; "Vibrotactile Perception of Musical Pitch"; Thesis submitted in accordance with the requirements of the University of Liverpool for the degree of Doctor of Phylosophy, Acoustic Research Unit, School of Architecture; Dec. 2013: p. 216.

(56) **References Cited**

OTHER PUBLICATIONS

Shaffer, F.; "A healthy heart is not a metronome: an integrative review of the heart's anatomy and heart rate variability" Front Psychol; Sep. 30, 2014; pp. 1-19; vol. 5; Article 1040; Switzerland.
Speaker allows deaf to feel music. Story from BBC News; Oct. 26, 2015; downloaded Dec. 17, 2015 from http://news.bbc.co.uk/go/pr/fr/-12/hi/uk _ news/england/london/4377 428.stm.
Sujata Gupta; "Music for your Skin"; Jul. 9, 2014; NOVA Next; downloaded from http://www.pbs.org/wgbh/nova/next/body/haptic-hearing/.
Teh, Y.H.; "Experiments on the Audio Frequency Response of Shape Memory Alloy Actuators"; Jan. 2005.
Terdiman, Daniel; "Beat it! New wearable device for musicians is like a sexy, wearable metronome"; VB; Mar. 31, 2015; downloaded on Dec. 17, 2015 from https://venturebeat.com.
The Soundbeam Project Ltd; "Vibroacoustic products"; 2002; Bristol UK; downloaded Dec. 18, 2015 from http://www.soundbeam.co.uk/vibroacoustics/.
Treuhaft, Teshia; "Feel the Beat: Soundbrenner creates the First Wearable Device for Musicians"; Core77; Apr. 3, 2015; downloaded on Dec. 17, 2015 from http://www.core77.com.
Van Der Linden, J et al.; "MusicJacket—Combining Motion Capture and Vibrotactile Feedback to Teach Violin Bowing"; IEEE T Instrum Meas; Jan. 2011; pp. 1-10; vol. 60; Issue: 1.
Woojer, the Wearable Audio Accessory That Lets You Feel the Sound; Wearable Tech; Nov. 31, 2013; downloaded on May 15, 2015 from http://www.wearabletechworld.com.
Yao, L. et al.: "Music-touch shoes: vibrotactile interface for hearing impaired dancers." Proceedings of the 4th International Conference on Tangible and Embedded Interaction 2010; Jan. 24-27, 2010; pp. 275-276; Cambridge, MA, USA.
Yi Yang;"Design and Control of an Integrated Haptic Interface for Touch Screen Applications"; Thesis presented in the application to obtain the Doctorate degree in Science of the University of Lille; Nov. 2013; pp. 185; France.
Yong, G. et aL; "Audio-Tactile Glove"; Proc. of the 16th Int. Conference on Digital Audio Effects (DAFx-13): Sep. 2-5, 2013; pp. 1-5; Maynooth, Ireland.
Yong, Gareth; "Sound and Music Computing Conference"; wordpress.com; Jul. 13, 2015; downloaded on Dec. 18, 2015 from https://garethyoung.org/2015/07/13/sound-and-music-computing-conference/.
Zoe Cormier; "The good vibrations helping the deaf experience music"; wired.co.uk; Nov. 30, 2014; downloaded on Dec. 17, 2015 from http://www.wired.eo.uk/article/good-vibes-for-the-deaf.
Sajan , "A portable phonatory feedback device for patients with speech disorders", (2010). LSU Master's Theses. 2837. pp. 43.
Benbasat, et al., "A framework for the automated generation of power-efficient classifiers for embedded sensor nodes", ACM, New York, NY, 219-232 (Year: 2007).
Ghasemzadeh, et al., "Ultra low-power signal processing in wearable monitoring systems: A tiered screening architecture with optimal bit resolution", ACM Trans. Embedd. Comput. Syst. 13, 1, Article 9 (Aug. 2013), 23 pages (Year: 2013).

* cited by examiner

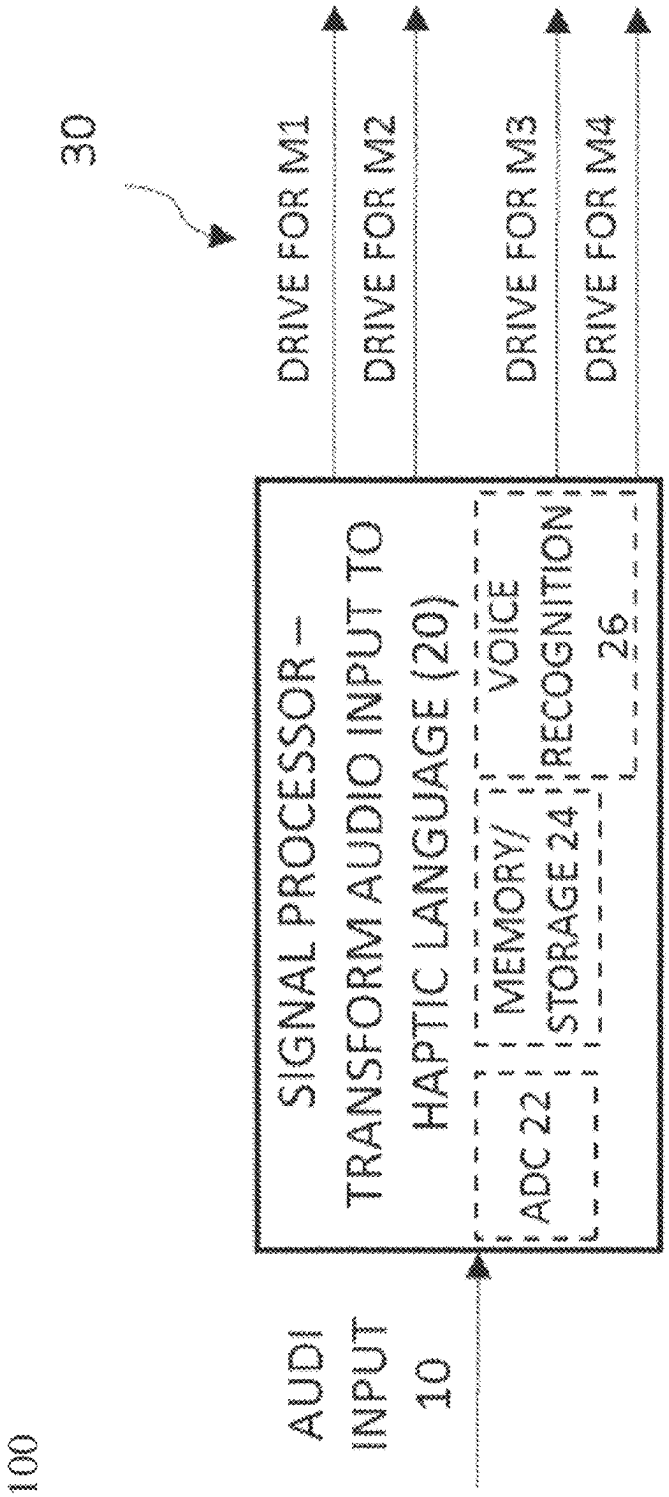
100
AUDI
INPUT
10
SIGNAL PROCESSOR–
TRANSFORM AUDIO INPUT TO
HAPTIC LANGUAGE (20)
ADC 22
MEMORY/
STORAGE 24
VOICE
RECOGNITION
26
30
DRIVE FOR M1
DRIVE FOR M2
DRIVE FOR M3
DRIVE FOR M4

FIG. 1

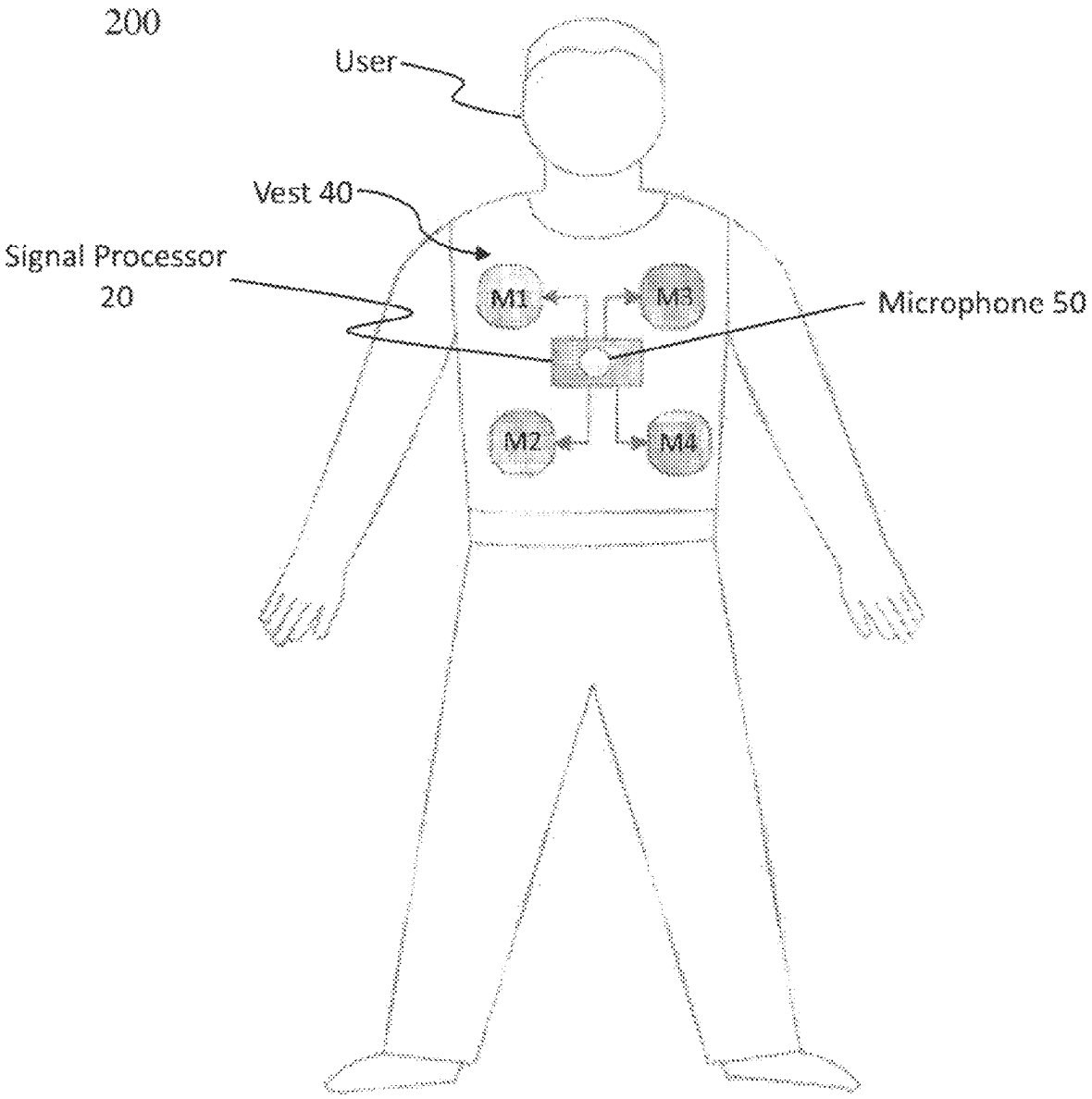
200
User
Vest 40
Signal Processor
20
M1
M3
Microphone 50
M2
M4

