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Skin Stroking Haptic Feedback Glove for Assisting Blinds in Navigation

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Abstract— **Visually impaired or blind people are unable to assess or analyze obstacles and tasks they wishes to perform. Lack of visual feedback has kept their lives restricted. Therefore, numerous techniques are available for sensing hurdles and irregularities in their paths. The real challenge is to develop a fast and spontaneous actuating technique. From manual white cane to Electronic Traveling Aid (ETA) and haptic feedback assistive bracelet, each has its own importance in the field. In this paper, two techniques of haptic feedback are explored namely, Vibrotactile and Skin Stroking. Skin stroking is a novel technique to be incorporated in haptic feedback systems, it is a painless and comfortable form of a tactile display. Requirements of this system is not limited to guidance and navigation purposes only that is why this device was experimented in maneuvering guidance, rotational and translational motion of hands. Vibrotactile and Skin stroking mechanism were connected with an android application via bluetooth which controls the motion of subjects throughout the experiments. The results gathered from experiments signifies that directional differentiating cues were better while using skin stroking haptic feedback mechanism and more can be expected from this field in the future.**

I. INTRODUCTION

Blind people have to rely largely on the environment and other senses for effective communication. 39 million blinds were observed in the year 2010 globally [1]. 51% people are suffering from cataract [2], which is the leading cause of blindness. According to an estimate, the number of blind people will increase up to 76 million by the year 2020 [3]. 82% of blinds are 50 years of age or older [2]. Their dependence for the lifetime can be considered as the most important aspect of this crisis. This paper highlights the human sensory dependence on the visual feedback system, especially for the motion of hand whether it be translational or rotational and as well as a perception of mobility during guidance.

The fundamental concept of this research is to compare different forms of tactile displaying techniques for the assistance of blind people. Thus the system had to be uncomplicated and intuitive. The frequent trials of different gadgets in order to quantify the amount of locomotion a blind person has to interpret in order to avoid the obstacle.

Human brain adapts every change occurred to a body, whether it be amputation [15] or realization of a response indicating distinct signals for the specific indication. Selective attended training will cause the mind to learn new methods to comprehend exteroceptive signals.

Cane or stick has its significance throughout history as a traveling aid for blinds. White cane detects static obstacles, holes and steps through tactile-force feedback. Cane used to be black from the day of its origin, then it was painted white in 1921 to make it more visible to the people around [4]. White cane has become a symbol of freedom and confidence of the blind community. Perkins School for the Blind states that only 2 to 8 percent of blinds uses white cane [5]. For difficult situations guide dog are useful. However, they are expensive which make them unaffordable and they have less working time [11].

Ultrasonic sensors were used in white cane to generate audio feedback for assistance [6] and the same method was also used to generate vibrotactile feedback [7]. Pyun et al. [8] discusses major issues regarding heights of obstacle and gives a suitable solution for the situation by detecting obstacles at four vertical intervals and providing multi-sensory feedback. Similarly, Fukasawa et al. [9] has done detailed work on electronic traveling aid (ETA) and the system proposed by Faria et al. [10], namely SmartVision which provides contextual geographical information using RFID technology for assistance in both indoor and outdoor mobility.

As mentioned above that this paper is specifically targeting blinds. The researchers have incorporated different sensors in white cane for obstacle and distance calculation. White can be once considered as a mechanical traveling aid and it has now become an electronic traveling aid (ETA), an advanced gadget for guiding blinds and obstacle detection. The more compact, simple and low-cost device are preferably the most required area for advancements. The wearable system with haptic feedback of any kind, which indicates the directions and guide a blind person effectively is the sole reason of this research paper. Aggravi et al. [12] designed a haptic feedback assistive bracelet for blind skiers involving vibrotactile feedback, whereas Scheggi et al. [13] designed a similar vibrotactile feedback bracelet for the guidance of older adults in crowded environment.

Another method for haptic feedback for the same purpose is skin stretch. Chinello et al. [14] experimented a unique skin stretch mechanism to exploit cutaneous receptors. It makes the concept of haptic feedback complicated, whilst there are numerous researches done in vibrotactile feedback which makes it easier to perceive and quantify the vibration and use them in the closed loop system.

