An Overview on Tactile Display, Haptic Investigation towards Beneficial for Blind Person

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Abstract— This paper presents the intellectual issue with proper information of several improvements on tactile display and haptic oriented research. Through this paper a specific study approach is implemented towards the tactile display with interdisciplinary action. Mobile apps and sophisticated Braille technologies are previewed with informative and comparative way. This overview focuses mainly on tactile prototype development issue with chronological research territory. Concisely, the advance level product based beneficial approach for visually impaired is presented infomatively. In addition, this study is carrying its importance towards the beneficial development of tactile display for visually impaired people in our society.

Keywords — Applications of Braille technology, B-Touch Mobile Phone, Braille Polaroid Camera, Braille Rubik Cube, Braun Bell Concept Mug, Colour Sensor, Eye Stick, Feel the Time, Finger Reader Gadget, Gadgets for visually impaired, Haptics Advancement, Haptic Set Of Flash Cards, Navigation Bracelet,Tactile display, Touch Color Painting Tablet, Wearable devices.

1 Introduction

THE tactile display has carried a crucial research area now a days as according to WHO (World Health Organization) there are about 285 million visually impaired worldwide. There have been various successful applications of tactile display being a utility for blind peoples [1-2].The visually impaired peoples are missing the most utilitarian receptor of all six receptors of human body i.e., Eyes. To overcome this paucity these peoples have been blessed with a very powerful touch sense. Appling touch sensing ability blind peoples grope the surrounding worlds as well as being able to read, write. The Braille Technology pioneered by Louis Braille in the year 1824, beneficiate towards blind people to interact with knowledge introducing the touch sensing publishing his first Braille book on musical notation in the year 1829 [3]. Braille system approaches presented the all character by combination of embossed dots on a six dot cell is getting used, standardized globally for various languages as well as symbols.

To enhance human – machine interaction for blind people lot of research work is being carried out till now along with a lot of new concepts all over the world. As outcomes various types of tactile display has been developed using the concept of stimulation by vibration or pressure. Various directions have been found in advancement of tactile display like general conversion of text or graphics into Braille notation, miniaturization in tactile display to develop various wearable display, incorporation of tactile display in mobile devices like phone handset, PDA etc. A brief of technological overview listed here with relevance to tactile display. In a brief, the haptic research presented its impotencies for visually impaired to produce innovative research with interdisciplinary technological aspects.

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2 Advanced Product Based Beneficial Technology Towards Blind People

As in respect of different conceptual advancement in utility devices & lifestyle products the technologies enhance & uplift lifestyle of visually impaired with elegance & comfort did came from the necessities. From over a decade visually impaired people use walking sticks for navigation everywhere. With the application of The Eye Stick with enhanced features concept the blind people accurately percieves their bearings in an environment by means of sonic vibration that is being fed from the sensor [4]. The Eye Stick is fitted with a sensor lens towards the bottom part and it picks up location bearings such as traffic lights, stairs, the subway etc. For each person as well as visually impaired people, there has been a necessity for realizing the time, thus Feel the Time concept is makes it brilliantly simple [5]. The minimalist black face of the watch features two separate discs for hour & minutes, each with one tiny nub. A break in the outer circle at the 12 o'clock mark acts as a guide to get an accurate reading by touch sensing only.

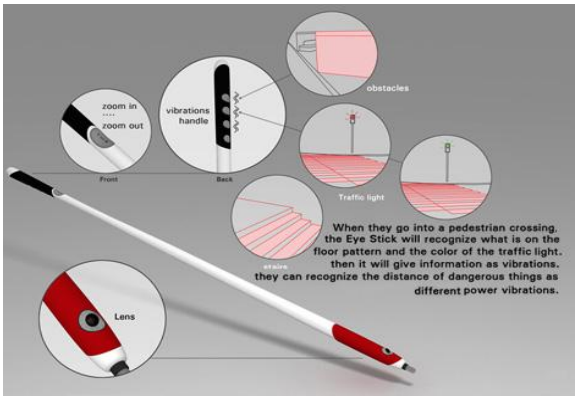

Fig. 1. The eye stick that sends sonic vibrations in response of visual structure & colour detected [4].

