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(54) Title: METHOD OF CONSTRUCTING HYBRID TACTILE DISPLAY

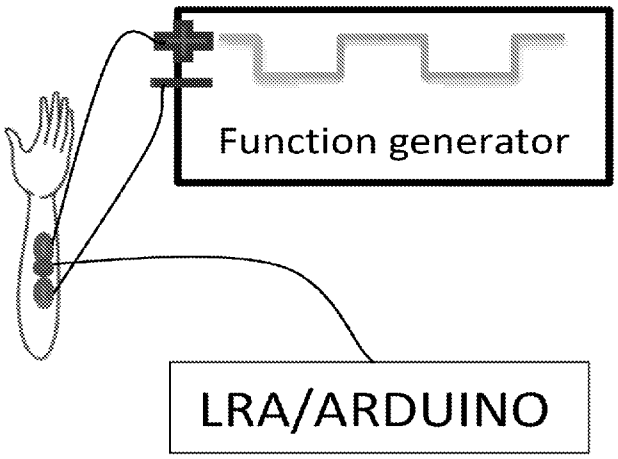


Fig:1

(57) Abstract: The present disclosure discloses a method of constructing tactile display with combination of different kinds of stimuli wherein the stimulus of the combination of two or more stimuli that are linearly aligned with each other is perceived at levels lower than the perception threshold values of individual kind of stimulus due to reduction in tactile threshold. The reduction in applied stimulus due to reduction in threshold prevents, discomfort, irritation, burns or any kind of damage in prolonged usage.

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METHOD OF CONSTRUCTING HYBRID TACTILE DISPLAY

FIELD OF INVENTION:

The present disclosure relates in general to tactile displays. Particularly, but not exclusively, the present disclosure pertains to Multiple-stimulus tactile displays.

BACKGROUND:

Touch is one of the five senses by which one perceives the world around us. Initially, tactile displays were made and used for people with sensory disabilities, particularly visual impairment. But with the explosion of technology in the past few decades, the use of haptic displays has become a part of daily life of everyone in the new technology driven world. The demand for experiences that feels almost real has been bringing about newer technologies in television displays, audio systems, virtual reality, augmented reality, providing multiple experiences like 4D,5D (includes 3D movies with seat movement and various special effects like snow, wind, drizzle, bubble etc.), 7D (is an interactive cinema in which one can use toy gun to shoot target) and even 9D (the viewer wears VR glasses and go into the world of the movie watching with a perspective of being center of all that is happening).

"Impacto" developed by Lopes et.al perceives impact in virtual environment like when one kicks a football or hits a baseball in a game and even being hit, with the help of tactile stimulation. There are two major types of tactile display: 1) Electro tactile displays and 2) Vibro-tactile display.

Electro-tactile displays directly stimulate the nerve fibers beneath the skin to communicate the message to the user. These displays are smaller compare to other tactile displays because the only requirement is a current source and the electrodes on skin. This makes it capable of fitting over other haptic devices as well. These types of displays provide higher spatial resolutions and can be designed with 3mm or lesser spacing between the actuators. The design of electrodes can be made transparent and as thin as a tattoo. However, the discomfort experienced by subject

on application of electrical stimulation and the cause of skin irritation and in certain cases in skin burn are limiting factors for electro-tactile displays.

Vibro-Tactile displays are well studied in comparison to the electrical ones. Human skin has 4 types of mechano-receptors beneath the skin: Merkel receptors, Meissner corpuscles, Ruffini cylinders, and Pacinian corpuscles. The frequency range of each receptor is different and can be stimulated separately as well. Merkel receptors located in the epidermis are slow responding receptors that perceives pressure and activates in the frequency range 0.3-3Hz, whereas Meissner corpuscles are located at dermis (just below epidermis) are rapid responding receptors that perceive stimulation as fluttering at 3-40Hz frequency range. Further, Ruffini cylinders located in the dermis are slow responding receptors that perceive the stretching and activates in 15-400Hz, and Pacinian corpuscles are located in the dermis (deep in the subcutaneous fat) are rapid responding receptors that perceive vibration and responds at 10-500Hz frequency range. A Vibro-tactile display is normally bit bulky and consumes higher power. They also have mechanical wear and tear problems.

