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Enhanced Braille Display

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Abstract:*Braille System is a method that is widely used by visually impaired people to read and write. Braille Code generally consists of cells of raised dots arranged in a grid to inscribe characters on paper. Blind people can sense the presence and absence of dots using their fingertips, giving them the code for symbol. It is difficult for visually impaired people to receive visual information. The main objective of this project is to establish a means of communication for them. Here we are implementing Enhanced Braille System that helps blind people to read text. We scan image from camera, process the image by image processing techniques and that will be converted into text. The detected text is given to the Raspberry Pi, which recognizes every character and convert it into Braille Code. Here solenoids are used to facilitate the vertical movement of the dots of the Braille Display which is controlled by Raspberry Pi. With this device, we are displaying that Braille Code on the Braille Keypad.*
Keywords: Braille Display, Braille Dots, Communication, Raspberry Pi, Solenoids, Braille Keypad.

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I. INTRODUCTION

As per the World Health Organization (WHO), 253 million people are visually impaired worldwide, including over 36 million blind people. These people face difficulties with their normal activities such as reading, walking, driving, socializing and writing.

Braille, a tactile system of writing used by the visually impaired or blind people was invented by Louis Braille in the early 19th century. It is the only medium of communication for the blind people worldwide along with speech. In this system patterns of raised dots were used to inscribe the characters on paper. It therefore helps visually-impaired people to read and write using single touch instead of vision. Its characters are six- dot cells, with two columns and 3 rows. Any of the dots may be raised above the paper plain thus giving 64 possible characters.

In this project, the camera will start capturing the imagesand sends it to Raspberry Pi. As soon as the images are received by Pi, it identifies each English characters, numbers and symbols in the image. Once the model gets the character it is mapped to each Braille alphabets, numbers and symbols. Upon mapping each character, its appropriate signal is sent to solenoids and with the help of these solenoids the Braille Code is displayed on the BrailleKeypad.

two major segments namely; generating captions from Images using Deep Learning and Making the generated caption available in Braille. For the generation of captions from images, a complex Deep Learning approach was implemented and for the second portion a simple, cost- efficient microcontroller-based scheme was designed. The fundamental problem in Artificial Intelligence (AI) is that it connects computer vision and natural language processing. Hence, they implemented generative model based on a Deep Learning library. It consists of three components;-An encoder CNN model which is pre-trained and used to encode an image to its features and it is implemented in VG16 model; A word embedding model converts the text into a proper format which is understandable by the computer and then convert it into Braille Code; A decoder RNN model is employed for getting captions using LSTM network. The model is implemented in python using keras with tensor flow in the backend. For this purpose, a 2x3 arrangement of push-pull solenoids is used to implement the Braille Cell. The microcontroller based circuit is designed in a way that it can serially communicate with the python interface of the caption generator. So when the input is given, it converts the text letters to Braille one by one. Some of the datasets used are Flickr8k, Flickr30k, MsCOCO, SBU, Pascal etc... The performance of this model was analyzed and calculated by BLEU-4[20]. On the Flickr8k dataset, the model obtained as core of 0.24 and the state-of-the-art-models have achieved a score of 0.26[21]. This model achieves comparable results while using Braille instead oftext.

II. LITERATURESURVEY

A. Paper [1] - "A Recurrent Neural Network Approach to Image Captioning in Braille for Blind-DeafPeople"

Authors- Sameia Zaman, M. Abid Abrar, M. Muntasir Hassan, A.N.M. Nafiul Islam.