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There has been another fabulous concept towards navigating a visually impaired person in an unknown surrounding by means of Navigation Bracelet concept [6]. The specially designed device looks like a modern piece of plastic jewelry is actually a navigation system that uses GPS as input, voice commands and haptic feedback as output. The device will track the movements of the wearer while integrating data from GPS satellites, when indoors; it will use visual information from cameras, and wireless information from pedestrian signals in order to enhance safety and mobility. It is designed to be able to work in challenging unstructured environments. Beside of these the B-Touch Mobile Phone concept makes it a giant leap towards modern technologies like cell phone to make the life of people with impairments easier [7]. This is a touch screen device that uses braille technologies, voice activated systems and software including voice activated dialing for better interaction with the user. The handset can be used as a navigation device, book reader and object recognizer

Fig. 2. B-Touch mobile phone with Touch Screen braille display, camera, GPS, speaker & character detection technology [7].

by means of inbuilt camera & GPS. Though braille printer is a reality now days, each book can't be converted. Thus to make different books readable by visually impaired people there has been a concept of Finger Reader Gadget [8]. Developed by MIT researchers, currently in prototype phase, the Finger Reader is essentially a ring that can be used to follow a line of

Fig. 3. Finger Reader detects letters & response with sensation and sound [8].

text in a book or on an electronic device screen. By using built-in camera, the gadget detects 12-point text, that will then be read aloud by the in camera, the gadget device. It can also recognize deviation & end of the line of text and offer feedback to adjust hand movement. For detection of colour by blind people there has been a concept of Colour Sensor by associating each colour with a particular sound [9]. A color sensing device consists of two different color sensors, a microcontroller and a display. The performance of the sensors was evaluated by converting the red, green, blue (RGB) values they produced back into colors on a computer and then comparing these colors with the colored tissue paper, hence it's utilitarian for visually disabled peoples. Another colour related concept has been developed as Touch Color Painting Tablet for the visually impaired person [10]. The Touch Color tablet uses thermal energy and a hand-held color wheel to create works of art. The color wheel can be used to select colour and even

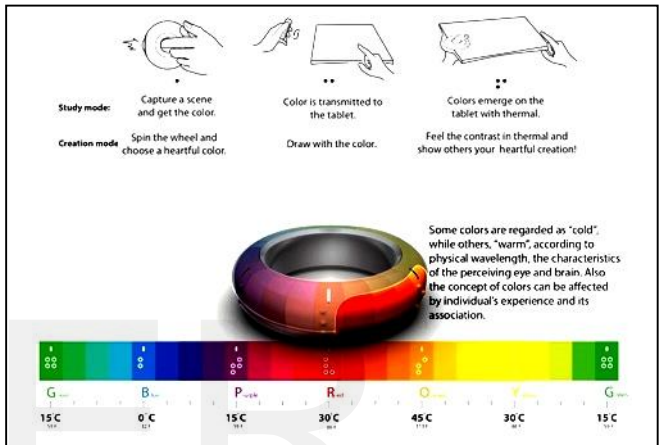

Fig. 4. Touch Colour painting tablet that detects colour & sprays to the tablet to creat a masterpiece [10].

capture actual colors from a user's environment and transmit it to the tablet, thus, creating stunning artwork without ever having a real sense of color. Touching an object helps a blind person get a sense of what it is, but unlike the sighted, they can't use photographs to capture and keep memories. The Braille Polaroid Camera, however, acts as an instant braille printer, translating the basic shape of an object into

Fig. 5. Braille Polaroid Camera with captured image [11].

texture so that the blind can collect "images" in an album [11]. Blind people can't identify the level of hot liquid pouring into a mug. Most of them have to use their fingers, but the awe-

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some Braun Bell Concept Mug by Sang-hoon Lee and Yong-bum Lim makes the process much more safe and sanitary[12]. The mug emits a certain sound when liquid reaches each

Fig. 6. Braun Bell Concept Mug with level sensor, level selector & speaker output [12].

water sensor. Thare has been a provision to even set the level they desire. Visually impaired peoples can't see, hence rely upon hearing and of course touch in order to learn. Haptic Set Of Flash Cards imprinted with the name of an object in Braille on one side and a physical texture on the other are a particularly effective way to become familiar with new things for blind persons [13]. To enhance problem solving ability & brain exercise Rubik Cube has been invented thus for the blind there a design has been developed as Braille Rubik Cube [14]. This Braille-equipped version consists of colors embossed include green, blue, red, yellow, white & pink is certainly an interesting challenge even for those who aren't visually impaired.