FIG. 2

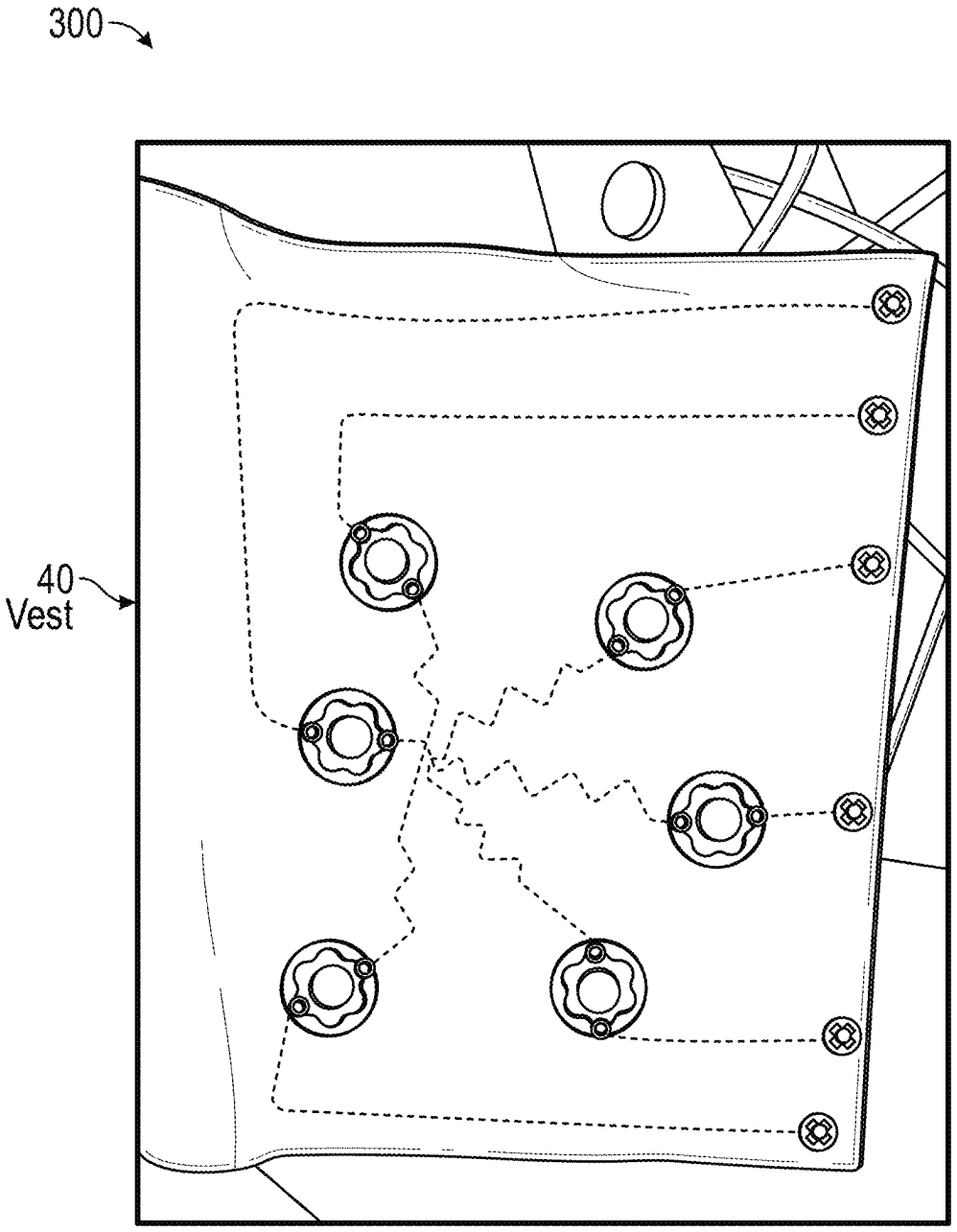

FIG. 3

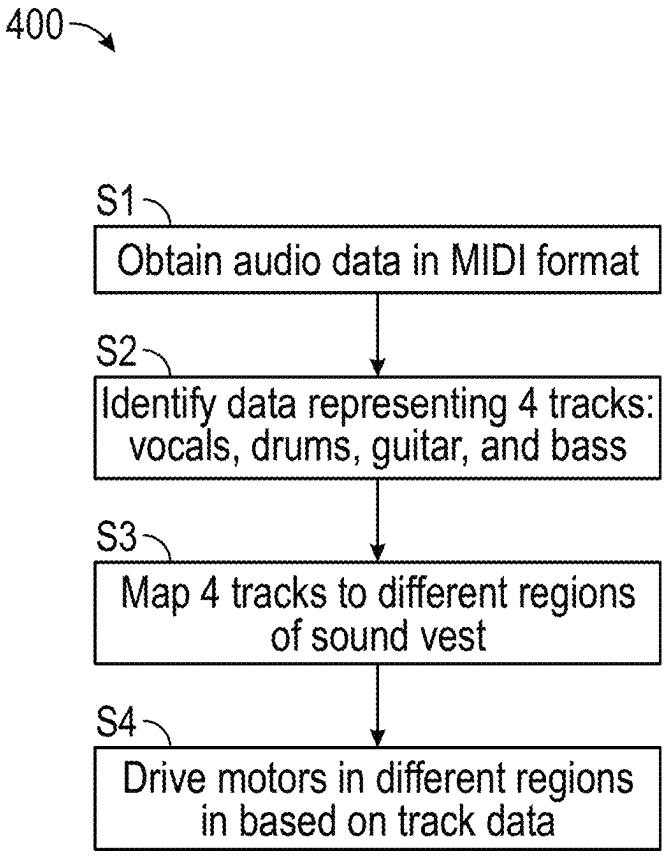
400
S1
Obtain audio data in MIDI format
S2
Identify data representing 4 tracks: vocals, drums, guitar, and bass
S3
Map 4 tracks to different regions of sound vest
S4
Drive motors in different regions in based on track data

FIG. 4

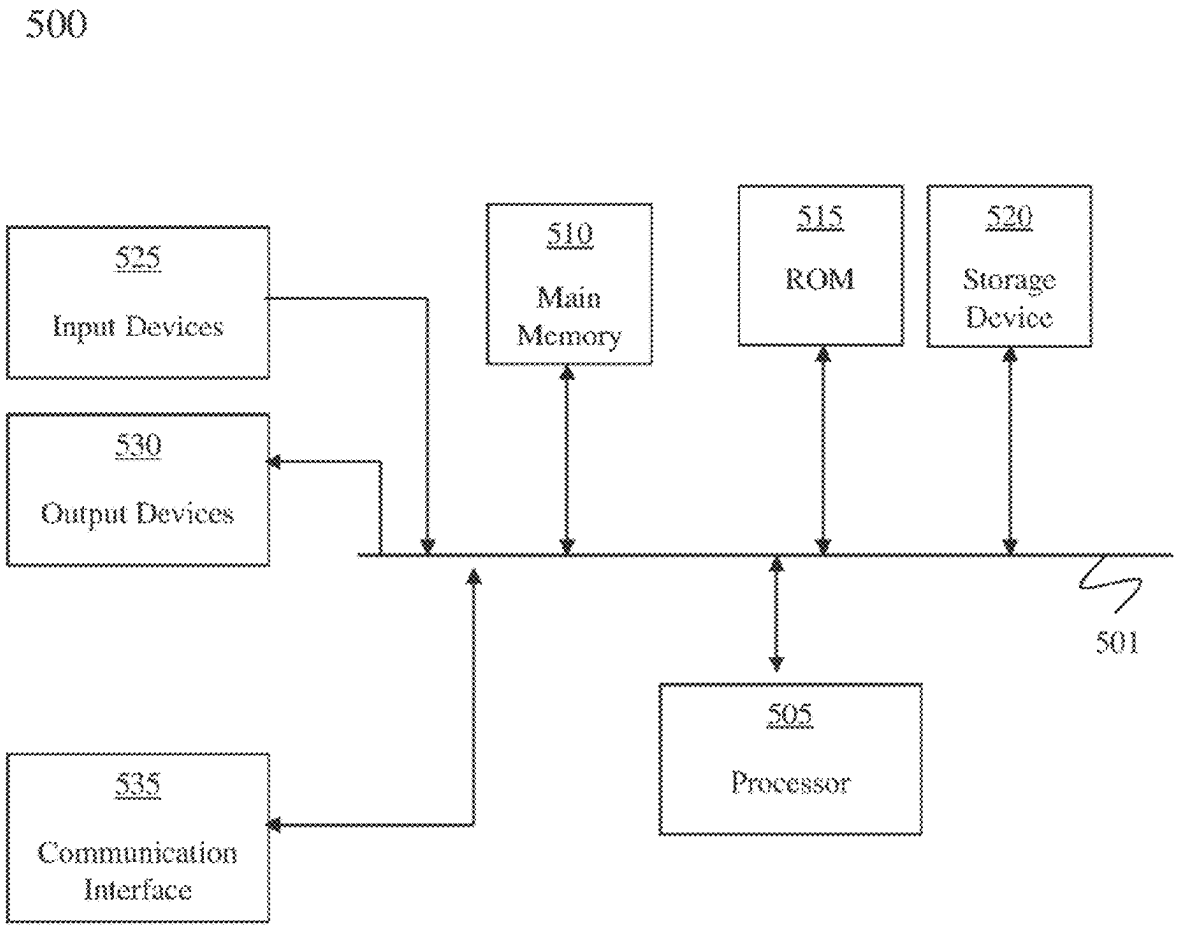
500
525
Input Devices
530
Output Devices
510
Main Memory
515
ROM
520
Storage Device
501
505
Processor
535
Communication Interface