A novel technique of skin stroking for haptic feedback is introduced in this paper. Skin stroking is experimental for this purpose and it seems to be effective in future, especially

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incorporated with the wrist mounted haptic bracelet, for guiding blinds during maneuvering in crowd and from hurdles . This system is largely based on guidance phenomenon rather navigation. Skin stroking is a unique technique which follows the fundamental law of tactile sensation and tactile display. Gentle stroking happens to be listed at the beginning of the touch perception on the hierarchy of proprioceptive sensations. The sensation of touch begins after it is sensed by low threshold mechanoreceptor and these activations further leads to skin stroking [15]. The sensitivity of skin stroking arises after sensing on multiple low sensitive circumferential endings.

II. SYSTEM TYPES

A blind person cannot perceive obstacles distance, the directions and size. For that matter, any form of signal is vital to notify at least for one of those. The most important of all is direction. A low cost, compact and robust guiding system which signals a blind person to turn left or right and move forward or backward. Human skin is the largest organ and it comprises of several receptors and mechanoreceptors located beneath its surface. The most feasible device for this purpose is the haptic feedback assistive bracelet. Filgueiras et al. [16] designed a vibrotactile feedback bracelet for the guidance of blinds to navigate. Less power consuming and lesser weight makes this device suitable for the job. RFID and GPS combined can make a very efficient system for guiding to a predefined destination or create a new route on the move [17] and another GPS-based with the blind friendly user interface to fill the gap between blind man and touchscreen mobile phone [18]. The vibrotactile feedback is most commonly used form of haptic feedback, but an alternate form of sensation should be presented. Vibration not only requires constant varying stimulus but also unable to protect skin from desensitizing occurring because of constant vibration on it [20], [21]. Skin stretch has allowed human to receive information other than from visual or audio cues and it is an improved form of tactile feedback. Chen et al. [22] tested lateral skin stretch on nine location on a human lower limb and three of them soleus, calcaneal tendon (upper), and fibularis longus (lower) were declared suitable for skin stretch feedback. In an isolated environment, users are able to detect rotational stretch of two to five degrees [23]. Skin stretch requires at least two firm contacts between rotation axle and skin. Out of seven classes of mechanoreceptors in human skin, skin stretch mechanism specifically exploits Ruffini ending. Ruffini ending has been categorized into SA II due to slow adapting [24]. However, it is a principal functionality of human brain to adopt its external and internal interactions. Furthermore, Chinello et al. [14] imparted skin stretch mechanism on a bracelet to transmit signals for navigation.

Skin stretch has its own limitations, one of them and might be that anything between the end effector and skin may change stretch into the slip. Moreover, skin stretch can be painful to users, let alone this is a major reason to look for another technique. A novel mechanism for haptic feedback is brush stroking on skin. A similar mechanism as skin stretch but different actuator can improve the viability of an idea. Lken et al. [25] describe that soft brush stroking on low threshold unmyelinated mechanoreceptor (C - tactile) acts very fast and efficiently. Meissner Corpuscels responsible for detecting skin strokes, it lies on top of all other mechanoreceptors with 140 receptors per cm3 on a fingertip. Frequency range goes up to 200 Hz from 10Hz and most sensitive at 200Hz 300Hz [24].

III. DESIGN AND TECHNIQUE

A. VIBROTACTILE FEEDBACK MECHANISM

The system should be portable and light weight. To make it feasible to exhibit a bracelet: light weight and small size were the most crucial part of designing. On the other hand, efficiency and fast real-time response were not to be compromised in this process. Therefore, the combination of a handful of tools were brought into operation for its construction. The wearable device for multiple purposes was the sole objective of this paper, it remains the fundamental objective of designing, and this wearable device can be worn on forearm, wrist, ankle or thigh as shown in Fig. 1. Hence the device should not be protruding and difficult in wearing and taking off. Each Vibrotactile bracelet comprises of 4 coin-shaped vibration motors (see Fig. 2), an Arduino Nano and an HC 05 Bluetooth module.

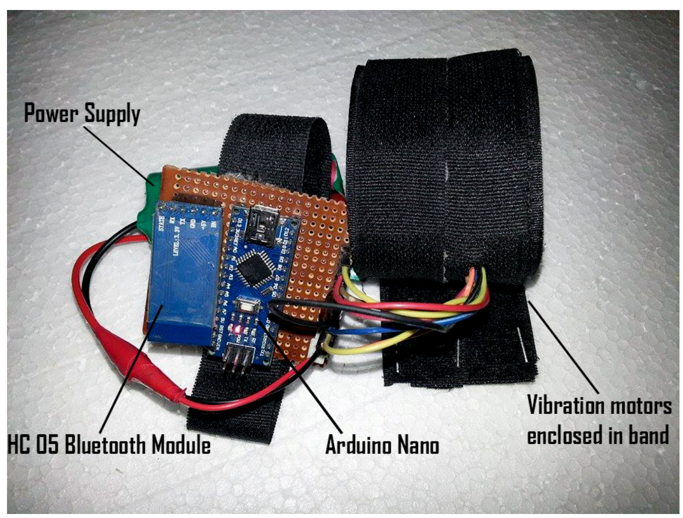

Fig. 1. Vibrotactile based haptic feedback assistive bracelet.