In this project, the proposed system can be divided intotwo major segments namely; generating captions from Images using Deep Learning and Making the generated caption available in Braille. For the generation of captions from images, a complex Deep Learning approach was implemented and for the second portion a simple, cost- efficient microcontroller-based scheme was designed. The fundamental problem in Artificial Intelligence (AI) is that it connects computer vision and natural language processing. Hence, they implemented generative model based on a Deep Learning library. It consists of three components;-An encoder CNN model which is pre-trained and used to encode an image to its features and it is implemented in VG16 model; A word embedding model converts the text into a proper format which is understandable by the computer and then convert it into Braille Code; A decoder RNN model is employed for getting captions using LSTM network. The model is implemented in python using keras with tensor flow in the backend. For this purpose, a 2x3 arrangement of push-pull solenoids is used to implement the Braille Cell. The microcontroller based circuit is designed in a way that it can serially communicate with the python interface of the caption generator. So when the input is given, it converts the text letters to Braille one by one. Some of the datasets used are Flickr8k, Flickr30k, MsCOCO, SBU, Pascal etc... The performance of this model was analyzed and calculated by BLEU-4[20]. On the Flickr8k dataset, the model obtained as core of 0.24 and the state-of-the-art-models have achieved a score of 0.26[21]. This model achieves comparable results while using Braille instead of text.

B. Paper [2] –"Enhanced Braille Display Use of OCR and Solenoid to Improve Text to Braille Conversion"

Authors -Sangeeta Kumari, Akshay Akole, Pallavi Angnani,
Yash Bhamare, Zaid Naikwadi

In this project, they are implementing Enhanced Braille System that helps blind people to read the text or content. The model is started when the camera captures the image and sends it to the Raspberry Pi. Then the OCR API gets activated and performs Optical Character Recognition on the images received and identifies each English character in the image. When the model gets the character, it maps it to each Braille alphabet. Upon mapping each character, it's appropriate signal is sent to Solenoids connected to Pi through the GPIO pins. When the Solenoids receive high signal, it will jump up to make a Braille alphabet. Relays and battery of low power capacity can be used. Thus this model will be small in size.

C. Paper [3] –"A Cost Effective Electronic Braillefor Visually Impaired Individuals" Authors - Md. Ehtesham Adnan, Noor Muhammad Dastagir, Jafrina Jabin, Ahmed Masud Chowdhury, Mohammad
Rezaul Islam

In this project, a text input is given from a computer which is processed by Arduino Uno. The Arduino Uno controls the switching circuit which is connected to the solenoids.When the Solenoids receive the electrical signals from Arduino Uno, they move independently forming different patterns to form the Braille Alphabets and thus these patternsare sensed by fingers of the visually impaired or blind user. Here Arduino Unomicrocontroller is used because it can be programmed easily. It requires 5V to operate.P-channel Logic MOSFET NDP6030PL was used which works as a switch when Arduino supply gate voltage. The aim of this study is to design a cost effective Braille which can be affordable by the people of developed or underdeveloped country. The results of this project was quite satisfactory as the Solenoids worked perfectly to show the desired formation to the corresponding character input and most of the participants were able to read the characters successfully.

D. Paper [4] –"Text Detection and Communicator Using Braille for Assistance to VisuallyImpaired"

Authors - Kimaya Kulkarni, Apoorva Mahajan, Yash Zambre, Faisal Belwadi, Shreya Killedar, Ashutosh Marathe

In this project, the image of a text document was captured and transferred to the computer. In the pre-processing stage, the image will be read as a grayscale image. In this stage, Noise Reduction, Normalization and Compression operations were performed. Otsu's method for thresholding was used for converting gray level image into a binary image. Optical Character Recognition (OCR) was used to convert images to machine encoded text. The binary images have undergone localized segmentation which separated characters from words. Bluetooth was used to send the characteristics from the text file to the microcontroller. Arduino is the microcontroller used in this project. Two types of actuators were used namely; Solenoids and Servo Motors.

Solenoids model occupies very less space and was very light. Hence the six dots can be felt by two fingers. It caused some heating problem at 12V but it was solved by using current limiting resistors. To avoid mutual induction, the solenoids were spaced 1.8cm-2cm apart hence it occupied space. Servo Motors were very bulky and occupied a lot of space but it was cost-effective. The overall results of this project was satisfactory and accurate.