FIG. 5

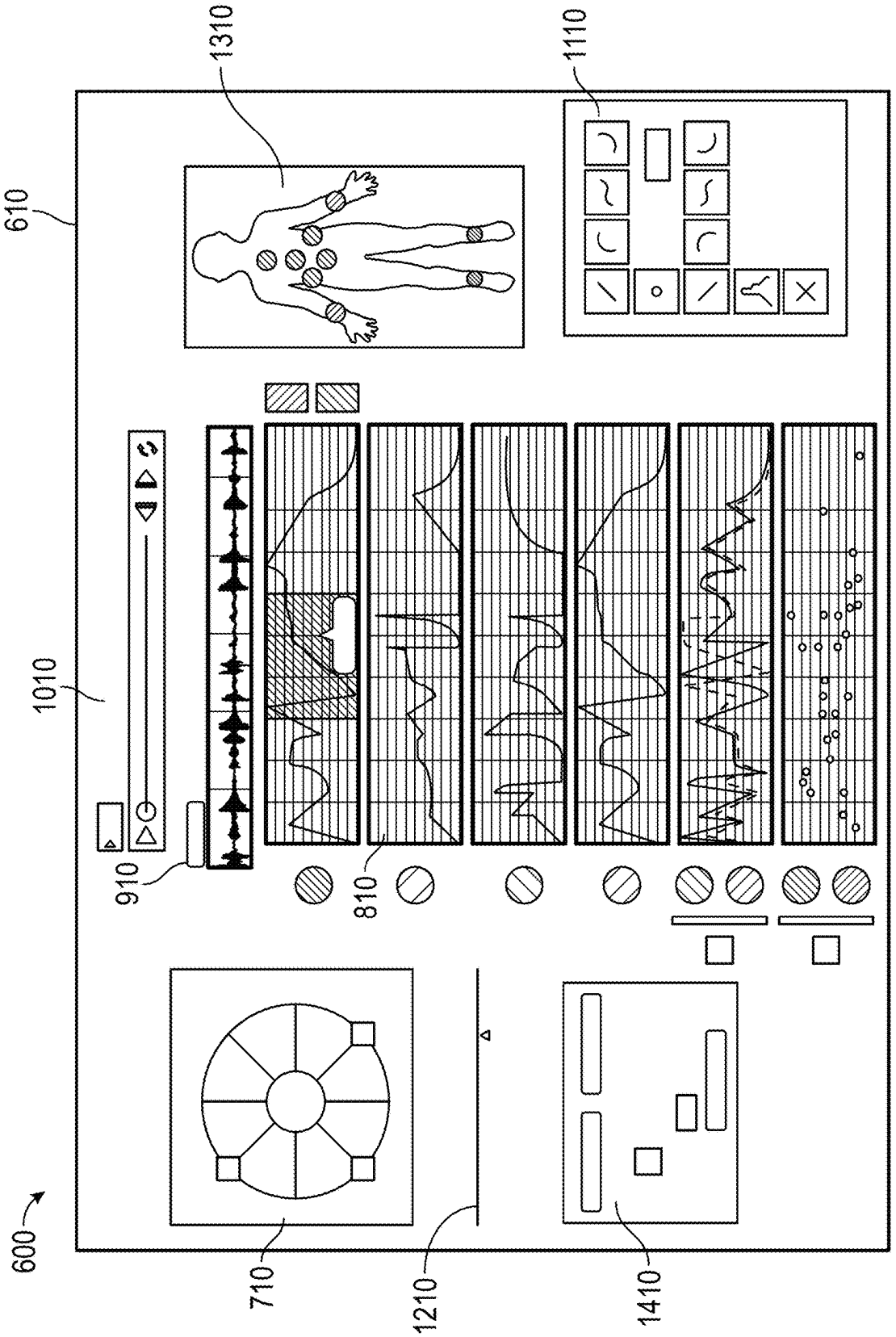

FIG. 6

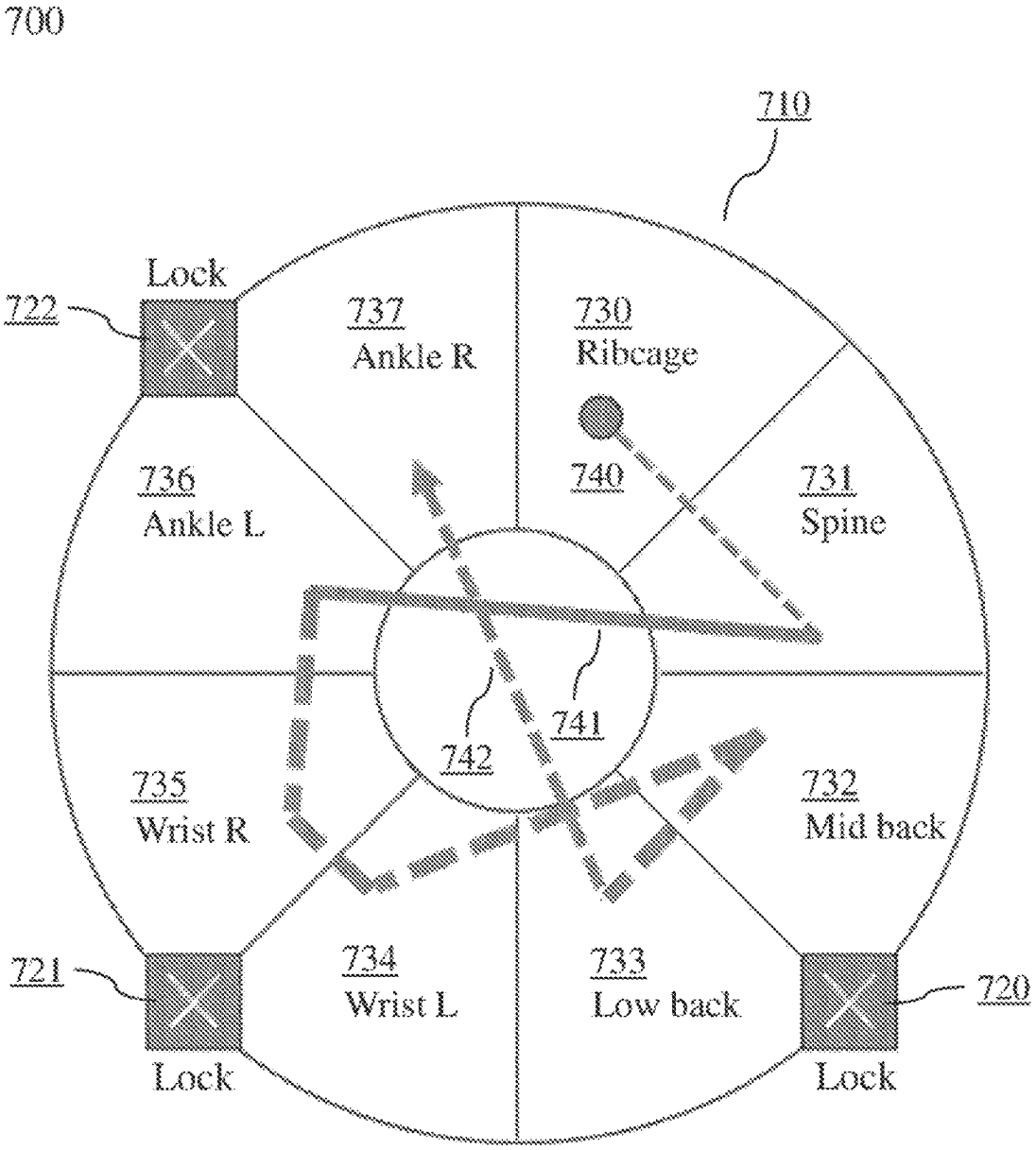
700
710
Lock
722
737
Ankle R
730
Ribcage
736
Ankle L
740
731
Spine
741
742
735
Wrist R
732
Mid back
721
734
Wrist L
733
Low back
720
Lock
Lock

FIG. 7

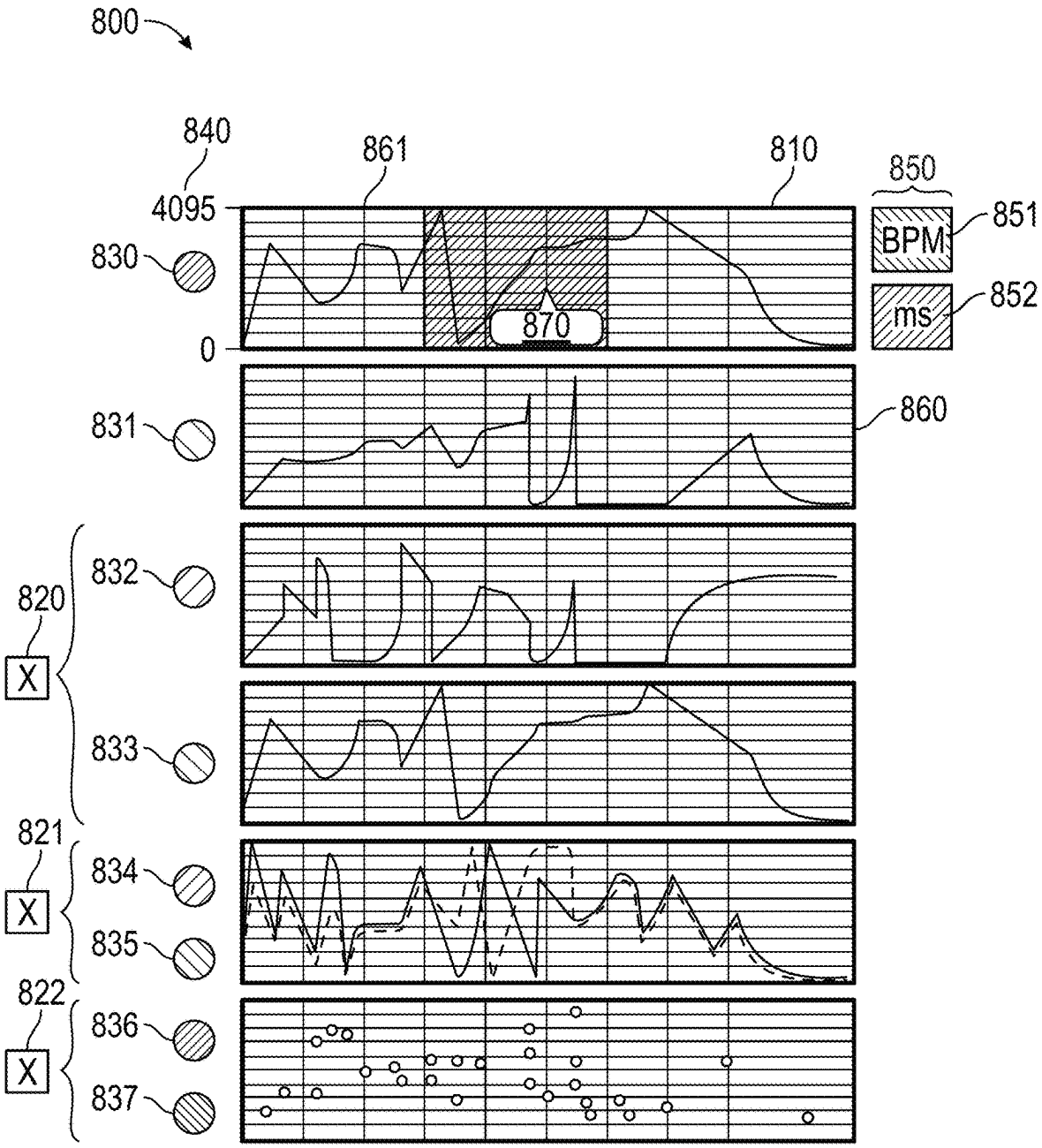
800
840
861
810
850
4095
BPM
851
830
870
ms
852
0
831
860
820
832
X
833
821
834
X
835
822
836
X
837

