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Vibrotactile Assistive Device for Visually Impaired with Text to Braille Conversion Using Haptic Technology

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***Abstract* - This paper explores the current technology and applications of vibrotactile devices used as an assistive tool for the visually impaired as effective information transfer modality emerging in haptic enhancements. Our main objective is to effectively encapsulate the foundational requirements for developing any vibrotactile haptic device based on existing and proven technology. We emphasize the efficient conversion of text to Braille based on established translation techniques while also shedding light on the human tactile perception capabilities. We then lay out the foundational guidelines for vibrotactile design for any emerging technology in the assistive haptics area with an emphasis on actuator types.**

Keywords: Vibrotactile, Haptics, Actuators, Sensory Perception, Text to Braille, Assistive Technology.

I. Introduction

The latest development in the area of human-computer interactions, known as haptic technology, embodies touch and tactile impressions. This is a new technology that provides users with an opportunity to touch the virtual objects as if they were real [1]. The combination of haptic technology with other sensorial modalities like the sense of sight or sound generates additional dimensions for interaction and can be considered to increase the general perceived realism.

Haptic technology besides serving in areas of education, training, computer-aided design, medical sector, has proved instrumental as an aid to people suffering from sensory impairments, especially visual. For instance, there is a new phenomenon known as Braille-enabled vibrotactile devices. This technology has quickly become an emerging new technology that is integral to blind assistance and finds itself in several applications.

Different researches examine the interaction between various pieces of hardware, and software tools, and their functionality in enabling the Braille learner process [2]. Recently, a braille-compatible vibrotactile device that converts text into tactile feedback was created[3], thus enabling the visually challenged to read and understand written information in a new and dynamic way as opposed to traditional Braille. This novel Braille-enabled vibrotactile device brings a new level of autonomy to the visually impaired. With an arrangement of several micro-tactile actuators that generate exact vibrations, the device can receive and convert digital information into specific vibrating patterns upon relayed through a computer or microcontroller device.

This enables an individual to get different kinds of information including books, documents, etc., available through a tactile input of Braille. Additionally, with advancements in haptic technology, this device can also provide feedback for navigation purposes, allowing blind individuals to navigate and explore their environment more independently. These braille-based vibrotactile devices usually come with the flexibility to handle various languages and braille codes [4]. It is easy for users to switch from one language option/dialect to another while in their preferred system, thus providing a sense of global inclusion.

II. Perception of Vibrotactile Sensation

To better understand the perception of vibrotactile sensation, there is a need to discuss the physiology behind any tactile perception. The most widely accepted theory that explains this is the four-channel theory, which suggests that our skin has four dedicated channels for tactile sensations: pressure, vibration, texture, and temperature, which have distinct sets of receptor types and neural messages that reach the brain.

Pressure perception is often regarded as the first channel in the four-channel theory. There are special receptors known as Pacinian corpuscles which can be found on our skin and are sensitive to any change in pressure exerted against the surface of the skin. The receptors transmit information regarding the level, position as well and direction of pressure. The second sensory channel is vibration, which is facilitated by the activation of Meisner's corpuscles. These specialized receptors are sensitive to high-frequency vibrations and allow us to perceive subtle differences in texture and sound. Research has demonstrated that applying vibrations on the skin also activates Meissner's corpuscles and sends electrical signals to the brain, where they are interpreted as tactile sensations.[5]

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Texture perception, through the third channel, is essential for distinguishing and recognizing objects through touch. It enables us to differentiate between a smooth surface and a bumpy surface, among other delicate patterns and textures. Texture is very sensitive and needs appropriate simulation, for this reason, vibrotactile actuators come in handy since they vibrate in a broad spectrum of frequencies and can simulate several textures.[6]

They may lack the capability for sensations on contact but they reproduce vibration patterns unique to various types of touch. Tactile stimulation activates the cutaneous mechanoreceptors in our integumentary system which generates mechanical waves that sweep across surrounding soft tissues and excite widespread tactile afferents. They constitute afferents transmitting information to the brain that help us sense touch and give tactile feedback.