E. Paper [5] –" Design of a High Power Density Electromagnetic Actuator for a Portable BrailleDisplay"

Authors -Tiene Nobels , Frank Allemeersch , Kay Hameyer

In this project, small and inexpensive linearelectromagnetic actuator is used which allows a considerable reduction in size and cost of the refreshable Braille display. Refreshable Braille displays are generally bulky and expensive; it consists of 20 to 80 Braille cells allowing one line of text to be shown at a time. The refreshable Braille cell used in this project consists of 8 pins in a 2 by 4 matrix, allowing eight-dot computer Braille. Each pin has two stable positions, a set (lifted position) and are set (lowered position), actuated by a linear electromagnetic actuator. The linear magnetic actuator has been designed for a portable Braille display application. The Braille characters can be sensed over a rotating ring on which Braille cells are located that rotates inside the housing. The rotating rings with bistable pins are created. A holding force of 0.1N was aims, as it is for piezo-electric actuators in regular Braille displays. The distance between the 2 pin, which is 2.4mm, restricts the diameter of the plunger-pins. The vertical displacement of the pins is atleast 0.8mm. Permanent magnets are used to create the lifted and the lowered stable position.Holding force is small linear actuators are limited by available energy density from permanent magnet materials. The paper illustrates the optimization of high power density linear actuators in order to obtain maximum output forces by using finite element models.

F. Paper [6] –" A Novel Braille Display Using the Vibration of SMA Wires and the Evaluation ofBraillePresentations"

Authors- Feng ZHAO, Changan JIANG, Hideyuki SAWADA.

In this study, a new Braille display is constructed based on the vibration of a Shape Memory Alloy (SMA) wire. A vibration actuator is used instead of conventional Braille dots to present Braille Information. The SMA wire is employed to develop a vibration actuator which is driven by a low voltage supply. By using the vibration actuators, a compact Braille display with 4 Braille cells has been constructed. Since the size of each Braille cell is just 2.0 [mm] x 4.5 [mm], the developed compact Braille display is portable. Each vibration actuator is made using only a 3 [mm]-long SMA wire. Through the vibration the users are able to read the Braille character without even moving their fingers to feel each dot in a Braille cell. The user just has to put their fingertip on top of the Braille cell in order to read the presented character. Here, multiple actuators constructed by using metal pins (0.7mm in diameter, 3mm in length) and SMA wires (50um in diameter, 3mm in length),are placed as to form standard Braille. The actuators are vibrated by Pulse-Width Modulated (PWM) signals with different frequencies and appropriate timings, and the effectiveness of the proposed method for Braille display were verified by experiments. From the experimental results, the highest recognition rate of 100% was achieved under the conditions of 50Hz vibration frequency and 500mstime delay. The Meissner corpuscle and Ruffini endings could easily sense the vibration stimulus at50Hz. The vibration generated by the vibrators could produce a continuous deformation of the skin which simulated the Ruffini endings. So the user r can recognize the Braille pins through the vibration, when he/she lightly touches the vibration actuators with his/herfingertips.

G. Paper[7]- "Braille Recognition using Convolutional NeuralNetworks"

Authors- Savarimuthu Prakash1, Sam Thomas, Sankara Malliga Gopalan.

In this project, Braille is converted to English letters. To communicate with a person who is not blind requires the knowledge of Braille. So, braille to text translator would be a bridge which connects them both. The conversion of braille to English letters is done with an implementation of deep learning. The novel image classification is implemented using Convolutional Neural Networks (CNN).A dataset of 14,378 braille images which corresponds to 26 English letters has been constructed. The conversion of a braille document to text involves, scanning the document or image. The image undergoes pre- processing techniques, to highlight the essential details and remove background. The pre-processing stage aims in removing noise and adjusting the contrast of the braille dots for it to be detectable. The segmentation stage reads the pre- processed image line by line and for each line, the braille cell is segmented and stored. The segmented braille cells are feed to CNN to classify the images. The dot detection stage is followed by cell recognition stage where dots are grouped together to convert the cell to the correspondingalphabet.The conversion stage can be used to for different language groups. The image classification stage identifies the segmented cell and maps to its corresponding letter. Deep learning is used to implement image classification and CNN is used to extract the features from the image. The implementation of deep learning-based braille to text conversion has high performance and compared to simpler neural network implementations, the convolutional layers extract the features achieving a accuracy of more than 95%. The system has a potential of providing an enhanced solution for communication between braille and non-braille readers.