Each of the 4 vibration motors operates when the direction is meant to the position on which it was installed. Motor mounted on the dorsal side of forearm direct a person to move forward and vice versa. So 4 of vibration motors collaborate to give 8 directions in total see Fig. 3. HC 05 is a Bluetooth module range up to 10 m which is suitable for the proof of concept. An android app is used to transmit an angle to avoid an obstacle, Bluetooth module receives the data packet, obtain the angle and operate motors accordingly.

Fig. 2. (Https://www.precisionmicrodrives.com/vibration-motors/coin-vibration-motors) Coin shaped vibration motors

	0 degree	45 degrees	90 degrees	135 degrees	180 degrees	235 degrees	270 degrees	315 degrees
Motor 1	ON	ON	OFF	OFF	OFF	OFF	OFF	ON
Motor 2	OFF	ON	ON	ON	OFF	OFF	OFF	OFF
Motor 3	OFF	OFF	OFF	ON	ON	ON	OFF	OFF
Motor 4	OFF	OFF	OFF	OFF	OFF	ON	ON	ON

Fig. 3. Sequence of Vibration motors

B. SKIN STROKING FEEDBACK MECHANISM

Skin Stroking is a unique idea in this perspective of its incorporation in a haptic assistive bracelet. The real constraint lie in its design, the portable and miniature mechanism to hold a motor upside down at a particular level above the skin surface is necessary as shown in Fig. 4. The orthogonal brush on the rotor pursue clockwise and anticlockwise sensation on the skin. N20 micro gear motors (see Fig. 4) were found suitable to incorporate in wearable haptic device for its lightweight. Due to its metal gears, it can manage high torque and high rpm when required at the same time.

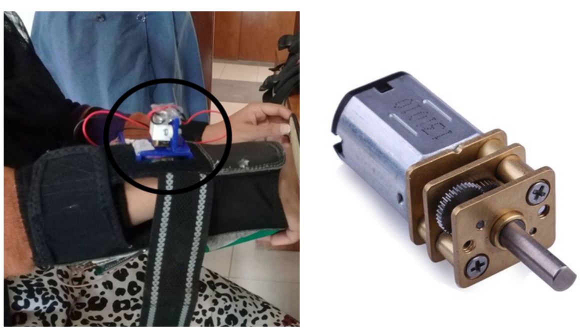

Fig. 4. Left: 3D printed structure holding motor upside down, Right: N20 gear motor

The structure on which the motor and brush held is 3D printed. The height is 11.24 mm and width is 25.40 mm. Motor rotates brush on the shaft to produce stroking effects on the skin through it bristles (Fig. 5 & Fig. 6). HC 05, transmit direction from instructor to the subjects and Arduino Nano used to control data and actuate the motors (Fig. 7).

IV. Experiments & Results

In order to validate the effectiveness of both the designs, experiments were conducted and every design were given

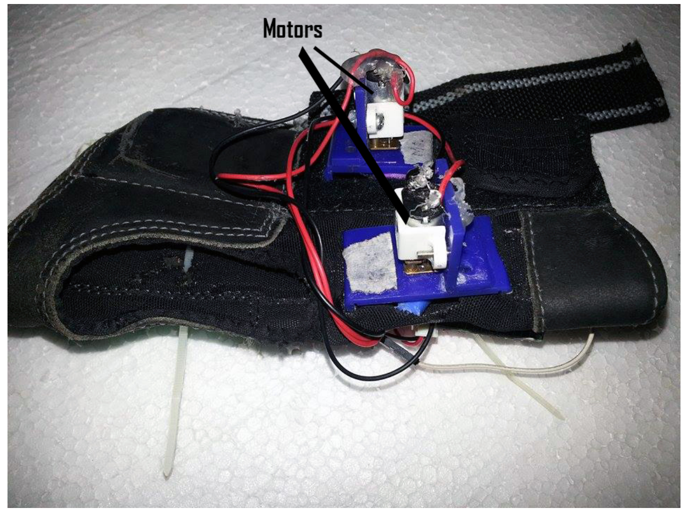

Fig. 5. Skin stroking based haptic feedback system (top view)