The fourth sense of touch is temperature. The thermoreceptors in our body can detect temperature variations and send signals to the brain, allowing us to perceive hot and cold sensations. These thermoreceptors are located all over the skin and are particularly concentrated in areas such as the fingertips and other extremities,[7] where temperature sensitivity is crucial. When exposed to different temperatures, these receptors generate neural impulses that are interpreted as sensations of warmth or coldness.

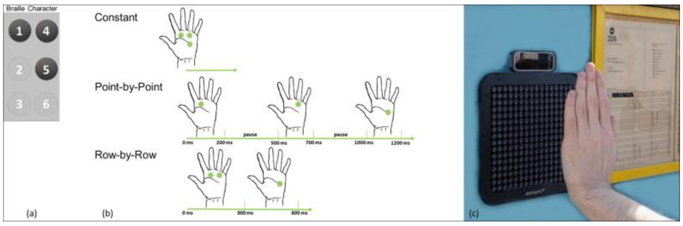

Figure 1: Haptic technology

Understanding temperature as a haptic perception modality is essential in various applications and technologies. For example, in the field of virtual reality, incorporating temperature feedback can enhance the sense of immersion and realism by providing subtle heat or cold sensations corresponding to virtual objects or environments. Furthermore, temperature feedback in medical applications can be used to monitor and control the temperature of surgical instruments or devices.

What is intriguing about this is that tactile feeling is not just about sensation from those mechanoreceptors. There are considerable indications that we may also be impacted by vision and sound for tactile perceptions.[8] An example is having the opportunity to see something before feeling it, for instance, allows the body to develop some kind of idea about that specific object's nature whether soft or hard, large, rough, etc which will then affect the way we experience its feel. Our brain combines these multisensory inputs to create a comprehensive feeling of touch helping us better relate to and comprehend our surroundings.

When it comes to touch perception, there are two main modes: single-site touch and multiple-site touch. To put it differently, single-site touch constitutes any kind of pressure on the body e.g., we place our finger on a surface. This term, multisite touch, describes the simultaneous stimulation of several parts of the body, for example, by rubbing smooth one's hand.[9] These different modes of touch perception should be understood to devise a comprehensive and holistic haptic technology.

III. Understanding Vibrotactile Devices

Haptic devices that apply vibration on the skin to elicit tactile sensations are known as vibrotactile devices. Such devices usually comprise actuators like motors or solenoids for vibration generation at particular frequencies and magnitudes. Vibrations may be felt by the mechanoreceptors found on our skin, especially Pacinian corpuscles and Meissner's corpuscles[10], which are specifically sensitive to vibrations and provide us with a sense of touch. Vibrotactile devices are employed in haptic media and they pass information to users through tactile sensations. [11]Haptic devices generate various kinds of tactile stimuli by vibrating vibrotactile actuators at different frequencies. Vibrotactile displays represent an exciting modality through which to convey information in the field of haptic media, affording users informative and naturalistic tactile feedback that supplements their sensory experience[12]. Vibrotactile devices help us feel touch better as they stimulate the sensory nerves in our skin vibrations. Such a type of mechanoreceptor is activated in the skin thus allowing replication of tactile perception like texture, force, or compliance. Different variables must be considered when designing and implementing vibrotactile displays. Some of these factors include choosing appropriate vibratory actuators with wide frequency ranges, understanding people's vibrotactile perception capabilities, and ensuring that tactors are correctly placed and attached to provide localized and consistent sensations.[13] Accordingly, it is critical to develop a broad operating The use of vibrotactile devices is increasing these days, as researchers and designers realize their ability to improve usability in diverse sectors like virtual reality, gaming, rehabilitation, and assistive technology[14].