H. Paper[8]- "A shared code for Braille and Arabic digits revealed by cross-modal priming in sighted Braille readers"

Authors – Katarzyna Raczy, Maria Czarnecka, Dominika Zaremba, Kinta Izdebska, Malgorzta Paplinska, Guido Hesselmann, Andre Knops, Marcin Szwed.

The paper deals with occurrence of priming effect which supports the notion of different format overlap on the same mental line. Little is known about tactile-visual overlap of symbolic numerosities that is Braille numbers to Arabic digits on the magnitude number representation. Number processing is fundamental achievement. Therefore quantities can be represented either symbolically or non-symbolically. There is also a debate on going between Visual and Auditory. Two experimental conditions were tested. In both conditions the target was presented visually as an Arabic digit (3,4 or 5).The results were taken from Braille Speed Test, Braille Number Recognition Test, Tactile Acuity Test.This study revealed three main findings. The first, there is significant impact of numerical primes in both prime notations, Braille and Number words. Second is this priming was best characterized by a V-shaped function in both notations. Third was that they observed priming is due to identity priming rather than semantic priming.In this study, they tested sighted people who learned Braille numbers when they were already fluent in recognizing Arabic digits. Such cross-modal number priming is in line with the notion of a generalized magnitude system. In conclusion, based on observation of cross-modal priming, best characterized as identity priming, they propose that tactile Braille numbers and number words are place coded. They presume that the observed eff ects are most likely due to pre- activation of a phonological code and thus, they bypass the mental number line.

I. Paper[9]- "Exploring User Interface Improvementsfor Software Developers who are Blind"

Authors – Guarionex Salivia,Flint Million, Megan Bening.

In this paper Software developers who are blind and interact with the computer non-visually face unique challenges with information retrieval. We explore the use of speech and Braille combined with software to provide an improved interface to aid with challenges associated with information retrieval. They use common tasks performed by students in a software development course using a Microprocessor without Interlocked Pipeline Stages (MIPS) architecture simulation tool. People who are blind face unique challenges as software developers. Screen reading technology is often unable to adequately represent the complex and dynamic nature of modern application interfaces often used for software development. Complex interfaces make the task of information seeking and retrieval particularly challenging to developers who are blind. Main goal is to help individuals who are blind with the problem of information retrieval in a non-visual manner from a graphical user interface. Particularly interested with graphical user interfaces related to software development.This study revealed main findings. Firstly, *Time*: We have observed an average improvement in speed of 2.75 xfaster when the participant was using the Braille display. The average time to completion for all tasks with the use of the additional Braille hardware and software was 50.1 seconds, while the average completion without was 2 minutes and 17.8 seconds.Secondly, *Braille Add-on Functionality Usage:* They measured the usage of the functions we provided in the Braille add-on to determine how they were used. Task 4 used the Braille functions the most of any task, and also used the most diverse set of these functions.From the notes taken during each test, we observed that when not using the Braille display, the participant exhibited many outward signs of frustration such as the use of uncouth language and facial expressions of aggression. In many cases, the participant needed to back up and repeat parts of the task due to losing her current place in the user interface, yet another sign of undesirable user experience outcome.

J. Paper[10]- "Classification of tactile event-related potential elicite by Braille display for brain–computer interface"

Authors- Junichi Hori, Naoto Okada.