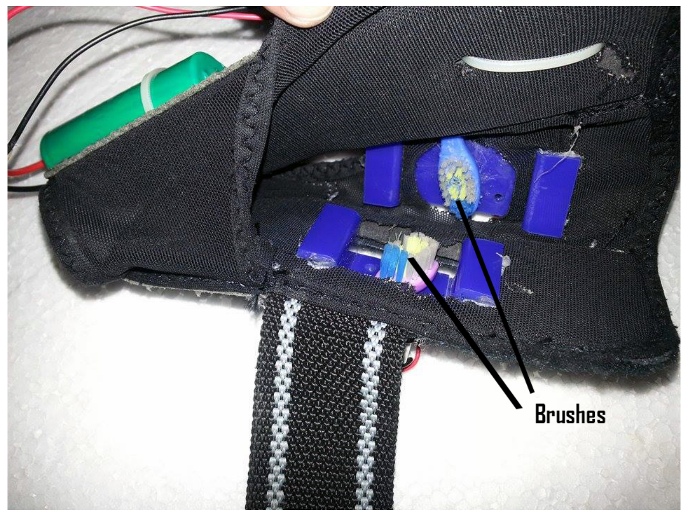

Fig. 6. Skin stroking based haptic feedback system (inside view)

same circumstances to achieve best comparative results. There were 5 subjects between the ages of 20 to 25. Subjects were blind-folded to impersonate blinds.

As a matter of fact, subjects required demonstration and practice to understand signals. For that purpose pre-training and post-training demonstration sessions were held. Subjects were only given ordinary cues and they had to interpret those cues. 73% of success rate in pre-training session climbed up to 78% in post training session.

A. Angle Targeting

1) Experiment: This experiment was designed in a special manner to bring their wrist rotation under their control through alternate actuation. As shown in Fig. 9 a closed loop angle determination handle was designed with a potentiometer incorporated with a handle and separate circuit was attached to measure the angle of rotation of the handle. The movable handle was fixed on a steady surface and the achieved angle of rotation was displayed on Arduino IDE

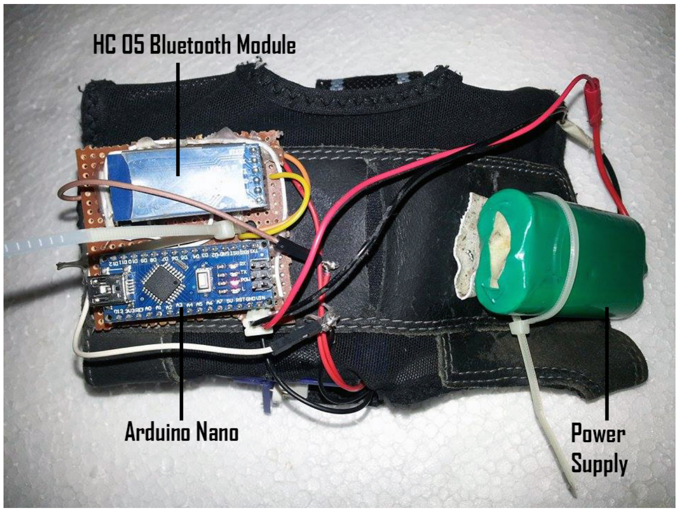

Fig. 7. Skin stroking based haptic feedback system (bottom view)

display.

Fig. 8. Angle recognition and simultion mechanism

Subjects would receive cues on their bracelet from the instructor through an android application and subject would rotate the handle accordingly. After the rotation of required angles the bracelet would become idle which signifies that required rotation is completed and subject no longer need to rotate. This process were demonstrated and each subject was required to make 3 attempts.