To overcome the limitations exhibited by the electro-tactile displays and vibro-tactile displays, both electrical and mechanical stimulus are used together. According to D'Alonzo et al. [1] combining the actuators together provides the user more effective perception to discriminate the different patterns of tactile stimulus and through the experiments they have presented the results where the subject is able to differentiate between the patterns. They have put the mechanical actuator on the top of the electrodes used for the electrical stimulation to make it compact. They have compared the results of psychophysical experiments of the Hy-VE (Hybrid Vibro-Electro tactile) display with the electrical or mechanical stimulus alone.

Kajimoto et. al. [2] have proposed a method of combining the electrical and mechanical stimulus. The influence of mechanical stimulus on electrical stimulus is discussed but with no clarity comprising contradictory statements and rejection of own hypothesis.

The shortcomings of the prior art are overcome, and additional advantages are provided through the invention and method of present disclosure.

SUMMARY OF THE INVENTION:

The present disclosure discloses a method of constructing tactile display comprising selecting one or more kinds of stimulus and placing the stimulators are aligned to linear or non-linear or anywhere in vicinity of the each other stimulator. Then the intensity and frequency of the stimuli is adjusted using the stimuli-generation and regulation circuitry. Further, the stimuli is applied together at sub-threshold levels, lower than the perception threshold of individual kind of stimulus, wherein the sub-threshold level for a subject is calibrated by varying a stimulus in the sub-threshold range while keeping the rest of the stimuli at a constant reference sub-threshold value and repeating the same for every other stimulus. The stimuli applied at levels lower than the threshold is perceivable.

In an embodiment, the kinds of stimuli are selected from electrical, mechanical, optical, thermal, chemical, acoustic and electromagnetic.

In another embodiment, the stimuli generation and regulation circuitry comprise function generator, drivers, microcontroller, power supply, and personal computer to program the microcontroller.

In another embodiment for thermal displays a Peltier element is used to generate the heat to increase or decrease the temperature, as these elements are voltage dependent and the output is proportional to voltage, a regulated voltage power source is used as the regulatory circuit for the thermal stimuli.

In another embodiment for optical displays a regulated IR lamp is used.

In another embodiment for chemical displays, regulated infusion pumps limited to tongue displays are used.

In a preferred embodiment, the threshold of each stimulus is reduced and the reduction is preferably of upto 10%.

In another embodiment the threshold of each stimulus is further reduced by improving the stimuli generation, regulation circuitry, contact conditions between the skin and the stimulators.

In yet another embodiment, the system for implementing the method comprises first stimulator placed on the surface of the skin to be stimulated, a second stimulator placed in linear or non-linear or anywhere in vicinity of the other stimulator and further comprises, stimuli-generation and regulation circuitry, wherein the stimuli-generation and regulation circuitry is used to control the intensity and frequency of the stimulus of the stimulators, wherein the stimulus of the combination of two or more stimuli that are linearly aligned with each other is perceived at levels lower than the threshold values of individual kind of stimulus due to reduction in tactile threshold. The reduction in applied stimulus due to reduction in threshold prevents, discomfort, irritation, burns or any kind of damage in prolonged usage.

In an embodiment, a tactile glove comprises the stimulators of the system.

In another embodiment, tactile body suit comprises the stimulators of the system.

BRIEF DESCRIPTION OF THE DRAWINGS AND FIGURES

Fig:1 Illustration of multimodal tactile display.

Fig:2 shows the threshold level of electrical stimulus over the varying frequency range, the top curve is the threshold of electrical stimulus alone and the lower curve is the threshold of electrical stimulus in presence of mechanical stimulus.

Fig: 3 shows the threshold level of mechanical stimulus over the varying % duty cycle, the bottom bar of each subject indicates the threshold of the subject with just mechanical without electrical stimulus and top bar of each subject indicates the threshold of the subject with both the stimuli applied together.

DETAILED DESCRIPTION

The embodiments of the disclosure as well as a preferred mode of use, objectives and advantages thereof, will best be understood by reference to the following detailed description of an illustrative embodiment when read in conjunction with the accompanying drawings.