3 Interdisciplinary Research Overview on Tactile Display

With acceleration of modern technology the tactile display related research have been enriched with several scientist. As this braille technological overview carried an ever growing interdisciplinary research preview towards proper mentoring of modern research flow from traditional action. Mainly, intellectual property oriented and model based industrial approaches are presented with proper technological manner. The first to above race, in the year 1966, a concept had been proposed by John G. Linvill et al. expressing the process of impression of printed matter is focused on a set of photocells coupled one-to-one to piezoelectric reeds making the tactile image processing pins vibrate and facsimile the printed material presented tactually [15]. After 3 years of effort onsame track it had been possible to find the way of aiding a vehicle operator to control his vehicle utilizing haptic tactile display system containing various useful information utilized by the operators in subsequent operations to obtain control over the vehicle [16]. Following the same way, at Stanford research Institute, J.C. Bliss et al. developed a rebellious concept of optical-to-tactile image conversion systems using 24-by-6 array of pins driven by piezoelectric bimorphs to construct the first reading aid along with a concept stating by maintaining a precise measurement various shades of gray is displayed by varying the threshold level [17]. On refashioning the effort, Millard J. Ickes fabricated a scene scanner with a tactile display to utilize electrically invigorated pins giving tactile display rendering the shape of object using a lens system focused on a matrix made up with optical sensor connected to display pins [18]. Based on Electro-mechanical operation a control unit has been designed to assist one-to-one tactile communication with variation in pressure and volume of responsive grip attachment by Thomas D. Shannon [19]. On further rework haptic man-machine communication system found its configuration by A. Michael Noll using sticklike mechanism controlled by servo motor and enliven by signals generated by computer as per stored definition of 3-D entities felt by sober touch of operators [20]. Following the concept behind all analogous devices a graphic capable tactile display with projecting pages forming Braille symbol had been fabricated in the year 1991[21]. Even after invention of above concept graphical approach in application software used by modern computer was significantly burdensome for blind peoples to use. In later half of same year an experimental evaluation of recognition performance was carried out by Steven F. Wiker et al. under various conditions like vibrotactile sensation on hand, size and complexity of graphical elements and variation in pixel- to- tactor mapping. Finally a conclusion came out stating the resolution of tactile display is more important in terms of recognition accuracy and response rate than the locus of stimulation [22]. To identify the condition for best recognition, in 1992, Morton A. Heller carried out a set of experiments and concluded with a concept saying performance of tangible array depend on its orientation, physical position of stimuli along with a best Braille recognition accuracy on vertical orientation of tactile board [23]. Coming behind with the same aim, in the year 1993, Joerg Fricke of Germany invented a novel approach towards tactile graphic display screen utilizing an array of electrode attached to pits filled with electrorheological fluid and a membrane over the top surface. Valves coupled to the electrodes connect and disconnect the pits containing fluids exerting specific pressure on membrane. Blind peoples grope information by touching the membrane [24].In the year 1994, Frank A. McKiel, Jr., have contrived the method of tracking down the position of icons in GUI (Graphical User Interface) by generating distinctive sounds of various chords of tone as per the position of pointer [25].With an aim of more effectual Tactile display design, Masami Shinohara et al. have assembled a 64X 64 arrangement of vertically movable pins with 3 mm spacing allowing pins to move to a maximum height of 10 mm with a step of 0.1 mm with certain information for variable haul up in the year of 1998[26].A totally new approach was invented by Frank Albert McKiel, J r. after two years. As per the invention an identifiable audible signal is associated with each individual displayed element by a periodic generation of composed audible signals as per the radius of cursor location on the computer monitor along with the process of identification of each pictorial element in similar way [27].Facilitating the concept of J.C. Bliss et al. of Stanford research Institute, proposed in the year 1970 [17], Nizamudeen Ishmael JR. et al. invented an Interactive Tactile Display for Computer Screen in the year 2002.The appliance encompasses a means for converting incident light from the visual image into electrical signals inversely proportional to the gray scale intensity of the light along with a tactile display device having a two-dimensional array