In this study, to construct brain–computer interface (BCI), an event-related potential (ERP) induced by a tactile stimulus is investigated for ERP-based BCI, visual or auditory information is frequently used as the stimulus. In the present study, we focus on tactile sensations to reserve their visual and auditory senses for other activities. Several patterns of mechanical tactile stimulation were applied to the index fingers of both hands using two piezo actuators that were used as a braille display.Human experiments based on the oddball paradigm were carried out. The extracted features were classified by applying step wise linear discriminant analysis. Thus, BCI is an attractive communication tool which doesnot involve body movements.There are Methods: Tactile

ERP measurement system of tactile ERP measurement system for tactile-based BCI implementation Several kinds of tactile stimuli were provided to the subject's fingers. The system that outputs the subject's intention was constructed by focusing on the specific stimulus. After EEG measurement, pre-processing, and feature extraction, the operation based on the classification result is executed. Tactile stimulus: A tactile stimuli to using a piezo electric actuator. They proposed a tactile-based BCI using ERP. Several patterns of mechanical tactile stimulation were applied to the index fingers using two Piezoactuators.Human experiments based on the oddball paradigm were carried out. As a result, an average accuracy of 80% and 65% were obtained for experiments. A high accuracy was obtained by increasing the number of electrodes, although the stimulus interval was short. Possible future studies can involve the investigation of the optimum position, pattern, and number of tactile stimuli to improve the discrimination accuracy.

K. Paper[11]- "Text to Braille Scanner with Ultra Low Cost Refreshable BrailleDisplay"

Authors- Shahruk Hossain, Abdullah Abyad Raied, Asifur Rahman, Zaowad Rahabin Abdullah, Dipanjan Adhikary, Ahsan Rabby Khan, Arnab Bhattacharjee, Celia Shahnaz, Shaikh Anowarul Fattah.

This study presents an open source text to braille scanner along with a unique low cost refreshable braille display. A user can just snap a picture of a regular page and convert the contents into braille in real time, which will then appear on the display. The app does not require any internet connectivity and all processes are run on board. The app utilizes Google's open source Optical Character Recognition (OCR) engine which is a free to use and modify software package that allows the acquisition of text from images. Voice guidance and vibrational feedback is included in the app to help a visually impaired person in positioning the phone on top of the page correctly. Once the text is acquired, it is sent over Bluetooth serial connection to the braille display. The display is constructed in a modular fashion with a main base module and one or more extension modules. The base module houses the battery, the main logic unit, and the Bluetooth receiver. The battery is a 7.4 V 1500mAh Lithium Ion (Li-On) Battery (two 3.7 V cells connected in series). The battery powers both the base module and all the extension modules. The Bluetooth module is the HC-05 model and can be paired with any smart phone. It receives the raw text data from the phone and passes it to the main logic unit, an AT Tiny85 microcontroller. The microcontroller processes the text and maps each character within it to its corresponding braille pattern. It then sends control signals to the extension modules to display the appropriate braille pattern.
The scanner app is currently capable of converting English text printed in a multitude of fonts into braille in real time without any internet connectivity. It also features assistive technologies such as voice guidance and tactile feedback to assist the visually impaired user in scanning documents. The performance of the proposed display device has been tested under various conditions and a very satisfactory performance was achieved, in terms of cost, comfort of use and speed.

L. Paper [12]- "Enhanced Performance on a science comprehension task in congenitally blindadults."

Authors- Rita Loiotile, Connor Lane, Akira Omaki,Marina Bedny.

In this paper for all reaction time analyses, they've used a mixed-effect generalized-linear (logit) model with participant and item included as random effects (Baayen, Davidson, & Bates, 2008; Clark, 1973; Jaeger, 2008). All experiments were run using either PsychoPy or Matlab's Psych tool box. Due to differing numbers of trials across movement and garden- path sentences, we analyzed them separately and compared each to their respective control sentences. Filler data were modeled separately.

M. Paper [13]- "Braille Script to voiceConversion."

Authors- K.Krishna Kishore, G. Prudhvi, M. Naveen

This paper deals with the aims to explore awearable messaging device that uses embedded technology for visually impaired person. The main objective of this project is to establish a means of communication for specially abled people. It is a method to communicate with the help of Braille keyboard where the output is displayed on LCD. The push buttons used here are based on switching mechanism which means if the push button is pressed, it will connect the two points in a circuit. Here 9v battery is used as an input to these push buttons. The 9v power supply is converted into 5v using IC7805.After pressing any button , the output from it will be given to the Arduino board and depending on the input given, it gets converted into text. The output will be displayed on the serial monitor. The output from the Arduino is given to the voice module, here we get the voiceoutput.