Before describing the present invention in detail, it is to be understood that this invention is not limited to particularly exemplified systems or process parameters that may, of course, vary. It is also to be understood that the terminology used herein is for the purpose of describing particular embodiments of the invention only and is not intended to limit the scope of the invention in any manner.

The abbreviations used in the disclosure are as follows:
Ag/AgCl: Silver/silver chloride electrodes
ECG: Electrocardiogram
LRA: Linear resonant actuator
PWM: Pulse width modulation

The terms "an embodiment", "embodiment", "embodiments", "the embodiment", "the embodiments", "one or more embodiments", "some embodiments", and "one embodiment" mean "one or more (but not all) embodiments of the invention(s)" unless expressly specified otherwise.

The terms "including", "comprising", “having” and variations thereof mean "including but not limited to", unless expressly specified otherwise. The enumerated listing of items does not imply that any or all of the items are mutually exclusive,

unless expressly specified otherwise. The terms "a", "an" and "the" mean "one or more", unless expressly specified otherwise.

Sub-threshold in the disclosure refers to a stimulus that is too small in magnitude to produce an action potential in excitable cells. In general, a sub-threshold stimulus leads to depolarization of the membrane, but the magnitude of the depolarization is not large enough to reach the threshold voltage.

Stimulator is something that provides stimulation. In the context of the disclosure stimulator as the medium that is used to provide particular kind of stimulus. For example, the stimulator to provide electrical stimulus implies the components comprising electrodes in the exemplified disclosure, similarly a stimulator to provide mechanical stimulus implies the components comprising actuator(s) in the exemplified disclosure etc.

Unless defined otherwise, all technical and scientific terms used herein have the same meaning as commonly understood by one of ordinary skill in the art to which the invention pertains. Although, a number of methods and materials similar or equivalent to those described herein can be used in the practice of the present invention, the preferred materials and methods are described herein.

The present disclosure discloses a method of constructing tactile display comprising selecting one or more kinds of stimulus and placing the stimulators are aligned in linear or non-linear or anywhere in vicinity of the each other stimulator. The intensity and frequency of the stimuli is adjusted using the stimuli-generation and regulation circuitry. Further, the stimuli is applied together at sub-threshold levels, lower than the perception threshold of individual kind of stimulus, wherein the sub-threshold level for a subject is calibrated by varying a stimulus in the sub-threshold range while keeping the rest of the stimuli at a constant reference sub-threshold value and repeating the same for every other stimulus. The stimuli applied at levels lower than the threshold is perceivable.

In an embodiment, the kinds of stimuli are selected from electrical, mechanical, optical, thermal, chemical, acoustic and electromagnetic.

In another embodiment, the stimuli generation and regulation circuitry comprise function generator, drivers, microcontroller, power supply, and personal computer to program the microcontroller.

In another embodiment for thermal displays a Peltier element is used to generate the heat to increase or decrease the temperature, as these elements are voltage dependent and the output is proportional to voltage, a regulated voltage power source is used as the regulatory circuit for the thermal stimuli.

In another embodiment for optical displays a regulated IR lamp is used.

In another embodiment for chemical displays, regulated infusion pumps limited to tongue displays are used.

In a preferred embodiment, the threshold of each stimulus is reduced and the reduction is preferably of upto 10%.

In another embodiment the threshold of each stimulus is further reduced by improving the stimuli generation, regulation circuitry, contact conditions between the skin and the stimulators.

In yet another embodiment, the system for implementing the method comprises first stimulator placed on the surface of the area to be stimulated, a second stimulator placed in alignment with the first stimulator in linear or non-linear or anywhere in vicinity of the other stimulator and further comprises, stimuli-generation and regulation circuitry, wherein the stimuli-generation and regulation circuitry is used to control the intensity and frequency of the stimulus of the stimulators.

In an embodiment, a tactile glove comprises the stimulators of the system.

In another embodiment, tactile body suit comprises the stimulators of the system.

In one embodiment, a tactile display comprises the stimulators of the system.

In another embodiment a visual display comprises the stimulators of the system.