2) Result: Precise rotation of wrist is not possible without maintaining visual feedback with the sight. This experiment was meant to check the feasibility of sensing rotational angles in blinds through the haptic assistive bracelet. Results acquired are listed down in Fig. 9

Subjects were supposed to start this experiment from the handle positioned randomly. As this is clearly visible on the table that 180 degrees and 0 degree are quite clearly specific for almost all the test subjects which means they were able to distinguish the direction from right or left. Average value

		Skin Stroke		Vibrotactile	
	Req. Angle	Achieved	Difference	Achieved	Difference
Subject 1	90	85	5	43	47
	180	180	0	180	0
	0	180	180	0	0
Subject 2	90	87	3	76	14
	180	180	0	180	0
	0	0	0	0	0
Subject 3	90	93	3	119	29
	180	180	0	180	0
	0	0	0	0	0
Subject 4	90	130	40	79	11
	180	180	0	180	0
	0	0	0	0	0
Subject 5	90	74	16	89	1
	180	180	0	180	0
	0	0	0	0	0
Average	90	93.8	3.8	81.2	8.8
	180	180	0	180	180
	0	36	36	0	0

Fig. 9. Result from the angle identification test

for the identification of 90 degrees while using skin stroking glove is better than that of vibrotactile bracelet.

B. Path Tracking

1) Experiment: The objective of this experiment was to follow the cues subjects receive through their bracelet. To validate the prime objective of this proposed idea, an experiment was conducted for better judgment of cognitive response of the blinds. Cues were given via Bluetooth, their bracelet actuates according to the direction suggested by the instructor. In an empty field, chairs were used as an obstacle and subjects had to walk blindfolded from Point A to Point B (Fig. 10). The architect of the experimenting site was completely unknown to the subjects. Subject would receive signals from instructor to turn according to the signals in order to prevent themselves from obstacles. Total time taken by the subjects were the required data in this experiment. Their response to the signals determines the effectiveness of the system.

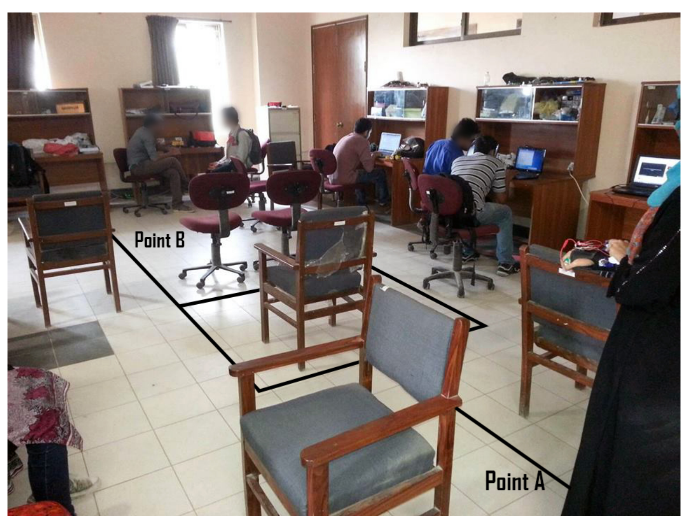

Fig. 10. Path tracking labyrinth and subject is blindfolded

2) Result: This experiment was performed on all kind of haptic feedback assistive bracelet presented in this paper. Total time taken by each subject of traveling from Point A to Point B were recorded. Each subject was given one attempt and 5 of them participated individually. Time of each subject was recorded and can be analyzed in Fig. 11. Average value of time taken using Vibrotactile technique was 53.4 sec. Standard Deviation in this method was calculated to be 11.13. Average time taken and Standard Deviation were 74.922 sec and 27.984 while using skin stroking haptic feedback mechanism.

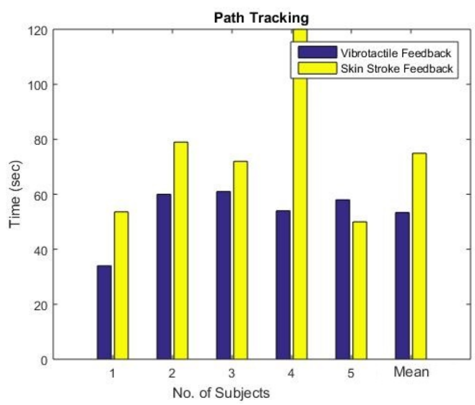

Fig. 11. Graph from the time taken of subjects in Path tracking experiment

C. Trajectroy following using Kinect

1) Experiment: This experiment was carried out to see the movements of hand precisely to perform any activity and effectiveness of proposed design in this context. The different mechanism does somehow contribute in some aspect of implementation but each of them possesses different properties in the application. Following trajectory using Kinect (shown in Fig. 14). Kinect is motion sensing input device, designed by Microsoft [28]. Furthermore, their accuracy of following the desired trajectory was required from this experiment which signifies its applicability in the real world environment. Separate environment for Kinect was created on computer to map the motion of subject's hand (see Fig. 13). In Test 1, instructor will guide the subject to draw a rectangle on the screen while wearing each of the bracelet. Subject would follow the correct direction while drawing a rectangle while interpreting the instructor's cues at the right time. In Test 2, instructor will guide to draw a right angle.