In recent years, more and more people have started to recognize the potential of these vibrotactile devices to enhance user experience in almost all fields, such as virtual reality, gaming, rehabilitation, and assistive Technology. For instance,

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vibrotactile devices can be used in assistive technology to offer tactile feedback for individuals with vision impairments for better navigation.[15]. Vibrotactile actuators are also the key components in the development and implementation of haptic communication systems, providing users a chance to directly share tactile information among themselves and their surroundings [16].

Such systems would enable users to experience haptic sensations across distance and an entirely new dimension in our communication and interrelation. With the introduction of vibrotactile technology, there has been a move towards modernizing haptic technology, allowing for simulations of tactile sensations and improved user experiences across different disciplines and also playing a major role in healthcare. Adding, vibratory feedback has been indicated to increase task performance and user satisfaction in sensor motor tasks [17]. However, integrating vibrotactile haptic feedback is likely to enhance the immediate perception. Therefore, its use in designs and systems can provide users with better perception, interaction, and overall rehabilitation experience [18].

IV. The Connection between Text Input and Braille Translation

Text input is associated with Braille translation through the process of converting written information to tactile data for visually impaired people. The written text in the software will be converted into vibrations that can be sensed by the user's fingertips, which means that they will feel the inputted characters and words translated into Braille. Using tactile feedback such individuals are capable of communicating effectively, accessing information, and closing the gap between visual text and Braille conversion. Vibration stimulation through text input and Braille translation systems helps provide real-time feedback to the users and check the correctness of the Braille translation.[19].

One example of this is demonstrated by the UbiBraille prototype, where six vibrotactile rings are worn on the fingertips as part of the text input process and to provide haptic feedback. These vibrating rings correspondingly vibrate to the typed characters enabling the user to confirm his input through feeling it in his fingers. Research has also established that including vibra-touch or vibrotactile feedback while reading braille can enhance reading speed and efficiency. Additionally, vibrotactile feedback has become a useful tool for supporting blind persons to perform many activities through Braille-enabled devices.

The improvement in vibrotactile feedback for scrolling (and inputting) tasks over mobile devices is better than the interface without vibrotactile feedback. Therefore, integration of vibrotactile actuators into Braille translation systems can greatly improve the end-user experience by providing instantaneous tactile feedback whenever the user types.

These include the development of vibrotactile technology and stimulation methods that address issues related to training, accuracy, throughput, and portability. Individuals can now encode alphanumeric symbols into tactile patterns for better word transmission. Combined with wearable gloves or sleeves, the portable Braille-enabled devices are now even more portable, allowing people to carry and use them anywhere they need. Studies have also demonstrated that haptic feedback can reduce error rates, and increase efficiency, and user satisfaction in sensorimotor tasks [20].

Generally, the inclusion of vibrotactile technology in Braille-enabled devices has demonstrated promising improvements in accessibility and usability among the visually impaired population.

V. Design and Functionality of a Vibrating Tactor Array

The design and functionality of a vibrating tactor array are crucial for the effective implementation of haptic feedback in Braille-enabled devices. Haptics are important in designing an efficient vibrating tactor array for vibratory feedback devices with Braille features. In particular, it is composed of a multitude of tactors organized to give precise information through the fingertip. Each tactor is positioned and oriented in a specific manner to ensure that it replicates certain Braille dots. For effective haptic feedback, the vibrating tactors in the array should share the same vibration patterns, frequency ranges as well as amplitudes.

Moreover, the tactors need to be light and energy efficient as users may have to wear the device for long hours. The flexibility and the comfort of the device are other factors that should be considered in its design. Flexible materials and ergonomic designs will make the vibrating tactor array comfortable to wear and non-restrictive in movement. [21]

Localization and the sensation magnitude are also important aspects of the vibrating tactor array design. The placement of each tactor in the array must be done with care so that they give feedback to the user's fingers correctly and very precisely. This makes it possible for the user to identify the differences in Braille characters so that he or she can navigate the text appropriately. However, for more benefits that spatially localized vibrotactile feedback can provide, using vibrotactile arrays comprising many factors can be a probable answer.