The present disclosure discloses a method for constructing tactile display wherein the stimulus of the combination of two or more stimuli that are aligned in linear or non-linear or anywhere in vicinity with each other is perceived when the stimulus is applied together at levels lower than the threshold values of individual kind of stimulus due to reduction in tactile threshold. In a non-limiting embodiment of the disclosed disclosure with the multimodal tactile display constitute combination of electrical and mechanical stimulation comprising the following components, is exemplified and depicted in Fig:1.

Electrodes: are used for electrical stimulation. For a unit setup, two electrodes are used, one for anode and other for cathode. The electrodes are spaced so as to accommodate the actuator in-between the two electrodes.

A mechanical actuator: is used to provide the requisite mechanical stimulation.

Function generator: is an electrical function generator which is used to produce the electrical stimulus. Frequency, duty cycle and amplitude can be adjusted according to our requirements.

A Microcontroller board: is used to program the actuator for adjusting the duty cycle and generating the Pulse width modulation (PWM) signal.

The electrodes for the electrical stimulation are placed in the middle of the forearm and pulse wave electrical signals using a function generator are applied wherein the input voltage is adjustable. A mechanical actuator is positioned between the

electrodes and the microcontroller board is used to programme the actuator to provide the mechanical stimulus.

In general, a sub-threshold stimulus leads to depolarization of the membrane, but the magnitude of the depolarization is not large enough to reach the threshold voltage to excite the nerves to realize perception of stimulus. So, when a stimulus of sub-threshold level for either of the mechanical or electrical stimulus is applied, it is not perceivable.

From the data obtained by measuring threshold of stimulus perceived by subjects in the presence of electrical stimulus alone, mechanical stimulus alone and in the presence of both mechanical and electrical stimulus, it is observed that the subjects perceived stimulus when both the stimuli are at subthreshold level, which is observed throughout the frequency range 20-640Hz. Fig:2 depicts the reduction of electrical stimulus threshold when both electrical and mechanical stimuli are applied as compared to just electrical stimulus (the upper line indicates the threshold of stimulus when just electrical stimulus is applied) and Fig:3 depicts the reduction of mechanical stimulus threshold when both electrical and mechanical stimuli are applied as compared to just mechanical stimulus (the bottom bar indicates threshold of stimulus when just mechanical stimulus is applied). This implies that all the mechano-receptors can by activated by applying both the stimulus in sub-threshold level.

The method of constructing tactile displays in the present exemplified embodiment comprise selecting electrical and mechanical stimulus for the combination of stimulus and placing the stimulators aligned in linear or non-linear or anywhere in vicinity of the other stimulator. Then the intensity and frequency of the stimuli is adjusted using the stimuli-generation and regulation circuitry which can comprise components like function generator for electrical stimulus and components like microcontroller for mechanical stimulus. Further, the stimuli is applied together at sub-threshold levels, lower than the threshold of individual kind stimulus, wherein

the sub-threshold level for a subject is calibrated by varying a electrical stimulus in the sub-threshold range while keeping the mechanical stimulus at a constant reference sub-threshold value (about 10% less than threshold) and repeating the same for mechanical stimulus while keeping the electrical stimulus constant at about 5% less than threshold obtained.

The method holds good for combinations of one or more kinds of stimuli selected from electrical, mechanical, optical, thermal, chemical, acoustic and electromagnetic, where the threshold of each individual kind of stimulus in the combination is reduced as compared to the threshold values of the stimulus when applied individually on their own.

The reduction in the tactile threshold realizes an increase in overall tactile sensitivity. So, a subject can perceive the tactile stimulus even when both the stimuli are applied at sub-threshold level, at which each of the individual kind of stimulus are not perceivable. The reduction in applied stimulus due to reduction in threshold prevents, discomfort, irritation, burns or any kind of damage in prolonged usage an so can be used to substitute traditional high power electrical displays. Further, this enables low power-consuming tactile displays. The method will enable improvement in the experience of virtual reality with the stimulators of disclosed system embedded on hand gloves to form tactile gloves. Further, the same approach can be used for a whole-body suit for tactile feedback.