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of dynamically variable height pixels, proportion to the electrical signals. The invented device has been assessed and patented in 2003 [28]. On promotion to existing work on Braille display, Kirk Tecuet al. devised a Tactile Display apparatus In 2003, The said device consist of a set of tactile output elements ordered in a 2-dimensional array of movable output elements corresponds to at least one pixel of the computer monitor, in response to an input value of pixel, to a predetermined level as per tactilely recognizable positions of tactile output elements providing a tactilely- recognizable pattern representing the information along with each position representing an n-bit gray scale value of said pixel providing tactilely-recognizable information relating to the computer screen image. The device obtained its recognition and had been patented next year [29]. In consideration of Joerg Fricke the novelty presented in the year 1993 with electrorheological fluid aspect [24], a marvelous scheme has been used by Jun Funaki to design a device consists of electrorheological fluid changing its viscosity with the change of conductivity of photo conductive layer changing as per display pattern from display board. Change in viscosity converted to the tactile information, the effort carried out towards Patent in 2009 [30].An Aristocratic approach has been proposed by Velazquez R. et al. in 2006. The prototype consists of an arrangement of pins propelled by shape memory alloys (SMAs) with 2.6 mm horizontal resolution and 1 mm vertical excursion producing it very light weight of 200 g hence easily portable [31]. As per survey in January 2006, only around 50,000 people in the USA could read Braille whereas there are 10 million blind or seriously visually impaired along with 1.5 million legally blind causing a requirement of alternative device assisting blind people to read even without knowing Braille. Utilizing electromechanical components to display a tactile conversion of letters, numbers and symbols containing rotating linear components and pointer variations, Brian Paul Hanley modeled such an utility device based on shape consisting of some movable part rotating or sliding instead of embossing like all existing device till 2006. The highly utilitarian device considered as a patentable invention in next year [32]. With a great review on various hypotheses and invention on tactile display till 2007, March Fernando Vidal-Verdúet al. mentioned various advantage and disadvantages of existing Braille display along with various advancement on research on specified area. As per the survey lot of concept originatedlike designed Tactile graphical display was enough ponderous to store as well as transport more over the devices are expensive, time consuming to fabricate. With an intension of rectifying frailties, research had been continued furnishing with lot of devices along with concept behinds.The work in said field has diverged into diverse areas considering from physiological studies to technological aspects and challenges showing the interest by other fields such as virtual reality, minimally incursive surgery and tele-operation gradually attracting more and more people in research besides money [33]. The 60 X 120 pin-matrix device is made up of a newly developed type of vertical Braille unit with multi touch features allowing for a compact assembly of all imperative components making it touch sensitive along with capability of detecting multiple points of contact [34]. Before 2009, most of the approaches to extracting surface text from videos were based on low-level features such as edge, color, texture information experiencing hindrances in handling textswith various contrasts or inserted in a complex background. A novel blue print to detect and extractthe text by formation of a transition map from the video scene consisting of transient colors between inserted text and its adjacentbackground was proposed.The detected text regions are localizedaccurately utilizing the projection of text pixels in the transition map conducting the final text extraction providing a robust method to different character size, position, contrast, and color as well as language independency with a reduce in processing time [35]. A tactile display had been obtained its shape in the year 2009 by Michael skinner. The gadgetconsist of the ability of codifying color of displayed image for blind peoples by providing various physical attributes like heat, vibration intensity to individual pins representing color or brightness. In 2013, developed color detecting device has been recognized by obtained Patent [36]. As a result of incessant research on tactile display, In the year 2010, at Korea Institute of Science And Technology, Sung Chul Kang et al. has proposed more compact device having set of vertically movable stimulation pins mounted on a closed rack with opening at one surface allowing stimulation outward to sense by touch. The Device has been patented in August of 2012 [37]. Examples of Strategies have been provided regarding systems and computer accessible mediums related to tactile image processing by Ezekiel Kruglick, introducing hierarchical perspective. The devised haptic communication system has been accepted as well as patented in the year 2012 [38]. A totally new technology 'Tesla Touch' had been introduced by Cheng Xu et al. providing tactile sensation to moving fingers on touch screens making visually impaired people able to interpret 2-D information supporting communication among blind peoples [39]. After a detail analysis of the existing software utilized by the visually impaired people to use conventional computers, Prof. Reeta Singh in 2012, proposed a easily installable computer code in the form of a compact disk for reading the screen of computer consisting of a built-in speech synthesizer sounding like a robot via attached speakers of the computer concerned along with a characteristic of screen image magnification [40]. A concept oftactile display providing tactile feedback with a touch surface layer in form of set of pixels having aperture for ejecting fluid along with a valve for opening and closing the aperture to inject the fluid at a frequency for recognition by the sensors on the human finger skin. The technology proceeds to register intellectual property in the year 2012 by W. Jacksonet al [41]. Same year , Akihito Sano et al, following the same track in research, devised a special equipment with 3 vertically movable rods allowing the bottom end to glide over the surface of object exerting a stroke as per the top layer of object whereas the top end is being touché sensed by the skin of palm. The work-piece was accepted along with a patent in the year 2014 [42]. Aneffective approach has been came out of the review on Synthetic and Bio-Artificial Tactile Sensing carried out by C. Lucarotti et al.in 2013, stating the physiological study on human touch without relating the coding process of tactile information for artificial as well as bio-artificial skin [43].A simple, easily manufactured haptic graphic computer