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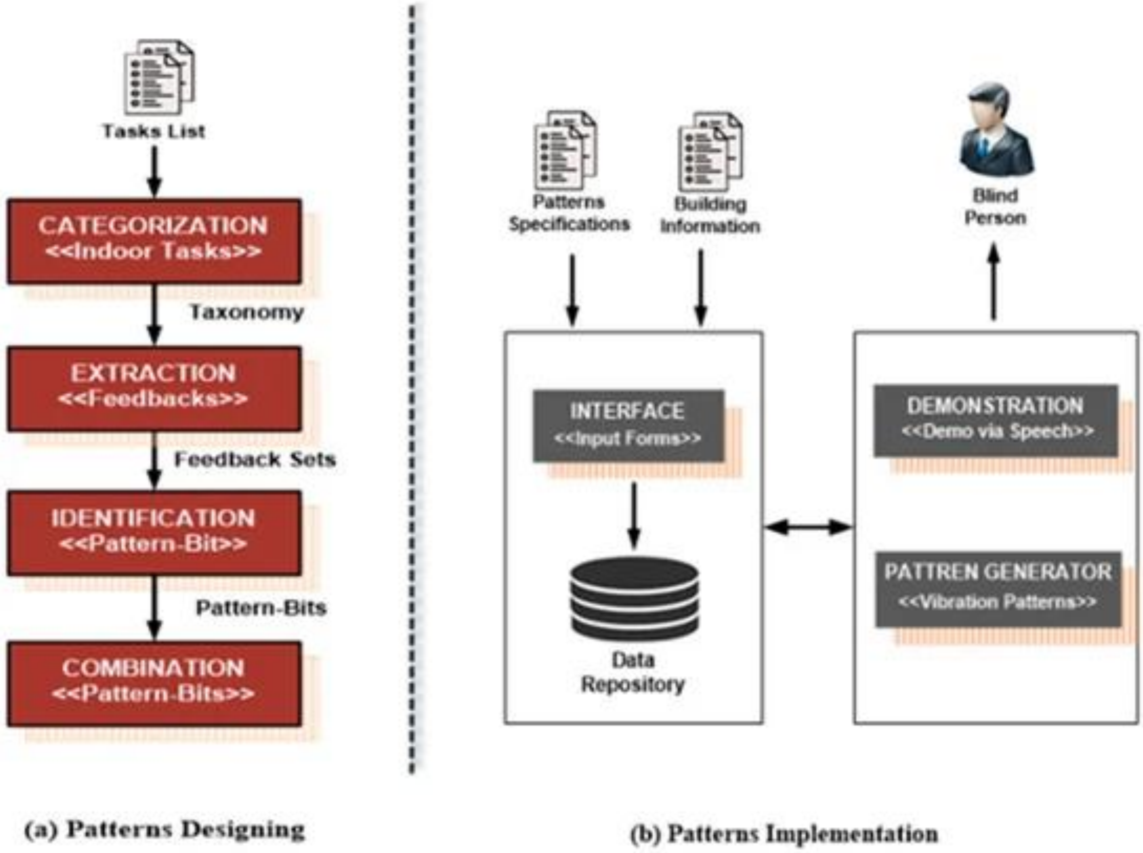

Figure 2: Design and Implementation

Adding more tactors in the array minimizes ambiguity to provide detailed and distinctive information to the user. Furthermore, the intensity or degree of sensation created by the vibrating tactors should be adjustable for purposes of accommodation to different user sensitiveness and preferences. Amplitude control mechanisms can be integrated into the vibrating tactor array, this can help to attain this [21]. In addition, haptic feedback needs effective communication between the Braille-enabled device and the user.

Haptics Actuators

The primary feedback components in vibrotactile haptic devices are the actuators, which can come both as readily available in the market or custom-made vibrotactile actuators. These vibrating actuators can work in different ways but essentially give the same vibration feedback. The different types of actuators usually used to make these assistive vibrotactile devices are mentioned in Table 1.