EXAMPLES

Example 1:

In an exemplified embodiment depicted in Fig:1, to deduce the effect of using both mechanical and electrical stimulus over the threshold values of applying only electrical stimulus, the electrodes used for electrical stimulation are Ag/Agcl electrodes (used for ECG usually) of 35mm diameter. Two electrodes are used, one for anode and other is for cathode, the gap between these electrodes is kept as 8mm such that a 8mm LRA can fit-in properly as depicted in Fig:1. The mechanical

actuator used is linear resonant Actuator (LRA), which is a vibration motor that produces an oscillating force across a single axis. When the voice coil is driven at the resonant frequency of the spring, the entire actuator vibrates with a perceptible force. LRA's resonance frequency is 235 HZ. The duty cycle of the LRA is varied to adjust the effective intensity (amplitude of vibration). The function generator Tektronix AGF1022 is used to produce the electrical stimulus. It has a digital/analog display and the change in parameters can be made up to three decimal values. Frequency, duty cycle and amplitude are adjusted according to the requirement. Further, ARDUINO microcontroller board is used to program the LRA for adjusting the duty cycle and generating the PWM signal. A driver circuit is required for the LRA and the drive board, for this purpose DRV2605L is used.

The threshold values of electrical stimulus alone are obtained initially by giving varying range of electrical stimulus with the help of power supply and noting the threshold values. In the second mode the mechanical actuator is kept in the middle of the anode and cathode with the mechanical stimulus amplitude kept at sub-threshold level and varying the electrical stimulus to find the new threshold values in the presence of mechanical stimulus.

Psychophysical method for threshold detection:

A total of 14 subjects-10 male and 4 females participated. The subjects were informed on the procedures of the study and an informed consent was taken from the participating subjects**.** For the detection of threshold Staircase method has been used. The data is collected by placing LRA above the skin and fixing it with a tape. Further, the setup includes an ARDUINO UNO microcontroller board and a driver for the LRAs (DRV 2605L). The LRAs are programmed such that the duty cycle can be changed to change the intensity of the stimulation. For example, if the duty cycle is 10% the intensity is lower and if the duty cycle is 50% the intensity higher. Psychophysical data is obtained by following the protocol wherein the duty cycle is increased from 0% till the perceivable percentage, during which the duty cycle of the mechanical stimulus is fixed to be below 10% of the perceivable duty cycle. The voltage signal is increased initially from 0 Volt till the detection, in the step of 1 Volt.

Once the signal is detected, the voltage is lowered by one volt and increased in the steps of 0.1 volt from there till the precise point at which the subject detects the stimulus. Once the signal is detected here again the stimulus is decreased by 0.1 volt until the signal is not perceived and raised again till the precise threshold of stimulus perception is obtained. This process is repeated for 5 ups and 5 downs and the average of the 10 values is taken to conclude the threshold at a particular frequency. Time taken for one subject at one particular frequency is about 15 minutes and a gap of 2 minutes is given after every frequency; so for one subject the total time taken is about 1.5-2hrs.

The psychophysical method is conducted in two different modes to maintain the incoherence for the subjects to provide unbiased response; 1) electrical stimulus without the mechanical stimulus and 2) electrical stimulus along with the mechanical stimulus. Further, for some frequencies, the threshold 'without the mechanical stimulus' is obtained first and for rest of the frequencies 'along with the mechanical stimulus' is obtained first and the selection of which one to conduct first is completely random. Results are represented in Fig2.

In this embodiment, the average reduction in electrical stimulus is 4-5%

Example 2:

In an exemplified embodiment depicted in Fig:1, the deduction of the effect of using both electrical and mechanical stimulus over the threshold values of applying only mechanical stimulus is done using a setup same as the one described in example 1.

The threshold values of mechanical stimulus alone are obtained initially by placing the LRA at the region of perception, varying the % duty cycle of LRA and noting the threshold values. In the second mode the mechanical actuator is kept in the middle of the anode and cathode with the electrical stimulus amplitude kept at sub-threshold level. The mechanical actuator is programmed to give the different PWM by an ARDUINO board. The % duty cycle of the mechanical stimulus is varied in the presence of the electrical stimulus to obtain the new mechanical threshold.