FIG. 8

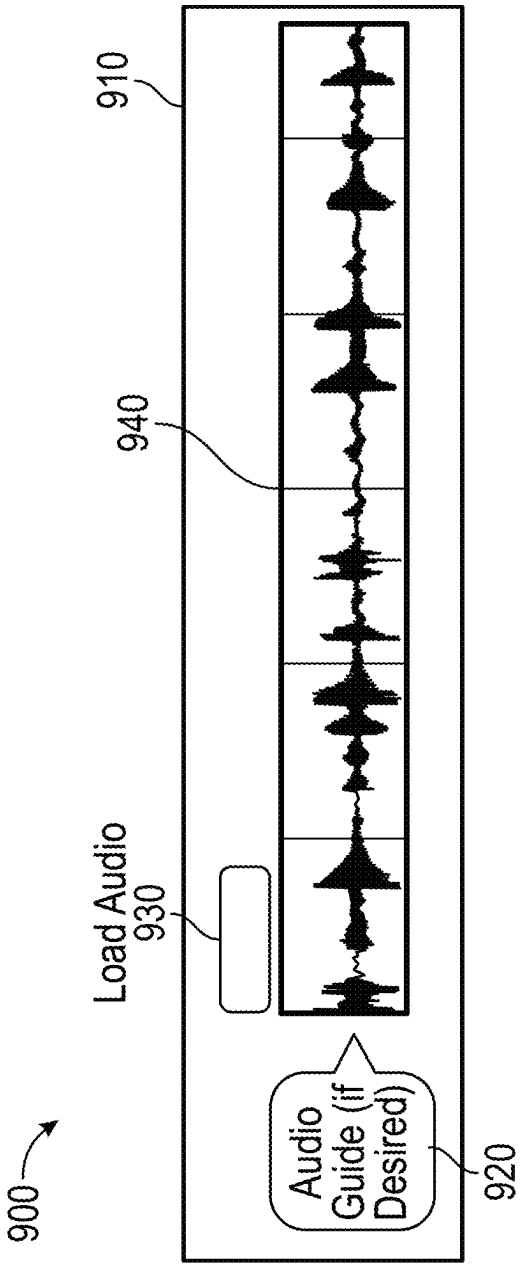

FIG. 9

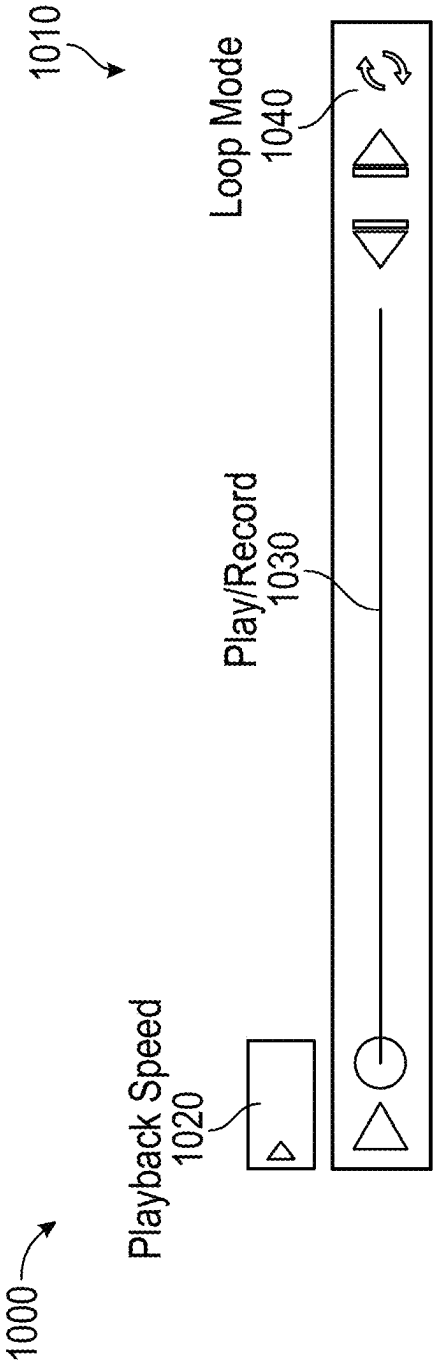
1010
Loop Mode
1040
Play/Record
1030
Playback Speed
1020
1000

FIG. 10

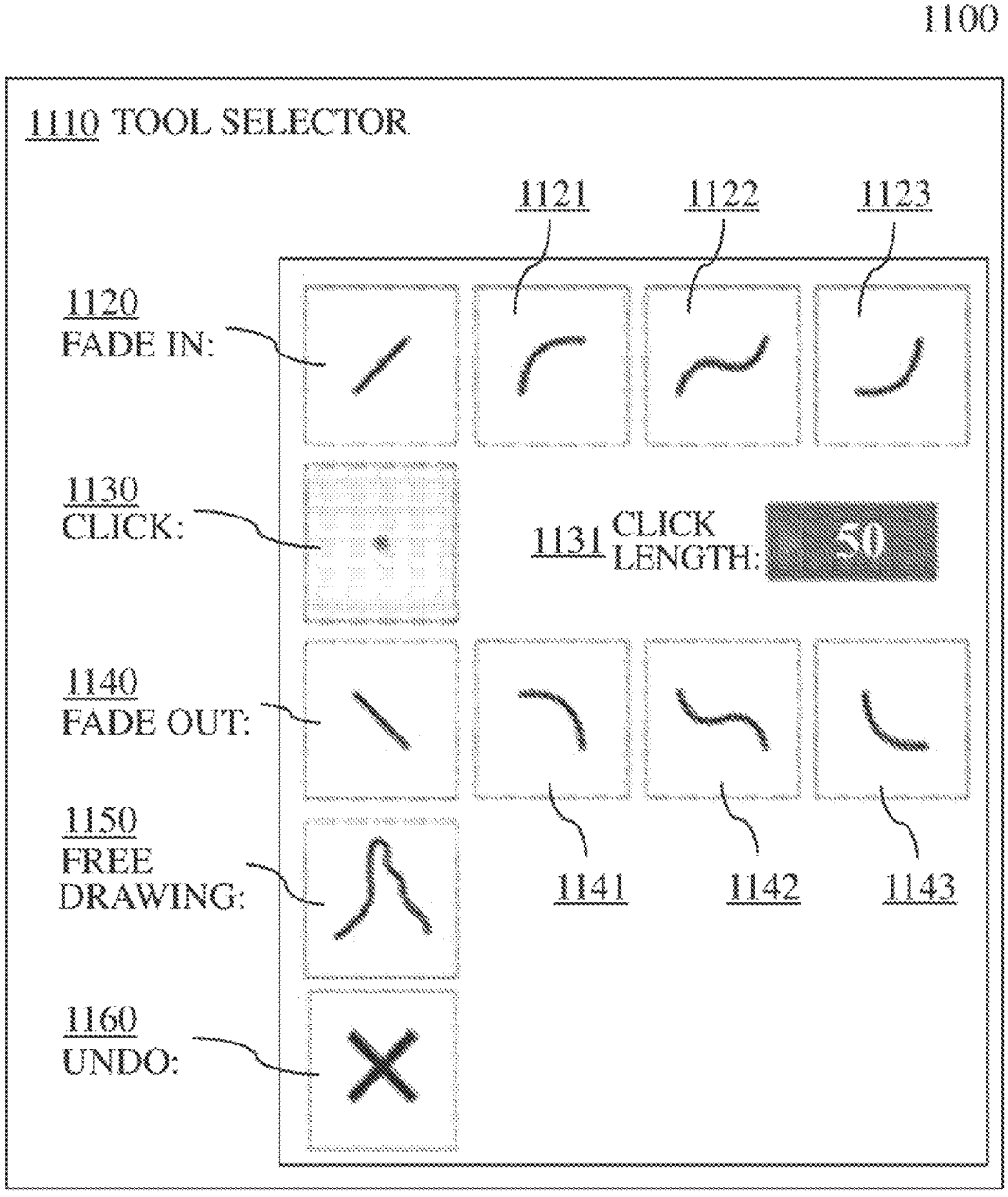
1100
1110 TOOL SELECTOR
1121
1122
1123
1120
FADE IN:
1130
CLICK:
1131 CLICK
LENGTH:
50
1140
FADE OUT:
1150
FREE
DRAWING:
1141
1142
1143
1160
UNDO:

FIG. 11

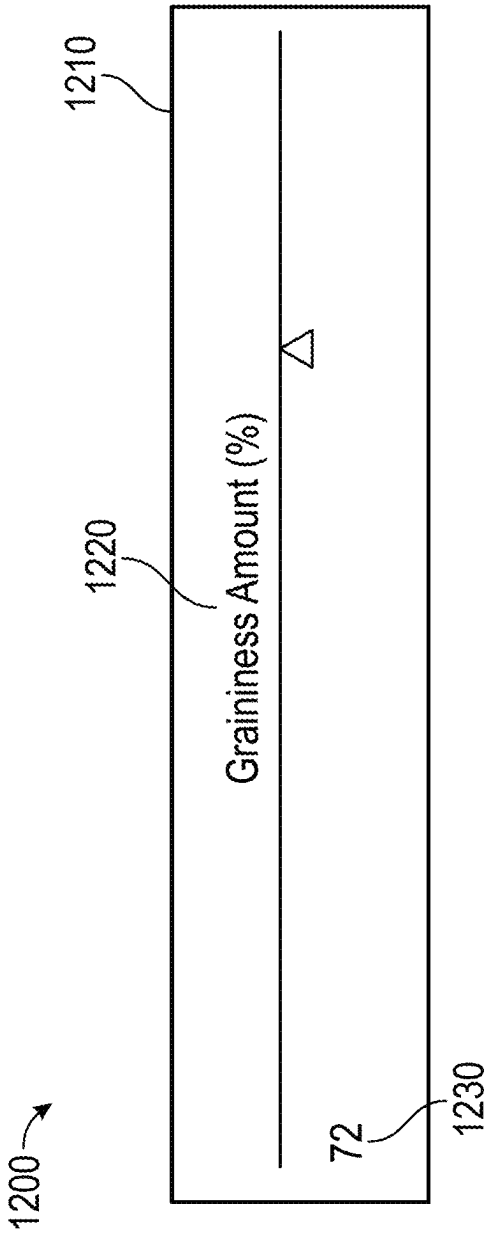

FIG. 12

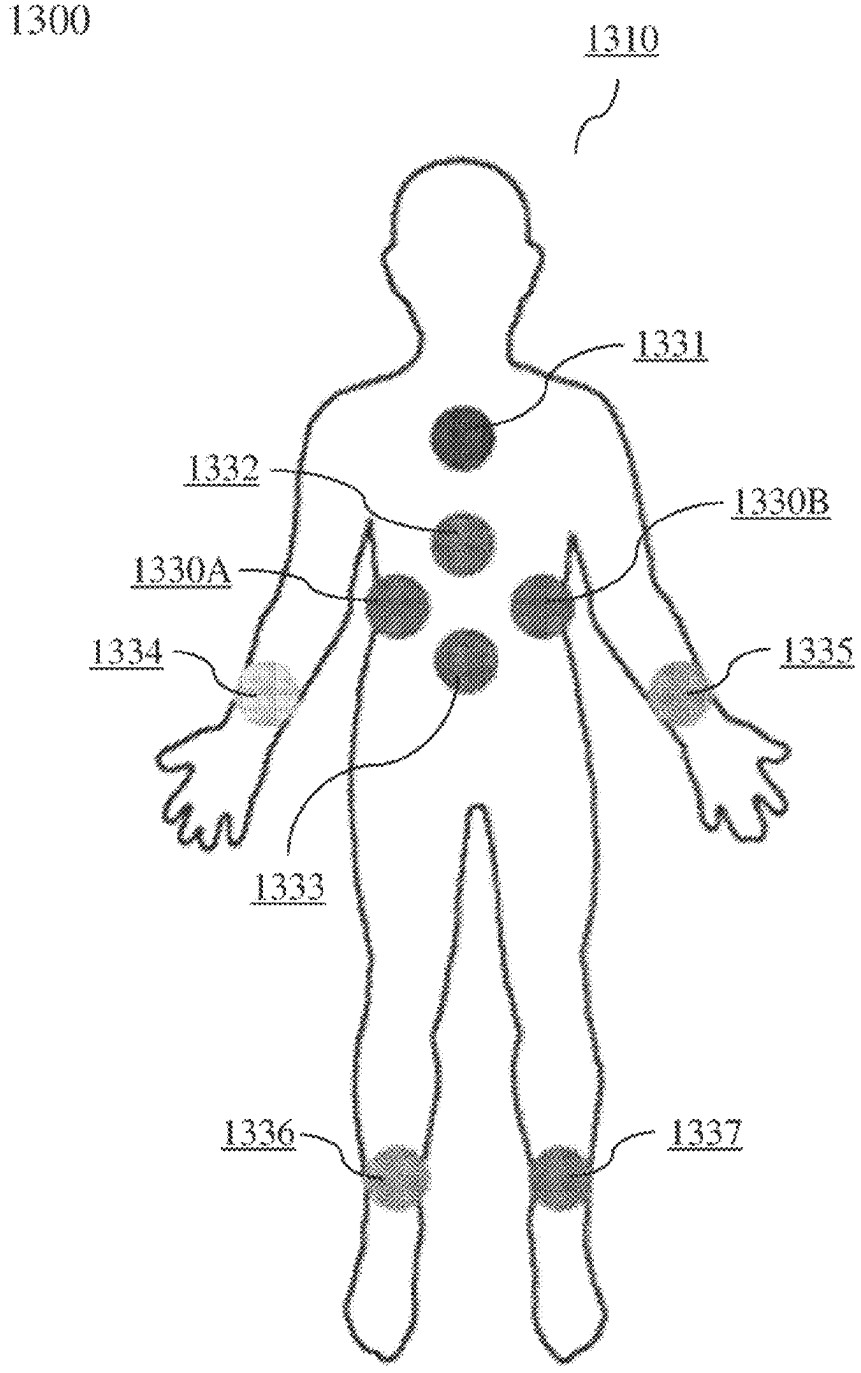

FIG. 13

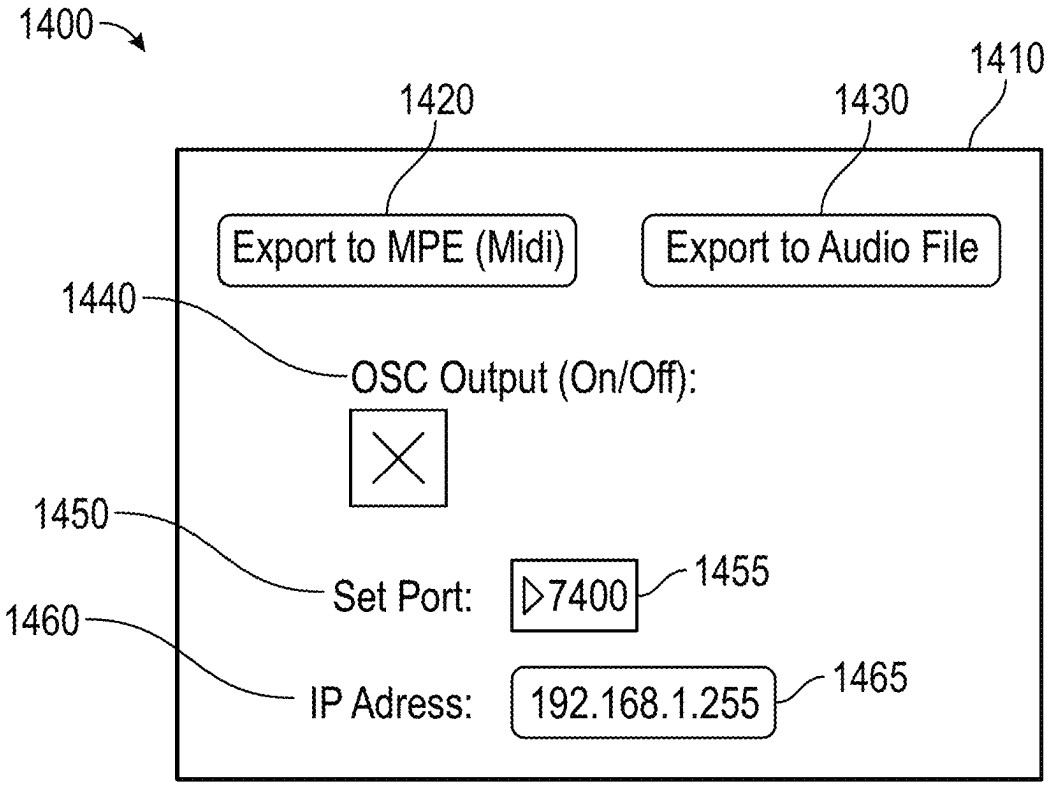
1400
1410
1420
1430
Export to MPE (Midi)
Export to Audio File
1440
OSC Output (On/Off):
1450
Set Port:
7400
1455
1460
IP Adress:
192.168.1.255
1465

FIG. 14

VIBROTACTILE CONTROL SYSTEMS AND METHODS

CROSS-REFERENCE TO RELATED APPLICATIONS

The present application is a continuation of U.S. application Ser. No. 18/190,857, filed Mar. 27, 2023, which is continuation of U.S. application Ser. No. 17/301,122, filed Mar. 25, 2021, now U.S. Pat. No. 11,625,994, which is a continuation of U.S. application Ser. No. 16/881,443, filed May 22, 2020, now U.S. Pat. No. 10,964,179, which is a continuation of U.S. application Ser. No. 15/381,610, filed Dec. 16, 2016, now abandoned, which is a continuation-in-part of U.S. application Ser. No. 14/713,908, filed May 15, 2015, issued as U.S. Pat. No. 9,679,546 on Jun. 13, 2017, which claims the benefit of priority to U.S. Provisional Application No. 61/994,753, filed May 16, 2014, each of which is incorporated by reference herein in its entirety.

TECHNICAL FIELD

The present invention relates to vibrotactile technologies, systems, and subsystems and, more specifically to systems to control vibrations to make it easy to create the sensation of vibrotactile movement on the body of a user. Also, this disclosure relates to a wearable vest designed to enable individuals such as hearing-impaired persons to experience sounds or other stimuli of various kinds, including but not limited to music, alarms, game events, and speech.

BACKGROUND

An aspect of the present disclosure is a system that uses vibratory motors to generate a haptic language for audio (or other stimuli) that is integrated into wearable technology. The inventive "sound vest" is intended as an assistive device for the hearing-impaired in certain embodiments. The disclosed system enables the creation of a family of devices that allow people, such as those with hearing impairments, to experience sounds such as music, or other inputs, to the system. The functionality of vests according to aspects of the present invention could include transforming sound/music/game input to haptic signals so that users can experience their favorite music in a unique way, and also systems that can recognize auditory cues in a user's everyday environment and convey this information to the user using haptic signals. Such pertinent auditory inputs could include a loud siren, someone calling out the user's name, etc.

It is desirable to address the limitations in the art.

BRIEF DESCRIPTION OF THE DRAWINGS

By way of example, reference will now be made to the accompanying drawings, which are not to scale.

FIG. **1** is a block diagram of an illustrative embodiment.

FIG. **2** depicts aspects of certain embodiments of the present invention integrated into a wearable vest.

FIG. **3** is a photograph of a prototype in which a network of motors is stitched into a piece of fabric according to aspects of certain embodiments.

FIG. **4** is a flowchart of an algorithm according to aspects of the present invention in certain embodiments for converting audio data or other stimuli into signals for driving a network of vibrating motors incorporated into a wearable vest.