Table 1: Overview of Actuators Used In Assistive Haptic Technology

Actuator Type	Description	Characteristic	Application\Challenges	Cost
ERM	DC motors with eccentric mass	- Frequency and amplitude not independently controllable - Hysteretic response speed - Limited diversity of vibration waveforms	- Simple vibration needs in small device parts	Cheap
LRA	AC-driven resonant frequency with voice coils	- Faster response than ERMs - Works in a narrow frequency range - Residual vibration	-Larger sizes lead to slower response speeds and increased energy consumption -Limited frequency range - Residual vibration - Sensitivity to environmental factors	Very High

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Electrostatic	Uses attractive forces between capacitor plates	- Simple design, suitable for MEMSs - Potential for pull-in instability - Performance affected by external factors like humidity	- Potential pull-in instability - Performance affected by external factors.	High
Piezoelectric	Converts electrical signals into physical displacements	- Accurate with fast responses - High acceleration rates and forces - Potential for miniaturization - High-definition tactile sensation	- Larger forces with smaller displacements - High voltage input requirements	Medium
Electrostrictive	Uses electrostrictive relaxor ferroelectrics or EAPs	- Quadratic relationships cause hysteresis and drift - EAPs are light, flexible, and cost -effective but may have smaller displacements requiring high driving electric fields	- Hysteresis non-linearity and drift behavior - EAPs may have smaller displacements requiring high driving electric fields - Exploration for haptic devices, mainly used in artificial muscles	Very high

Out of the different actuators mentioned in this table, one actuator that stood out to us is based on ERM, as it was the cheapest and most affordable type to effectively achieve our objective. Their simplicity, reliability, and cost-effectiveness make them a popular option in the realm of tactile feedback. With an ERM, you benefit from a straightforward design featuring a DC motor paired with an eccentric mass, ensuring easy integration into your devices without introducing unnecessary complexity. If your goal is to provide basic vibrational alerts or notifications—common in mobile phones, gaming controllers, or wearables—ERM actuators offer a tried-and-true solution. Their familiarity and proven performance make ERMs a go-to option, allowing you to enhance user experiences through a straightforward and reliable tactile interface without compromising on efficiency.

VI. Implications and Benefits of Haptic Technology for Blind Individuals

The use of haptic technology particularly Braille-enabled vibrotactile devices is essential and helpful for the visually impaired population [20]. The tactile form of braille is one example of such a device that allows blind people to interact with written information thereby enhancing inclusivity in their day-to-day activities. Haptic technology goes further than just reading Braille or other raised letter characters to be interpreted by a blind person.

These include increased spatial awareness and navigation. Integrating spatially localized vibrotactile feedback into wearable devices improves the tactile guidance of blind people's movements and makes it simpler for them to navigate environments. Take, for instance, a haptic device that offers vibratory patterns indicating obstacles or landscape changes to let people move in uncommon settings with enhanced security and confidence.

Figure 3: Practical implementation of Haptic

Haptic technology offers another benefit to the blind, especially the possibility of more effective communication and contact. Vibrotactile devices with Braille can convey information through tactile devices to facilitate visual impairment-free communication and interaction.

Another example is that a blind person may use a haptic device to have some text SMS or email sent in the Braille format so that he/she can better stay informed and participate in the community more widely.

Challenges and Limitations of Current Haptic Devices

Despite the numerous benefits and potential applications of haptic technology for blind individuals, there are also several challenges and limitations associated with current haptic devices. However, these devices suffer from a lack of scalability and affordability as one major challenge. Haptic devices that have touch-sensitive vibe features are either

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costly or not easily available for everyone. Also, their bulkiness is considerable, which makes them inconvenient or less portable [17]. Another difficulty is that there are no defined standards for developing and sending haptic materials thereby inhibiting the variety of the information and media that can be attainable by blind people.