Psychophysical data is obtained by following the protocol wherein the duty cycle is increased from 0% till the perceivable percentage, during which the amplitude of the electrical stimulus is fixed at a level 5% lower than the threshold. The psychophysical method of threshold deduction is performed on 4 consenting male subjects by applying varying mechanical stimulus in accordance with staircase method as described in example 1.

The psychophysical method is conducted in two different modes to maintain the incoherence for the subjects to provide unbiased response; 1) mechanical stimulus without the electrical stimulus and 2) mechanical stimulus along with the electrical stimulus. Further, for some % duty cycles, the threshold ' without electrical stimulus' is obtained first and for rest of the % duty cycles, the threshold 'along with the electrical stimulus' is obtained first and the selection of which one to conduct first is completely random.The results are represented in Fig:3. In this embodiment the average reduction in the threshold of mechanical stimulus in the presence of 5% sub-threshold electrical stimulus is 3-7%

Although the invention herein has been described with reference to particular embodiments, it is to be understood that these embodiments are merely illustrative of the principles and applications of the present invention. It will be apparent to those skilled in the art that various modifications and variations can be made to the method and apparatus of the present invention without departing from the spirit and scope of the invention. Thus, it is intended that the present invention include modifications and variations that are within the scope of the appended claims and their equivalents.

The claim:

1. A method of constructing tactile display comprising

selecting, combination of one or more kinds of stimulus and placing the stimulators linear or non-linear or in vicinity of the other stimulators;

adjusting, the intensity and frequency of the stimuli by using the stimuli-generation and regulation circuitry;

applying, stimuli together at sub-threshold levels, lower than the perception threshold of individual kind of stimulus;

wherein the sub-threshold level for a subject is calibrated by varying a stimulus in the sub-threshold range while keeping the rest of the stimuli at a constant reference sub-threshold value and repeating the same for every individual kind of stimulus;

wherein the combination of the stimuli applied is perceivable.

2. The method as claim in claim 1, wherein the kinds of stimuli are selected from electrical, mechanical, optical, thermal, chemical, acoustic and electromagnetic.

3. The method as claimed in claim 1, wherein the stimuli generation and regulation circuitry comprises of function generator, drivers, microcontroller, power supply, regulated voltage power source, regulated IR lamp, regulated infusion pumps and personal computer to program the microcontroller.

4. The method as claimed in claim 1, wherein the stimuli-generation and regulation circuitry is used to control the intensity and frequency of the stimulus of the stimulators.

5. The method as claimed in claim 1, wherein the threshold of each stimulus is reduced, and the reduction is upto 10%.

6. A system for implementing the method as claimed in claims 1 to 5, comprising first stimulator, placed on the surface of the skin area to be stimulated; second stimulator, placed in linear or non-linear or anywhere in vicinity with the first stimulator.

7. The system as claimed in claim 6, wherein the stimuli generation and regulation circuitry comprise function generator, drivers, microcontroller, power supply, regulated voltage power source, regulated IR lamp, regulated infusion pumps and a personal computer to program the microcontroller.