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display has been invented in 2013 by Yu Jie Tsai.The computer module of designed device has been connected to a control unit consisting of arrangement of tubes with selectively extendible sliding part, movable in/out from tubes with electromagnetic parts to shape various pattern, graphs, digits as well as alphabets displaying at bottom portion of designed device [44]. With the financial contribution from Bulgarian National Science Fund, S. Simeonov et al. carried out assiduous research on graphical display for blind people in the year 2013 representing a brand new concept of simple graphical tactile display consisting of bi-stable solenoids with PIC controller along with the algorithm for row wise activation of active components [45].With an aim to bridge the gap between normal text book to its Braille notation a proficient hypothesis was contributed by D. Sreenivasan et al. in 2013, saying the printed text recognized by OCR, converted to ASCII code sending to microcontroller processing to corresponding Braille notation [46]. A very useful concept has been proposed on Audio-haptic Map Explorer by LiminZeng et al. in 2014.The system consists of a touch-sensitive pin-matrix display representing a pre-defined set of tactile map symbols consisting of vertically moving pins providing an interactive user interface allowing users to acquire auditory along with Braille geographic information by touching the involved map elements preparing pre-journey routes by exploring large-scale areas through zooming [47].In the same year Paolo Motto Ros et al. Proposed the design of a flexible dynamic tactile display device consist of 8X8 matrix of plastic pins with high resolution of 0.7 mm pin gap, tunable strength of displacement along with a good refresh rate by utilizing the already established reliable piezoelectric technology, providing reduction in arbitrary patterns and contingent user needs, rendering of non character information as well as reconfigurable rendering [48]. After 2 months of the said concept in July 2014 Jesse R. Cheatham, III et al. invented a system containing an ultrasound transmitter acoustically associated to an ultrasound conducting display surface, configured to deliver modulated ultrasound wave to the delineated area of display surface having a high power density and thereby producing a stress perceivable by the human touch sense [49]. In November 2014, a new variety of MEMS enabled, high resolution tactile display of 28-element prototype has been published in the Journal of Micromechanics and Micro-engineering by XinXie et al. fabricated with each element consists of piezoelectric extensional actuator along with micro fabricated scissor converting the in plane actuation into high amplitude, out-of-plane vibration being sensed by fingers, having displacement of 3mmX10mm exceeds 10 µm providing force exceeding 45 mN [50].

4 Wearable type Tactile Study for Visually Impaired

Towards the improvement for credential of tactile device, some of motivated researcher implements sophisticated and compact design. Light weight and handiness criteria mentioned on the commercialization oftactile products, scientists are presented several research study carryings its importance. Hong Z. Tan et al. proposed a wearable tactile directional display taking advantage of 'Sensory Saltation' along with a handful of facile interpretive applications [51] in 1997. Tactile displays are perfect for being utilized in wearable application because of its close propinquity to a large surface of human body i.e. skin. Based on above utility, in 2001 Gemperle F. et al. introduced few useful wearable implementation of tactile display [52]. In an international conference held in Korea in 2006, a spectacular concept had been presented by Igmo Koo et al. In the conference the concept of wearable fingertip tactile display came out an innovative tactile display device based on soft actuator technology having 4X5 actuator array with Electro Active Polymer(EAP) offering advantageous miniaturized devices with intrinsic flexibility, softness, high power density having easy as well as cost effective fabrication with options to wear on finger, palm as well as arm [53].In the year 2012 Ramiro Velázquez of Universidad Panamericana, alluded about various types of wearable assistive devices for the blind people in a book chapter published by Springer. It intended to review the most significant work done in the area of wearable tactile devices presenting the latest approaches for assisting visually impaired population along with universal design concepts for the wearable assistive devices and systems [54]. A newly designed wearable tactile display has been disclosed by PrakashCrj Naidu in 2014, employing two or more vibrating pins located close to each other in one curved plane by the help of underlying vibratory actuation piezoelectric bending elements fashioned in a cantilever configuration partially overlapping over each other as another set of planes providing the ability to be compatible with a curved human body part such as a fingers ensuring a proper sensation [55].