Fig. 12. Kinect for Xbox 360

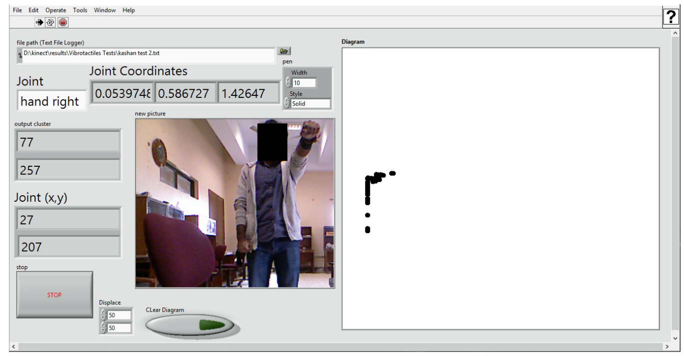

Fig. 13. GUI of motion of hand detection through Kinect

2) Results: Each subject had to perform twice with each type of haptic assistive bracelet, with the different pattern each time. There was major difference in understanding and movement of hands between vibrotactile and skin stroking technique, the difference is clearly visible in Fig. 14. As shown in Fig 14, the directional cues for all the subjects were same for each test. They were tried once for skin stroking based mechanism and once with vibrotactile based haptic bracelet. The brighter white line in the image is pattern drawn while wearing skin stroking based gloves and vice versa. In image of "Subject 5 Test 2", subject was able to interpret upward then to the right motion correctly, on the other hand, "Subject 2 Test 2" got confused between right and left motion while using vibrotactile based bracelet. Similarly, all the subject drew similar pattern for test 1 but Subject 2 in this test confused to left for right while using skin stroking bracelet.

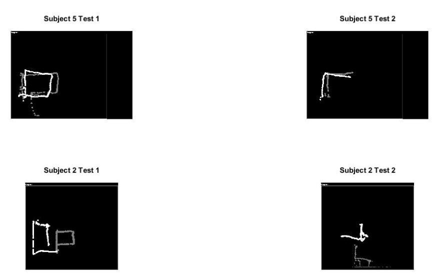

Fig. 14. Each pattern drawn from each subject is superimposed on one image, bright lines are drawn from skin stroking glove and damped lines are drawn with the use of vibrotactile bracelet.

V. CONCLUSIONS

This research was initiated to compare different types of haptic feedback assistive guiding mechanism for blinds. The conclusion of this comparison should not desensitize either of the two . Since the experiments and tests were in the initial phase and it is suitable to compare the prospects and future viable development options.

The comfortability of device is an important factor, indicates by the initial psychophysical experiments rate skin stroking method to be more comfortable for the users and more intuitive to perceive directional cues. It is advised to continue this method for experimentation and this method will appear as an important form of tactile display to trigger artificial stimulus on the skin. Firstly, the ability to distinguish incoming signals was better with skin stroking mechanism through the clockwise and anticlockwise motion of brushes. Gentle stroking is an important part of proprioceptive senses. Meissner corpuscle responsible for skin stroking is the shallowest mechanoreceptor of all and this receptor per cm2 is highest of all i.e. 140. Detection of skin stroking is abrupt and this type of sensation is further mentioned as pleasant touch in [29] on certain velocities. Modulated velocities also possess the advantage to transmit varying signals with respect to the situation. This ability of skin stroking to implicate pleasant touch is by far the widest aspect to bring advancement in this technique.

However, Vibrotactile feedback mechanism, on the other hand, is a contemporary of skin stroking. Vibrotactile is widely used for a broad range of tactile sensation and it is considered to be reliably generating a wide variety of tactile sensation but its complication includes human skins attribute of interpreting the multiple vibrating elements. Discomfort and annoyance of user and disregard of the signal if it is continuous. Therefore, a substitute to the Vibrotactile feedback and catering the need of a comfortable and painless form of tactile display, skin stroking is presented in this paper. In future, more tests will be done with improved designs and improved controlling algorithm to improve this idea of skin stroking.

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