FIG. **5** is an exemplary diagram of a computing device that may be used to implement aspects of certain embodiments of the present invention.

FIG. **6** is an exemplary diagram of a main display of the vibrotactile control system VCS in any given computing device that may be used to implement aspects of certain embodiments of the present invention.

FIG. **7** is an exemplary diagram of a movement wheel device that may be used to implement aspects of certain embodiments of the present invention.

FIG. **8** depicts an exemplary timeline chart that enables the vibrotactile creator to draw intensities over time, according to certain embodiments of the present invention.

FIG. **9** is an exemplary diagram of a wave sound representation, which is a standard audio file representation that can be utilize as an audio guide, according to certain embodiments of the present invention.

FIG. **10** depicts an exemplary play/record bar that controls the system play and record engine, according to the embodiments of the present invention.

FIG. **11** depicts an exemplary tool selector to draw the desired shape on the timeline, according to the embodiments of the present invention.

FIG. **12** depicts an exemplary Brownian grain display according to embodiments of the present invention. The graininess created, adds a Brownian random generator that increases the seed size so the values wiggle around each given number instead of ramping up straight.

FIG. **13** is an exemplary diagram of a vibrotactile body display VBD showing the points of the body being vibrated at any given time at a given intensity, according to embodiments of the present invention.

FIG. **14** depicts an exemplary file export display that will export a file to a MPE MIDI file or an eight-channel .aiff file that may be used to implement aspects of certain embodiments of the present invention.

DETAILED DESCRIPTION

Those of ordinary skill in the art will realize that the following description of the present invention is illustrative only and not in any way limiting. Other embodiments of the invention will readily suggest themselves to such skilled persons, having the benefit of this disclosure, and the general principles defined herein may be applied to other embodiments and applications without departing from the spirit and scope of the present invention. Thus, the present invention is not intended to be limited to the embodiments shown, but is to be accorded the widest scope consistent with the principles and features disclosed herein. Reference will now be made in detail to specific implementations of the present invention as illustrated in the accompanying drawings. The same reference numbers will be used throughout the drawings and the following description to refer to the same or like parts.

The data structures and code described in this detailed description are typically stored on a computer readable storage medium, which may be any device or medium that can store code and/or data for use by a computer system. This includes, but is not limited to, magnetic and optical storage devices such as disk drives, magnetic tape, CDs (compact discs) and DVDs (digital versatile discs or digital video discs), and computer instruction signals embodied in a transmission medium (with or without a carrier wave upon which the signals are modulated). For example, the transmission medium may include a communications network, such as the Internet.

The present disclosure in certain embodiments relates to a system, or "sound vest", that uses vibratory motors to generate a haptic language for music or other sound, or other stimuli, that is integrated into wearable technology. A technical challenge to creating such a system is to design a system that decomposes auditory or other input into control signals that can be streamed out to a network of motors. The present inventors have designed a preliminary system that in certain embodiment performs entry-level signal processing techniques on the incoming sound or other stimuli in order to determine the spectral profile of the input. The motors are then powered based on the magnitude of the spectral power.

A preliminary design of the system in certain embodiments enables the use of up to 64 motors to represent the incoming audio or other stimuli. A revised design in certain embodiments utilizes 64 motors on each of the front and back sides of the vest, for a total of 128 motors. For example, each of **M1**, **M2**, **M3**, and **M4** in FIG. **2** could represent up to 16 separate motors, for a total of 64 motors on the front side of the vest **40**. A similar network of 64 motors could be deployed on the back side of the vest. The user's entire torso may be utilized to create a tono-topic map of the torso that is, vibratory motors on the left (L) side of the vest may be mapped to the left speaker, vibratory motors on the right (R) side of the vest may be mapped to the right speaker, vibratory motors on the bottom of the vest may be mapped to low frequencies, and vibratory motors on the top of the vest may be mapped to high frequencies.

FIG. **1** depicts the basic system in certain embodiments, including signal processor (**20**) that receives audio input (**10**) (e.g., from a microphone (**50**, see FIG. **2**) or audio jack) and transforms the input audio signal into a haptic language for driving (**30**) a network of motors denoted **M1**, **M2**, **M3**, and **M4**. The signal processor may also include an analog-to-digital converter (ADC) (**22**) for digitizing real-time audio signals provided in analog form, memory or storage (**24**) for storing audio data, executable instructions, and the like; and a voice recognition module (**26**).

As shown in FIG. **2**, the motors **M1** through **M4** may be integrated into a wearable vest (**40**) such that **M1** and **M2** are on the right side of the user's torso, and **M3** and **M4** are on the left side of the user's torso. Moreover, motors **M1** and **M3** may vibrate to represent the higher frequency components of the audio input, whereas motors **M2** and **M4** may vibrate to represent the lower frequency components. It should be understood that in a commercial implementation, there would likely be many more than four motors in certain embodiments.

As shown in FIG. **3**, using conductive thread and relatively low-cost vibratory motors, an initial prototype was made by stitching thread into fabric, as illustrated.

Applicants are aware of information in the public domain relating to wearable technology with haptic feedback. Copies of this information are being submitted in conjunction with this application in Information Disclosure Statements (IDS). Some of the known prior art references translate sound to vibration, but the present disclosure is different in certain embodiments in that it goes beyond a simple sensory substitution. The brain is an amazingly "plastic" organ, and we will take advantage of its plasticity by giving the hearing impaired the opportunity to experience music through a haptic "language." This difference lies in the real-time spectral analysis performed as the music streams into the micro-controller at the heart of the sound vest in certain embodiments—the audio streams in and is broken down to a representation of its basic frequency components. Then, each frequency domain is sent to a different part of the body (i.e., if the user is listening to Alvin and the Chipmunks, he will feel a lot of vibration up by his collarbones, and not much down low; listen to Barry White, and it will be the other way around due to the dominance of Mr. White's low frequency components). The inventive system in certain embodiments can also represent stereo by streaming to the left side of the body for the left speaker and right speaker to the right side.

FURTHER DEVELOPMENTS

During the course of further developing the system described above, we have discovered that the process of creating musical sensation though tactile stimuli can be improved in several ways in certain embodiments:

1. The audio signals or other stimuli can be improved by converting them into the MIDI (i.e., Musical Instrument Digital Interface) data format in certain embodiments, and then reducing the data to a small defined number of tracks, e.g., four (4) tracks representing drums, bass, guitars, and vocal. Other selections could be used as well, depending on the type of music. (Those skilled in the art understand that MIDI is a technical standard that enables a wide variety of electronic musical instruments, computers and other related devices to connect and communicate with one another. A single MIDI link can carry up to sixteen channels of information, each of which can be routed to a separate device.)
2. Instead of mapping the audio signals to the motors as described above (i.e., mapping higher frequencies to the top of the vest and mapping the lower frequencies to the bottom of the vest), it may be advantageous in certain embodiments to map each of the 4 tracks to different parts of the vest. For example, the signals corresponding to vocals can be directed to the mid-section while the drums, bass, and guitar signals are directed to respective regions surrounding the mid-section. This mapping has been found to create less cross-over and less "muddiness" to the vibrations created by the motors.
3. If the system is unable to convert live audio to MIDI data in real time, it can be advantageous in certain embodiments to provide a mode in which the music data is first downloaded and then played back through the vest. In this way, the user can experience the music, albeit not in a real-time, "live" setting.

As shown in FIG. **4**, an algorithm for converting audio data or other stimuli into signals for driving a network of vibrating motors incorporated into a wearable vest comprises the following steps in certain embodiments: First, in step S1, audio data in MIDI format is obtained. The data can either be downloaded to the system from a third party provider, or created using recorded audio and an audio production software tool. In step S2, the MIDI data is organized into 4 tracks representing vocals, drums, guitars, and bass. In step S3, the 4 tracks are mapped to different regions of the sound vest; and in step S4 the respective tracks of data are used to drive the motors in the different regions.

The system in certain embodiments may be enhanced by providing wireless links between the signal processor and the motors. In addition, a voice recognition module may be incorporated to enable the system to recognize specific spoken words for selective playback through the motors. For example, the user's name may be specifically recognized and used to signal the user through the motors.

FIG. **5** is an exemplary diagram of a computing device **500** that may be used to implement aspects of certain embodiments of the present invention. Computing device **500** may include a bus **501**, one or more processors **505**, a main memory **510**, a read-only memory (ROM) **515**, a storage device **520**, one or more input devices **525**, one or more output devices **530** (including vibrotactile actuators such as motors, as described herein), and a communication interface **535**. Bus **501** may include one or more conductors that permit communication among the components of computing device **500**. Processor **505** may include any type of conventional processor, microprocessor, or processing logic that interprets and executes instructions. Main memory **510** may include a random-access memory (RAM) or another type of dynamic storage device that stores information and instructions for execution by processor **505**. ROM **515** may include a conventional ROM device or another type of static storage device that stores static information and instructions for use by processor **505**. Storage device **520** may include a magnetic and/or optical recording medium and its corresponding drive. Input device(s) **525** may include one or more conventional mechanisms that permit a user to input information to computing device **500**, such as a keyboard, a mouse, a pen, a stylus, handwriting recognition, voice recognition, biometric mechanisms, and the like. Output device(s) **130** may include one or more conventional mechanisms that output information to the user, including a display, a projector, an A/V receiver, a printer, a speaker, and the like. Communication interface **535** may include any transceiver-like mechanism that enables computing device/server **500** to communicate with other devices and/or systems. Computing device **500** may perform operations based on software instructions that may be read into memory **110** from another computer-readable medium, such as data storage device **520**, or from another device via communication interface **535**. The software instructions contained in memory **510** cause processor **505** to perform processes that will be described later. Alternatively, hard-wired circuitry may be used in place of or in combination with software instructions to implement processes consistent with the present invention. Thus, various implementations are not limited to any specific combination of hardware circuitry and software.

In certain embodiments, memory **510** may include without limitation high-speed random access memory, such as DRAM, SRAM, DDR RAM or other random access solid state memory devices; and may include without limitation non-volatile memory, such as one or more magnetic disk storage devices, optical disk storage devices, flash memory devices, or other non-volatile solid state storage devices. Memory **510** may optionally include one or more storage devices remotely located from the processor(s) **505**. Memory **510**, or one or more of the storage devices (e.g., one or more non-volatile storage devices) in memory **510**, may include a computer readable storage medium. In certain embodiments, memory **510** or the computer readable storage medium of memory **510** may store one or more of the following programs, modules and data structures: an operating system that includes procedures for handling various basic system services and for performing hardware dependent tasks; a network communication module that is used for connecting computing device **510** to other computers via the one or more communication network interfaces and one or more communication networks, such as the Internet, other wide area networks, local area networks, metropolitan area networks, and so on; a client application that may permit a user to interact with computing device **500**.