5 Mobile Interaction based Haptic development

With the drastic growth of application of Mobile phone technologies, the use of a cell phone became a part of our daily life introducing a new problem causing large population of blind people being missed the flavor of the same by missing utilization of messaging technique of communication. It has been essential to implement the concept of tactile display in mobile devices to ensure it available for use to visually impaired peoples for using texting as well as various apps of smart phones. Primarily, Topi Kaaresoja et al. devised a Mobile phone capable of transmitting and receiving of tactile sensation patterns, obtained Patent in 2005. Such device produce a tactile sensation in response to control signal introduced based on predefined instruction to interpret tactile sensation pattern generated on reception of a message containing tactile icons [56]. In 2006, Joseph Luk et al. mentioned that a vicious cycle introducing inadequate haptic technology obstructs the inception of various application, limits the advancement of use of haptics in mobile devices. A preliminary approach to break that cycle has been proposed introducing handheld display based on lateral skin stretch [57]. In the very next year, Eve Hoggan et al. of University of Glasgow proposed a Multi-actuator display for mobile phones in 2nd international conference on Haptic and audio interaction design held in Berlin.Till then almost all the systems was utilizing single actuator containing vibration as information being sensed by a sin-

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gle finger whereas, the proposed hypothesis shows the utilization of multiple actuators situated in four locations on mobile device containing 2D information being sensed with entire hand as well as fingers like lower thumb, upper thumb, index finger, ring finger [58]. Based on illustrious tactile illusions of apparent tactile motion as well as phantom sensation saying spatially separated vibrotactile actuators that stimulate different skin zones induce a tactile sensation midway between the two stimulation points, a spatially moving vibrotactile sensations using two vibrotactile actuators in a mobile device has been created by Jongman Seo of Pohang Univ. of Sci. & Technology in the year 2010. Various experiment with different vibration translating process, duration of signal, direction of sensation movement, a concept has been found stating the vibrotactile flow can be reliably produced in a mobile device providing a performance depending on the method and signal duration used for vibration rendering, being used in the user interface design of a mobile device with enriched vibrotactile sensations with an improved information transfer bandwidth [59]. M. ErcanAltinsoy introduced a new electrotactile system in an IEEE Transaction in 2012, stating a process of sending tactile information to the finger tip of a blind people by using small electrodes showing a high current and low pulse frequency is suitable for represent roughness of the touched surface [60]. In Doctoral Thesis of Teemu Ahmaniemi, various process of dynamic vibrotactile feedback during user interaction with mobile devices has been introduced. The said thesis contains the experiments of assessing of perceptual dimensions of the feedback by wavetable synthesis on coupling with gesture, turning a tactile display out as target detectors, utilizing dynamic tactile feedback during play of virtual musical instruments as well as performing force replication tasks [61]. In 2013, Indian scientists M. Rahmath Riswana et al., proposed an approach using the mostly used speech recognition software along with audio interfacing technique in computers for blinds. In proposed system the messages are being collected by using modem are recognized by audio interface sending acknowledgment for specific message by utilizing speech recognition with help of Braille technology providing the option for blind peoples to use all the applications in mobile phone as a normal person [62]. In a book chapter of 'Wiley [Imprint], Inc.', Stephen A. Brewster et al. mentioned that being very small in size, tactile displays can be mounted with mobile telephones or PDAs, including tactile feedback to enhance games as well as ring tones along with various rhythmic notifications for different types of voice calls, text messages, multimedia messages as well as considering the call priority [63]. With latest research, in end of 2013, Robest Yong proposed an modern concept making a blind people able to utilize a smart mobile phone to make voice calls as well as sms, providing a device to locate any key position along with option for games as well as educational use by accessing Wikipedia, newspaper portals etc. [64].

6 Conclusion

During last few decades, lots of research works as well as inventions have been carried out, pointing towards the future advancement of Tactile Display for Visually impaired peoples. Above chronological overview study is an endeavor to visualize all the research works till recent past based on tactile display as much as possible. The said review is not intended to be an exhaustive study on above mentioned subject matter and any omission of other works is absolutely unintentional. Future research aims at fabricating smarter as well as more utilitarian tactile display board, by better integration of state-of-art embedded technology with state-of-art communication engineering, computer science and social science.

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