Haptic devices should be safe and reliable, especially for medical applications. Surgeons can make use of haptic devices to experience the actual sense of touch and tactile feedback for medical training or in real procedures. It could improve surgical precision and thereby increase the quality of patient care. Nevertheless, extensive testing and verification of haptics' safety and efficacy are a must before the implementation of this technology in medical practice. Haptics devices must be subjected to stringent testing and compliance requirements by regulatory bodies to ascertain their safety before allowing use in the market. This covers the assessment of its electrical safety, mechanical stability, as well as bio-compatibility.

Future Directions in Haptic Technology

Haptic technology will continue to progress in providing help for people with vision disabilities and overcome any existing constraints [19]. Haptics, researchers, and developers are endeavoring to make haptic devices more scalable, affordable, and user-friendly. Such efforts are directed towards designing small and lightweight devices that the blind can easily transport from place to place and employ in diverse settings.

The efforts here include standardization of haptic materials and formats to broaden the coverage of the type of information and media used for blind people. Such should result in the creation of standards and procedures for the generation and transmission of tactile data between multiple equipment systems working on respective devices and networks. Haptics for specialized applications, including medical training and surgery is also an area of concern. Haptic tools for the next-generation surgeons under research to enhance realistic touches and tactile feedback during medical operations are working on designing haptic devices that can provide surgeons with a realistic sense of touch and tactile feedback during medical procedures. Safety and reliability also play a significant role in designing haptic devices for use in medicine. It is essential to ensure adequate rigorous testing and verifying of safety and efficiency of the haptic devices before utilizing them within a medical setting. All these devices must be subjected to tough testing, meet the standards of compliance in electricity and mechanics, and demonstrate compatibility with biology [18].

However, the prospect of applying haptic technology in sight assistance looks very promising too. The ongoing research and developments are aimed at solving current haptic scalability, affordability, and usability problems. Attempts are being undertaken to develop compact and movable gadgets, which blind people can carry with them and use in different locations.

VII. Conclusion

The challenges of scalability, affordability, and usability are being addressed through subsequent iterative research and development on haptic devices. They aim at producing small, mobile devices that visually impaired persons can carry along and use at various places. In addition, haptics have a huge application potential for specific tasks like medical training and surgery. Surgeons encounter a more lifelike textural sensation while researchers strive to improve touch and physical response during medical operations. Ensuring safety and reliability are primary concerns when designing haptic devices for medical purposes. The effectiveness of these measures is heavily dependent on rigorous testing and validation processes that aim to identify any existing dangers. Haptic interface devices should improve surgical operations safety by providing surgeons realistic feeling of touch in an environment that is more accurate than their natural one.

In addition, haptic-based technologies could make it possible for blind people to assist themselves in seeing without a necessity in medical applications. Researchers continue working on issues of cost, size, and ease of use of haptics. Small and mobile devices are coming into existence for blind persons who can carry them to any place of need and use them.

REFERENCES

[1] Chen, C., & Ding, S. (2019). How the skin thickness and thermal contact resistance influence thermal tactile perception. Micromachines, 10(2), 87.

[2] Rouhafzay, G., & Cretu, A. M. (2019). An application of deep learning to tactile data for object recognition under visual guidance. Sensors, 19(7), 1534.

[3] Kuroki, S., Hagura, N., Nishida, S. Y., Haggard, P., & Watanabe, J. (2016). Sanshool on the fingertip interferes with vibration detection in a rapidly-adapting (RA) tactile channel. PLoS One, 11(12), e0165842.

[4] Choi, S., & Kuchenbecker, K. J. (2012). Vibrotactile display: Perception, technology, and applications. Proceedings of the IEEE, 101(9), 2093-2104.".

[5] Jeong, W. (2005, October). Touchable online Braille generator. In Proceedings of the 7th International ACM SIGACCESS Conference on Computers and Accessibility (pp. 188-189).

ISSN (online): 2581-3048
Volume 7, Issue 12, pp 289-295, December-2023
https://doi.org/10.47001/IRJIET/2023.712039

[6] Remache-Vinueza, B., Trujillo-León, A., Zapata, M., Sarmiento-Ortiz, F., & Vidal-Verdú, F. (2021). Audio-tactile rendering: a review on technology and methods to convey musical information through the sense of touch. Sensors, 21(19), 6575.