8. A tactile glove comprising the stimulators of the system as claimed in claim 6.

9. A tactile body suit comprising the stimulators of the system as claimed in claim 6.

10. A tactile display comprising the stimulators of the system as claimed in claim 9.

11. Visual display comprising the stimulators of the system as claimed in claim 10.

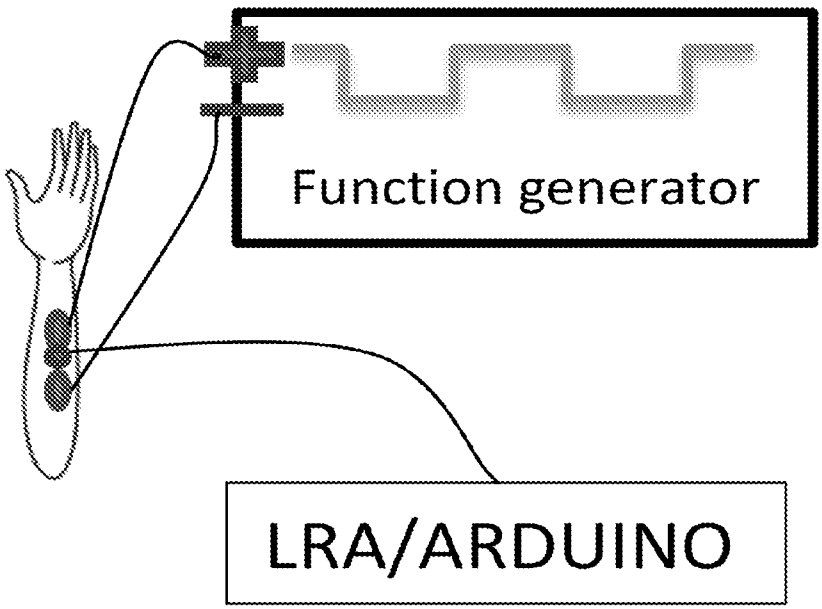


Fig:1

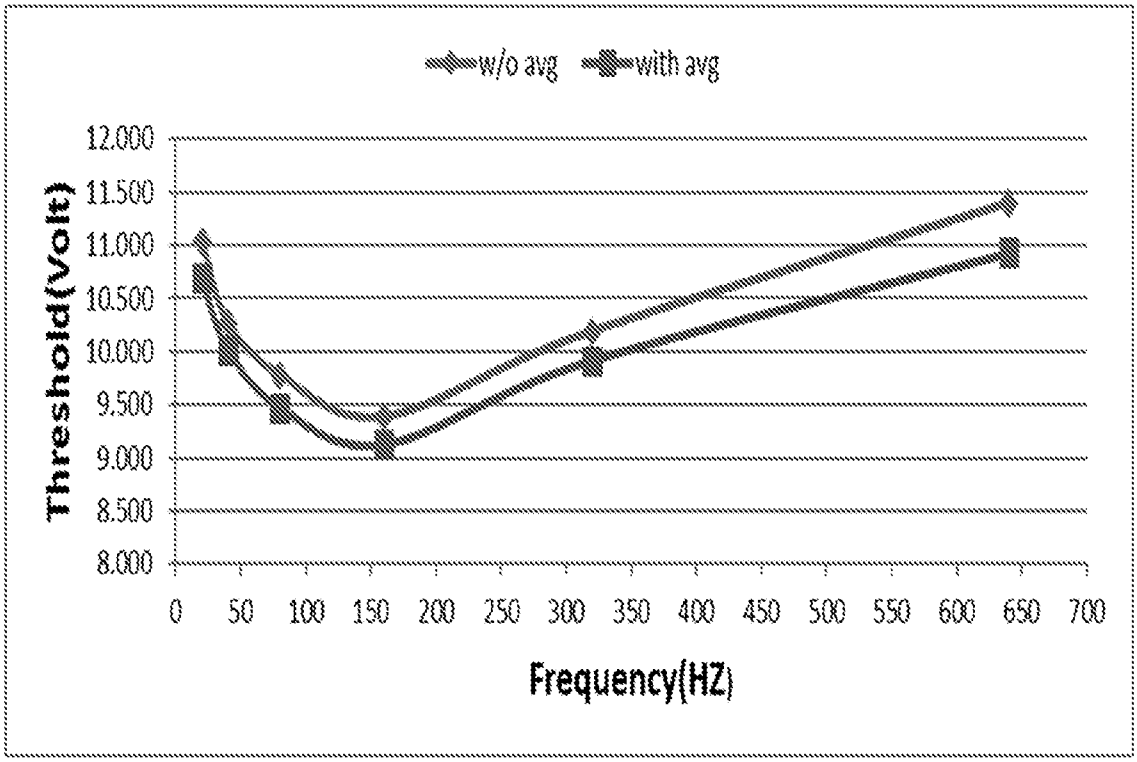

w/o avg
with avg
Threshold(Volt)
12.000
11.500
11.000
10.500
10.000
9.500
9.000
8.500
8.000
0
50
100
150
200
250
300
350
400
450
500
550
600
650
700
Frequency(HZ)