N. Paper[14]- "BRAPTER: Compact Braille Transput Communicator"

Authors- Shubhom V T, Keerthan S, Swathi S, Abhiram G.

A 328 microcontroller is programmed usingArduinoIDE. The Braille e-notepad is a sensory input keypad which takes in Braille data using 3*2 matrix cells. This matrix cell consists of keys, which when pressed in a pattern specified by ICEB, followed by an ENTER button '#', receives Braille code. This Braille code is then translated to English by the microcontroller and later stored in a SD card in English and the corresponding voice response is received. The contents in the SD card matched with the given input when verified using a smart phone. Then the SD card was inserted to the Braille embosser to print the contents on the embossed paper. The visually impaired could sense and type the keys on the membrane hex-keypad. They received the voice response which matched with the given input. They could also read the Braille output on the embossed paper printed by the Braille embosser.

O. Paper[15]- "Transliteration of text input from Kannada to Braille and viceversa"

Authors- Saritha Shetty, Savitha Shetty, Sarika Hegde, Karuna Pandit

A UTF-8 code is generated for the input Kannada text. This Kannada text is given as input to the system and mapped to the corresponding Braille code. TheBrailleoutput is given as input to the reverse transliteration system and it is converted to Kannada text. This indication is used only for the letters ಅ, ಬ, ಚ, ದ, ಎ, ಗ, ಹ , ಜ. Ottakshara or compound character of Kannada Braille is indicated by dot 4 of Braille.They conducted a mapping system which takes Kannada text input, preprocesses it and converts it to Braille code. It gives 100% accuracy for Kannada to Braille transliteration and vice versa. The Braille code generated can be printed on the Braille paper and it can be used by the visually impaired, since the availability of Braille document is scarce. We tested our system by taking input from online Kannada websites like Kendasampige and online Kannada newspapers Udayavani and Vijay Karnataka. It works for any Kannada text input including any number of ottaksharas.

III. CONCLUSION:-

This project represents the design and implementation of Enhanced Braille Display. The text is scanned from an image and mapped to the Braille alphabet. The Raspberry Pi recognizes every character and convert it into Braille alphabets. These Braille alphabets are then physically represented using Solenoids. This system is small in size andportable.

IV. FUTURESCOPE:-

As a part of future scope, we can implement Audio Spatialization by connecting speakers through which the blind can also hear to the converted text. The use of smaller Soleniods helps in reduction of size and would require lesser power.

REFERENCE

[1]. Sameia Zaman, M. Abid Abrar, M.Muntasir Hassan, A.N.M.NafiulIslam, "A Recurrent Neural Network Approach to Image Captioning in Braille for Blind-Deaf People", November,2019.

[2]. Sangeeta Kumari, Akshay Akole, Pallavi Angnani,Yash Bhamare, Zaid Naikwadi, "Enhanced BrailleDisplay Use of OCR and Solenoid to Improve Text to Braille Conversion ", June 2020.

[3]. Md. Ehtesham Adnan, Noor Muhammad Dastagir,Jafrina Jabin, Ahmed Masud Chowdhury, Mohammad Rezaul Islam, "A Cost Effective Electronic Braille forVisually Impaired Individuals ", December 2017

[4]. Kimaya Kulkarni, Apoorva Mahajan, Yash Zambre,Faisal Belwadi, Shreya Killedar, Ashutosh Marathe, "Text Detection and Communicator Using Braille for Assistance to Visually Impaired ", December2019

[5]. Tiene nobles, Frank Allemeersch, Kay Hameyer,"Design of a High Power Density Electromagnetic Actuator fora Portable Braille Display ", 2002

[6]. Feng Zhao, Changan Jiang ,Hideyuki Sawada , "ANovel Braille Display Using the Vibration of SMA Wires and the Evaluation of Braille Presentation ", Vol. 7, No. 4,2012

[7]. Savarimuthu Prakash,Sam Thomas , Sankara Malliga Gopalan, "Braille Recognition using Convolutional Neural Networks", Volume XVI, Page no.206-214, Issue VII, July 2020.