Certain text and/or figures in this specification may refer to or describe flow charts illustrating methods and systems. It will be understood that each block of these flow charts, and combinations of blocks in these flow charts, may be implemented by computer program instructions. These computer program instructions may be loaded onto a computer or other programmable apparatus to produce a machine, such that the instructions that execute on the computer or other programmable apparatus create structures for implementing the functions specified in the flow chart block or blocks. These computer program instructions may also be stored in computer-readable memory that can direct a computer or other programmable apparatus to function in a particular manner, such that the instructions stored in computer-readable memory produce an article of manufacture including instruction structures that implement the function specified in the flow chart block or blocks. The computer program instructions may also be loaded onto a computer or other programmable apparatus to cause a series of operational steps to be performed on the computer or other programmable apparatus to produce a computer-implemented process such that the instructions that execute on the computer or other programmable apparatus provide steps for implementing the functions specified in the flow chart block or blocks.

Accordingly, blocks of the flow charts support combinations of structures for performing the specified functions and combinations of steps for performing the specified functions. It will also be understood that each block of the flow charts, and combinations of blocks in the flow charts, can be implemented by special purpose hardware-based computer systems that perform the specified functions or steps, or combinations of special purpose hardware and computer instructions.

For example, any number of computer programming languages, such as C, C++, C # (CSharp), Perl, Ada, Python, Pascal, SmallTalk, FORTRAN, assembly language, and the like, may be used to implement aspects of the present invention. Further, various programming approaches such as procedural, object-oriented or artificial intelligence techniques may be employed, depending on the requirements of each particular implementation. Compiler programs and/or virtual machine programs executed by computer systems generally translate higher level programming languages to generate sets of machine instructions that may be executed by one or more processors to perform a programmed function or set of functions.

In the descriptions set forth herein, certain embodiments are described in terms of particular data structures, preferred and optional enforcements, preferred control flows, and examples. Other and further application of the described methods, as would be understood after review of this application by those with ordinary skill in the art, are within the scope of the invention. The term "machine-readable medium" should be understood to include any structure that participates in providing data that may be read by an element of a computer system. Such a medium may take many forms, including but not limited to, non-volatile media, volatile media, and transmission media. Non-volatile media include, for example, optical or magnetic disks and other persistent memory such as devices based on flash memory (such as solid-state drives, or SSDs). Volatile media include dynamic random access memory (DRAM) and/or static random access memory (SRAM). Transmission media include cables, wires, and fibers, including the wires that comprise a system bus coupled to a processor. Common forms of machine-readable media include, for example and without

limitation, a floppy disk, a flexible disk, a hard disk, a solid-state drive, a magnetic tape, any other magnetic medium, a CD-ROM, a DVD, or any other optical medium.

FIG. **6** is a grayscale version of an exemplary embodiment of a main view display **600**, also called the vibrotactile control system VCS **610** herein. In the embodiment of FIG. **6**, each section of the system represents different components of the main display that may serve to craft the vibrations that are coupled to a sound file. In certain embodiments of this invention, the sound file could comprise prerecorded sound or a live system. In both cases, the intention would be to replicate the vibrations of live instruments or sounds being play in real time.

The main view display **610** may facilitate understanding and interaction with the system in certain embodiments, and may be used to create an intuitive experience with little or no stiff learning curve, allowing the user to easily adopt the technology.

In the example of the main view display **610** shown in FIG. **6**, starting from the top left corner, the embodiment of the present invention may include a movement wheel **710**, a Brownian grain display **1210**, and a file export display **1410**. In the center, from top to bottom it may also include a play/record bar **1010**, a wave sound representation **910**, which may be a standard audio file representation, and a timeline chart **810**. Finally, on the left portion of the main view display **610**, an embodiment may show a vibrotactile body display **1310** and a tool selector **1110**.

Embodiments of the present invention may be used to implement aspects that will create a surround body experience, in which the vibrotactile creator can craft and control vibrations to any part of the body at any given point in time.

FIG. **7** is a grayscale version of an exemplary embodiment of the movement wheel **700**. In the embodiment of the present invention, the movement wheel **710** can be used to easily create or craft the sensation of vibrotactile movement on the body of a user, and it allows a vibrotactile creator to control movement and intensity.

Each section of the embodiment of FIG. **7** shows a different part of the body, such as the ribcage **730** section of the body, the spine **731**, the mid back **732**, the low back of the body **733**, the left wrist **734**, the right wrist **735**, the left ankle **736**, the right ankle **737** of a human body. Each module of the moment wheel **710** could be color coded, labeled or add a patter that would be associate to a specific part of the body described within the embodiment of the moment wheel **710**.

In certain embodiments, the vibrotactile creator may simultaneously use the movement wheel **710** and the Brownian grain display **1210** to draw a path **740** that represents the movement from one part of the body to the other controlling the intensity of the line as it is drawn and the graininess of it. The thickness of the line is directly related to the intensity of the vibration. The thinner the line, the weaker the vibration and the thicker the line the stronger the vibration. Each line has the possibility of been drawn with different intensities as the user moves throughout the movement wheel **710**. The movement varies with intensity in time.

For example, the user may start to draw the path **740** in the mid back **732** and move down to the low back **733**. As the path moves down the vibrations could increase or decrease in intensity. In certain embodiments of this invention, the path **740** drawn by the vibrotactile creator may depict smooth lines **741** or dotted lines **742**. Dotted lines **742** will indicate that in that specific vibration a degree of graininess is applied. Smooth lines **741** will indicate that in that specific part of the path **740** graininess was not applied.

In certain embodiments, the vibrotactile wheel **710** and the Brownian grain display **1210** may be visualized as a dynamic display that has to be operated at the same time to craft the vibrations as the sound is being played. Their operation could depend, for example, on the operation of a mouse or a touch screen to draw the path **740** of the movement and the intensity of the lines, and an expression pedal to select the level of graininess for the purpose of making the experience more dynamic.

In certain embodiments of the movement wheel **710**, the user may lock adjacent positions of the body, toggling a switch with a feature called "lock group" herein. For example, the left ankle **736** may be locked with the right ankle **737** using the lock group option **722**. Similarly, the left wrist **734** may be locked with the right wrist **735** with lock group option **721**, and the low back position **733** may be locked with the mid back position **732** with lock group **720**. A lock group may be used to automatically replicate the vibration created for one area into whichever area is locked with it. When a lock group feature is on, in certain embodiments one vibration triggers both parts of the body for symmetry.

FIG. **8** is a grayscale version of an exemplary embodiment of the timeline chart **800**, which enables the vibrotactile creator to draw intensities over time for an specific part of the body.

In the embodiment of FIG. **8**, the intensity values **840** range from 0 to 4095. These ranges of values are represented in the timeline **810** by horizontal lines **860** parallel to the x axis, and they show the intensity of the vibration. Time is measured along the x axis in intervals marked by vertical lines parallel to the y axis; these intervals are called tempo **861**, and they represent the time that it is taking the vibration to move across intensities. The tempo **861** helps to divide the wave sound representation **910** into segments, in order to have a better visualization of the waveform at any given time. The time **850** in the timeline chart **810** can be adjusted in milliseconds **852** or beats per minute BPM **851**. This visual aid may help to craft the vibration for the particular part of the piece that is being played.

In the embodiment of FIG. **8**, the timeline **810** may feature the same body part names and/or colors as the movement wheel **710**, but arranged in channels. In certain embodiments, channel **830** corresponds to the ribcage, channel **831** is the spine, channel **832** corresponds to the mid back, channel **833** to the low back, channel **834** and **835** correspond to the left and right wrist respectively, and channels **836** and **837** correspond to the left and right ankles.

Because the embodiment of the timeline **810** may feature the individual body parts, also seen in the embodiment of the movement wheel **710**, the vibrotactile creator or user can concentrate in crafting the vibrations one part of the body at a time. Each body part has its own channel (**830**, **831**, **832**, **833**, **834**, **835**, **836** and **837**) in certain embodiments, which means that the user can mute all but one channel and begin the crafting process for an individual body part, or, if using the lock group feature (**820**, **821** and **822**), for a set of body parts. These lock group features are also seen in the embodiment of the movement wheel **710**.

The gray area shown in the ribcage timeline chart **830** is an exemplary depiction of an area called a loop point **870**. This area may be selected to be repeated for purpose of editing and/or for playing back an audio file. The loop point **870** selection within a channel may be a particular part of the

timeline or the entire timeline, the vibrotactile creator **620** can change the size of the loop point.

The waveforms or "vibrotactile forms" shown in the embodiment of FIG. **8** represent vibrations. In certain embodiments of the present invention, these vibrotactile waveforms allow the user of the sound vest system to feel different type of vibrations. For example, dots may feel different from line-based waveforms.

FIG. **8** depicts a visual example of the vibration that may occur in each channel. This example shows the vibrotactile forms for the vibrations on the ribcage **830**, the spine **831**, the mid back **832**, the low back **833**, the left wrist **834**, the right wrist **835**, left ankle **836** and the right ankle **837**.

FIG. **9** is a grey scale version of a wave sound representation of a standard audio file **900**. In the embodiment of FIG. **9**, the wave sound representation **910** may be loaded (see LOAD AUDIO button **930**) into the VCS **610** so it can be visualized in the display of the audio guide **920** to be used when crafting vibrations. The lines that divide the audio guide represent the tempo **940**. The tempo lines **940** of the standard audio file align with the tempo lines **861** of the time line as shown in FIG. **8**.

A grey scale representation of a bar **1000**, shown in the embodiment of FIG. **10**, controls the play and record engine of the system. The playback speed **1020** can be adjusted in the corresponding box. The negative values play the file backwards, and the positive values play the file forwards **1030**. The loop mode **1040** may be set to: (1) off (i.e., circular, goes to the end and starts again); or (2) palindrome (i.e., goes to the end and plays backwards to the beginning).

For example, when a sound file is played in the play and record engine of the exemplary system **1010** shown in FIG. **10**, the sound may be visualized as a wave sound representation **900**. This visual match may help the vibrotactile creator **620** to craft the vibrations for the specific part of the piece that is being played, visualizing the vibrations in the channels of the timeline **810**.

In the embodiment of the tool selector **1100** shown in FIG. **11**, the user may select a tool from the tool selector **1110** to draw the desired shape on the timeline **810**. The tool selector **1110** works like a photo editor or an audio distorted station, because it lets the user select what kind of line it would be used to craft the waveforms in the timeline **810**.