[7] Islam, Md Shafiqul & Lim, Sol. (2022). Vibrotactile Feedback in Virtual Motor Learning: A Systematic Review. Applied Ergonomics. 101. 10.1016/j.apergo.2022.103694.

[8] Gonzalez-Rodriguez, A., Ramon, J. L., Morell, V., Garcia, G. J., Pomares, J., Jara, C. A., & Ubeda, A. (2019). Evaluation of optimal vibrotactile feedback for force-controlled upper limb myoelectric prostheses. Sensors, 19(23), 5209.

[9] Nicolau, H., Guerreiro, J., Guerreiro, T., & Carriço, L. (2013, October). UbiBraille: designing and evaluating a vibrotactile Braille-reading device. In Proceedings of the 15th International ACM SIGACCESS Conference on Computers and Accessibility (pp. 1-8).

[10] Nicolau, H., Montague, K., Guerreiro, T., Rodrigues, A., & Hanson, V. L. (2015, May). Holibraille: Multipoint vibrotactile feedback on mobile devices. In Proceedings of the 12th International Web for All Conference (pp. 1-4).

[11] Williams, S. R., & Okamura, A. M. (2020). Body-mounted vibrotactile stimuli: simultaneous display of taps on the fingertips and forearm. IEEE Transactions on Haptics, 14(2), 432-444.

[12] Okamoto, S., Konyo, M., & Tadokoro, S. (2011). Vibrotactile Stimuli Applied to Finger Pads as Biases for Perceived Inertial and Viscous Loads. IEEE transactions on haptics, 4(4), 307–315. https://doi.org/10.1109/TOH.2011.16

[13] Kim, J. I., Jo, G., Koo, J. H., Kim, D. J., Kim, Y. M., & Yang, T. H. (2022). Development of a Thin Vibrotactile Actuator Based on the Electrostatic Force Mechanism for Large Haptic Touch Interfaces. Mobile Information Systems, 2022.

[14] Chen, J., Teo, E. H. T., & Yao, K. (2023, February). Electromechanical Actuators for Haptic Feedback with Fingertip Contact. In Actuators (Vol. 12, No. 3, p. 104). MDPI.

[15] Lahav, O., Schloerb, D. W., Kumar, S., & Srinivasan, M. A. (2011). A virtual map to support people who are blind in navigation through real spaces. Journal of Special Education Technology, 26(4), 41-57.

[16] Andò, B., Baglio, S., Marletta, V., & Valastro, A. (2015). A haptic solution to assist visually impaired in mobility tasks. IEEE Transactions on Human-Machine Systems, 45(5), 641-646.

[17] Kirschner, H. E., & Streeter, H. (2021). Considering the Use of Haptic Feedback in Navigational Technologies for the Blind and Visually Impaired Population.

[18] Kumar, D., Khan, F., & Islam, S. (2010, February). Mobile SMS to Braille transcription: a new era of mobile for the blinds. In Proceedings of the International Conference and Workshop on Emerging Trends in Technology (pp. 70-74).

[19] Dangxiao, W., Yuan, G., Shiyi, L., Zhang, Y., Weiliang, X., & Jing, X. (2019). Haptic display for virtual reality: progress and challenges. Virtual Reality & Intelligent Hardware, 1(2), 136-162.

[20] Harrison, J., Lucas, A., Cunningham, J., McPherson, A. P., & Schroeder, F. (2023, July). Exploring the Opportunities of Haptic Technology in the Practice of Visually Impaired and Blind Sound Creatives. In Arts (Vol. 12, No. 4, p. 154). MDPI.

[21] Shazhaev, I., Mihaylov, D., & Shafeeg, A. (2023). A Review of Haptic Technology Applications in Healthcare. Open Journal of Applied Sciences, 13(2), 163-174.

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