Fig: 2

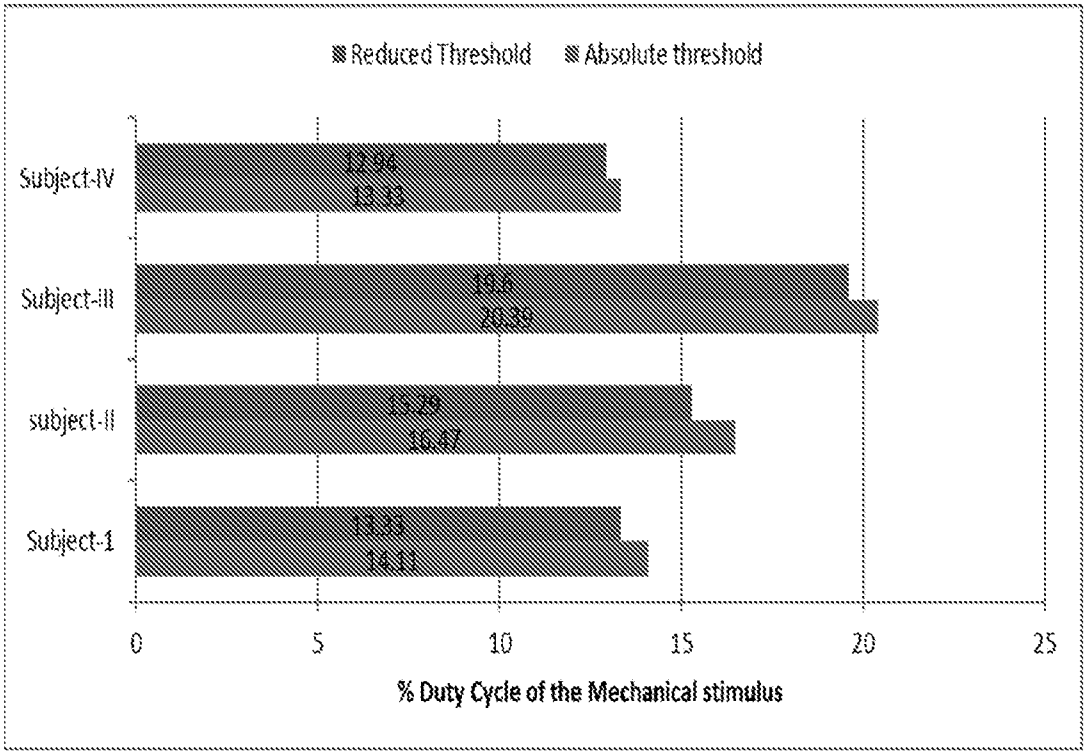

Reduced Threshold
Absolute threshold
Subject-IV
12.96
13.43
Subject-III
19.6
20.39
subject-II
15.99
16.47
Subject-1
13.93
14.11
0
5
10
15
20
25
% Duty Cycle of the Mechanical stimulus

Fig: 3

INTERNATIONAL SEARCH REPORT

International application No.
PCT/IN2020/050385

A. CLASSIFICATION OF SUBJECT MATTER
G06F3/01,G06F3/03,G09B21/00 Version=2020.01

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B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

G06F, G09B

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

Databases: TotalPatent One, IPO Internal Database
keywords: tactile display, stimulus, threshold, circuit

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	JP 5057068 B2 (University of Tokyo), 24 October 2012 (24/10/2012) claims [1, 6-12], paragraphs [0002 ,0005-0006,0030-0050, 0058-0062]	1-11

☐ Further documents are listed in the continuation of Box C. ☒ See patent family annex.

* Special categories of cited documents:
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"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
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Date of the actual completion of the international search	Date of mailing of the international search report
17-08-2020	17-08-2020
Name and mailing address of the ISA/ Indian Patent Office Plot No.32, Sector 14,Dwarka,New Delhi-110075 Facsimile No.	Authorized officer Pritish Ranjan Pradhan Telephone No. +91-1125300200

INTERNATIONAL SEARCH REPORT
Information on patent family members

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JP 5057068 B2	24-10-2012	EP 1970877 A1	17-09-2008
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