The tool selector depicted in FIG. **11** may be used to implement embodiments of the present invention. For example, when the user works with the linear "fade in" part of the tool selector **1110**, he or she may draw a part of the waveform that would be a straight line **1120**. When **1121** is chosen, it depicts a movement that goes fast at first and then slows down at the end; **1123** would be the opposite to **1121**. The s-curve **1122** shows a combination of the movements described in **1121** and **1123**, where the waveform moves fast initially, then stabilizes in a plateau, then ends with a fast movement towards the maximum vibration. This type of moment may emulate what is called in music a psychoacoustic emotional effect. The user may feel a sudden burst of vibration followed by a plateau that will have him/her in suspense and then another burst of vibration. It may have an emotional effect.

In vibrotactile language according to certain embodiments, **1130** is called a click herein. In the display **1110**, it is the equivalent of a staccato note in music. The click **1130** may be set **1131** from 10 to 50 milliseconds. After 50 milliseconds it turns into a small line because the vibration achieved is not a click per se but a short buzz. The click cannot last more than 50 milliseconds, its maximum value, otherwise it is received as a line, not a dot. But also, it cannot be shorter than 10 milliseconds because it may be hard to perceive due to the spinning limitation of the eccentric rotating mass vibration motors (ERM) used as vibrotacile actuators in certain embodiments. The ideal click using this technology may be between 30 and 50 milliseconds, based on experimental results.

In the embodiment of FIG. **11**, the fade-out display that comprises **1140**, **1141**, **1142** and **1143** works opposite to the fade in display (**1120**, **1121**, **1122** and **1123**). Instead of fading in a vibration, it fades out.

The free-drawing display may allow the user to draw an uneven line. For example, if the main display timeline **810** is in a touch screen a user could create any line shape and it would create endless possibilities for the waveforms. Finally, the undo button **1160** is provided to remove any part of the wave form in the timeline **800** that the user does not want to use anymore.

When the tool selector **1100** fade-in and fade-out waveforms are visualized in the main display **600**, the user can modify them by changing the time or the amplitude. This gives the craft of the vibration endless possibilities.

In the embodiment of FIG. **12**, the graininess amount **1210** creates a vibration that is not smooth. It is a type of noise in the vibration, that would distort a smooth vibration, creating crackling. The graininess amount **1220** can be set from 0 to 100% as shown in exemplary embodiment of FIG. **12**. The graininess may add a Brownian random generator effect **1200** that increases the seed size **1220** so the values "wiggle" around each given number instead of ramping up straight. The effect may feel like a vibrotactile distorted guitar; it may add expressiveness and interest to an otherwise clean signal.

The visual expression of graininess is given in the embodiment of the movement wheel **710**. When graininess is applied the otherwise smooth lines **741** in the drawn path **740** will acquire spaces, like dotted lines **742** that will represent unevenness.

FIG. **13** presents an embodiment of the vibrotactile body display VBD **1310**. This embodiment shows the points of the body being vibrated at any given time at a given intensity. The gray scale points (**1330**A, **1330**B, **1331**, **1332**, **1333**, **1334**, **1335**, **1336**, **1337**) may correspond to the gray scale colors on the movement wheel **710** and the grey scale colors in the timeline **610**, for cohesiveness. The stronger a color is seen on the display, the stronger the vibration is on that point.

After the vibrotactile creator or user is finished crafting the experience, in certain embodiments he or she can then export the file to a MPE (multidimensional polyphonic expression) MIDI file **1410**, as shown in FIG. **14**. In the embodiment of FIG. **14**, the user may export to a MPE (midi) file **1420**, allowing the vibrotactile creator to control the video notes, this would typically not be possible without the MPE (midi) file. The user may also export into an eight channel .aiff audio file **1430**. The user may turn on Open Sound Control OSC **1440** on and off to send the data in real time to other applications (e.g., audio, video and lighting software for example). The set port **1450** can be customized, traditionally to 7400-7500 (**1455**) for sending out the vibrations to an access point so it can be transmitted to the wearer's body wirelessly and finally the user can type in (see 1060) the Internet Protocol ("IP") address **1465** needed for OSC output in the network, Internet, Ethernet, etc.

Certain embodiments implement methods and systems for creating and/or applying vibrations to a user's body, including simultaneous stimulation of multiple parts of a user's body during gaming sessions such as in virtual reality

("VR") applications. According to aspects of the present invention, in certain embodiments, vibration stimuli matching the audio and/or visual effects found in VR environments are applied to a user's body, and in some of those embodiments, two or more such stimuli are applied simultaneously to different parts of a user's body.

Methods and systems implemented in certain embodiments use what is call "haptic panning" herein. This is similar to audio panning—when viewers watch a car moving from left to right on a screen they can also hear the sound following the image. The sound does not actually "move" with the car. The speakers placed at the left and right of the screen modulate the intensity of the sound according to well-known equations to create the illusion of movement of the sound source.

Likewise, various methods may be implemented similar to those known to skilled artisans for panning audio (e.g., constant power, vector-based amplitude panning (VBAP), ambisonics, etc.) to move vibrations around the body of a user. So, if it goal is to "move" the vibrations from left wrist to right wrist, for example, the following three different stages are implemented in certain embodiments: (A) "Left", vibrations at 85% on Left Wrist, 10% on Ribcage, 5% on Right Wrist; (B) "Center," vibrations at 10% on Left Wrist, 80% on Ribcage, 10% on Left Wrist; (C) "Right," vibrations at 5% on Left Wrist, 10% on Ribcage, 85% on Right Wrist. Any desired "movement" can be implemented following variations of this technique, from any point A to point B, passing through the areas in between.

Methods and systems implemented in certain other embodiments use what is called "hit spreading" herein. For example, if a game character is punched in the stomach, the user should also feel the energy of the punch going all the way to the user's back. In a VR simulation, when an area is hit by a punch, a fireball, or any other of form of energy that hits the user's character in the virtual world, the energy will spread to other areas. If a virtual enemy launches a fireball and the character defends it with bracelets, in the real world the energy felt vibrating on the user's wrist that got hit will trigger vibrations on the ribcage with less intensity and on the back with even less intensity.

In certain other embodiments, for example, a game character may enter a zone with a "force field," and in response in the real world, the vibrations get stronger in the area of the body that is closer to the field but other areas of the user's body will vibrate as well, although with less intensity.

In certain other embodiments, what are called the "Laser Sword Penetration" methods and systems herein can be understood as vibrations spreading on the areas that are being poked by a sword, but in order to make the effect more compelling, the vibrations also pulse in the neighboring areas, though with less intensity.

While the above description contains many specifics and certain exemplary embodiments have been described and shown in the accompanying drawings, it is to be understood that such embodiments are merely illustrative of and not restrictive on the broad invention, and that this invention is not limited to the specific constructions and arrangements shown and described, since various other modifications may occur to those ordinarily skilled in the art, as mentioned above. The invention includes any combination or sub combination of the elements from the different species and/or embodiments disclosed herein.

The invention claimed is:

1. A haptic stimulation device, comprising:

a plurality of wearable vibratory motors comprising:

a first motor configured to be disposed at a first portion of a user's wrist; and

a second motor configured to be disposed at a second portion of the user's wrist; and

a signal processor configured to receive an input signal and generate a plurality of electrical driving signals in real time,

wherein the plurality of electrical driving signals generated by the signal processor are configured to drive the plurality of vibratory motors according to a predefined mapping of portions of the input signal to the plurality of vibratory motors.

2. The haptic stimulation device of claim **1**, wherein the plurality of vibratory motors are coupled to one or more wearable articles.

3. The haptic stimulation device of claim **1**, wherein each of the plurality of vibratory motors is coupled to a strap configured to be worn about the user's wrist.

4. The haptic stimulation device of claim **1**, wherein the plurality of vibratory motors further comprises at least a third motor coupled to a wearable article.

5. The haptic stimulation device of claim **1**, wherein the vibratory motors are wirelessly coupled to the signal processor.

6. The haptic stimulation device of claim **1**, wherein the input signal comprises real-time audio detected via one or more microphones.

7. The haptic stimulation device of claim **1**, wherein the input signal comprises a pre-recorded audio signal.

8. The haptic stimulation device of claim **1**, wherein the signal processor is configured to generate the electrical driving signals such that at least two of the vibratory motors vibrate at different frequencies from one another.

9. A wearable device, comprising:

a plurality of vibratory motors comprising:

a first motor configured to be disposed at a first location of a user's body; and

a second motor configured to be disposed at a second location of the user's body; and

a signal processor communicatively coupled to the plurality of vibratory motors, the signal processor configured to:

receive an input signal; and

based at least in part on the input signal, and according to a predefined mapping of the input signal to the plurality of vibratory motors, generate a plurality of electrical driving signals.

10. The wearable device of claim **9**, wherein the plurality of vibratory motors further comprises at least a third motor coupled to the device.

11. The wearable device of claim **9**, further comprising one or more microphones, wherein the input signal comprises real-time audio detected via the one or more microphones.

12. The wearable device of claim **9**, wherein the input signal comprises a pre-recorded audio signal.

13. The wearable device of claim **9**, wherein the signal processor is configured to generate the electrical driving signals such that at least two of the vibratory motors vibrate at different frequencies from one another.

14. A method, comprising:

disposing a plurality of wearable vibratory motors about a user such that:

a first motor is disposed at a first location of the user's body; and

a second motor is disposed at a second location of the user's body;

receiving, at a signal processor, one or more input signals;

generating, via the signal processor, a plurality of electrical driving signals for the plurality of vibratory motors in real time and according to a predefined mapping from the one or more input signals to the plurality of vibratory motors; and

providing the electrical driving signals to the plurality of wearable vibratory motors such that the first motor vibrates against the first location of the user's body and the second motor vibrates against the second location of the user's body.

15. The method of claim **14**, wherein the vibratory motors are coupled to one or more wearable articles.

16. The method of claim **14**, wherein the plurality of wearable vibratory motors comprises at least 4 vibratory motors.

17. The method of claim **14**, wherein the vibratory motors are wirelessly coupled to the signal processor.

18. The method of claim **14**, wherein the one or more input signals comprises real-time audio detected via one or more microphones.

19. The method of claim **14**, wherein the first location of the user's body comprises a first portion of the user's wrist and the second location of the user's body comprises a second portion of the user's wrist.

20. The method of claim **14**, wherein the signal processor is configured to generate the electrical driving signals such that at least two of the vibratory motors vibrate at different frequencies from one another.

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