[8]. Katarzyna Rączy, Maria Czarnecka, Dominika Zaremba, Kinga Izdebska, Małgorzata Paplińska, Guido Hesselmann, André Knops, Marcin Szwed , "A shared code for Braille and Arabic digits revealed by cross-modal priming in sightedBraille ", 2019

[9]. Guarionex Salivia, Flint Million, Megan Bening, "Exploring User Interface Improvements forSoftware Developers who are Blind ", Vol. 23,No. 1, Journal of Science Education, July 2020.

[10]. Junichi Hori, Naoto Okada , "Classification of tactile event-related potential elicited by Braille display for brain– computer interface ", 2016, journal homepage: www.elsevier.com/locate/bbe Available online at www.sciencedirect.comScienceDirect

[11]. Shahruk Hossain, Abdullah Abyad Raied, AsifurRahman, Zaowad Rahabin Abdullah, Dipanjan Adhikary, Ahsan Rabby Khan, Arnab Bhattacharjee, Celia Shahnaz, Shaikh Anowarul Fattah, "Text to Braille Scanner with Ultra Low Cost Refreshable Braille Display", 2018

[12]. Rita Loiotile,Connor Lane,Akira Omaki,Marina Bedny , "Enhanced performance on a sentence comprehension taskin congenitally blind adults ", Department of Psychologicaland

[13]. Brain SciencesJohns Hopkins University Problems were taken from the Kit of Factor-Referenced Cognitive Tests, 2016

[14]. K.Krishna Kishore, G. Prudhvi, M. Naveen,"Braille Script to Voice Conversion",2017

[15]. Shubhom V T, Keerthan S, Swathi S, Abhiram G, "BRAPTER: Compact Braille Transput Communicator ",2017

[16]. Saritha Shetty, Savitha Shetty, Sarika Hegde, Karuna Pandit Department of MCA, "Transliteration of text input from Kannada to Braille and vice versa ", June 2020

[17]. Lutfun Nahar , Riza Sulaiman , Azizah Jaafar, "An interactive math braille learning application to assistblind students in Bangladesh", March 2020, [Online] Available: https://doi.org/10.1080/10400435.2020.1734112

[18]. Rafael Grigoryan,DariyaGoranskaya,Andrey Demchinsky,Alexander Kaplan , "Difference in somatosensory event-related

potentials in the blind subjects leads to better
[19]. performance in tactile P300 BCI", June 2020, [Online] Available: https://doi.org/10.1101/2020.06.16.155796
[20]. Daniel Goldreich ,Ingrid M. Kanics , "Tactile Acuity is Enhanced in Blindness", The Journal of Neuroscience, April 15, 2003 • Pg No:3439–3445
[21]. Kai Crispien ,Wolfgang Wiirz ,Gerhard Weber , "Using Spatial Audio for the Enhanced Presentation of Synthesised Speech within Screen-Readers for Blind ComputerUsers. ",1994
[22]. Email: crispien@ftsu00.ee.tu-berlin.de
[23]. N.D.S.M.K.De Silva, S Vasanthapriyan, "Optical Braille Recognition Platform forSinhala",2018
[24]. OD Sasanka Fonseka, Nirosha Wedasinghe, " A software solution for image identification and artistic skills for visually impaired people using braille ",2018
[25]. Sunil Kumar KN, Vinayak S, Sathish R, Tarkeshwor Parasad Pandit, "Braille Assistance System for Visually Impaired, Blind & DeafMute people in Indoor & Outdoor Application ", May 2019
[26]. Albert Sudaryanto, Sulfan Bagus Setyawan, Hanum Arrosida, "Calculator for Blind with Self Correction Feature using Voice Output",2019
[27]. Siddhesh Sushil Shirsekar, "Education with Braille and Typography",2017