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An IoT Based System for Printing Braille Letter from Speech

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***Abstract*—Visually impaired person cannot perform their activities like ordinary person. It becomes more difficult when a person is visually impaired along with deafness. Sometimes, it is quite impossible to communicate with such people whether in speaking or writing format. Therefore, Expert Braille Communicating System (EBCS) is a promising solution which provides braille writing format from voice. Unfortunately, people of underdeveloped countries are not getting the facilities of advanced electronic braille system for overpricing. In this work, an attempt has taken on designing a modified braille device which is economical and more compelling than previous. The device takes voice as input from an android apps and can convert the voice signal into text format of braille and prints the braille letter in paper. EBCS is trained with 1 epoch and the accuracy is achieved of 97.6%. By implementing the considered Braille system, visually impaired person can entirely engage themselves in the society.**

***Index Terms*—Braille, Expert Braille Communicating System (EBCS), Speech to Braille (S2B), Hidden Markov Model (HMM), Braille letter generator.**

I. Introduction

Communication is very tough when it comes to make a communication between two visually impaired person or even between a regular and a vision impared person. EBCS can be the best solution for this immense problem. Globally, at least 2.2 billion people have vision impairment or blindness, of whom at least 1 billion have a vision impairment that could have been prevented or has yet to be addressed [1]. Approximately 314 million people have visual impairness all over the world where 45 million of them are completely blind and in every 5 seconds one person and every minute one child goes blind [2-3]. According to fact sheet of World Health Organization (WHO) for visual impairment updated August 2019, 314 million people in the world are visually impaired with 89% living in developing countries and 55% of them are women [4-5]. In Bangladesh approximately 7,50,000 people suffers from blindness [6]. The ratio of Braille literacy to the population of visually challenged people is very poor. Literacy rate for visually challenged people is as low as 3% to 5% and 26 million out of all visually impaired people are employed. Some of the suitable jobs for them are financial advisor, physical therapist, occupational therapist, speech-language pathologist etc [7]. The basic Braille system uses a combination of six raised dots giving a possible combination of 64 different signs. There are three levels of Braille encoding of which the first level is majorly used for learning Braille. This level presents a one- to-one mapping of alphabets, numerals and special characters. The conventional Braille system uses slate and sharp nipped pen called stylus which is routined to punch holes on a Braille parchment and reproduce the combination of words, alphabets and numerals. The opposite end of the punched region of the paper can be used by the visually impaired to sense the Braille codes [8]. In Fig. 1 the standard

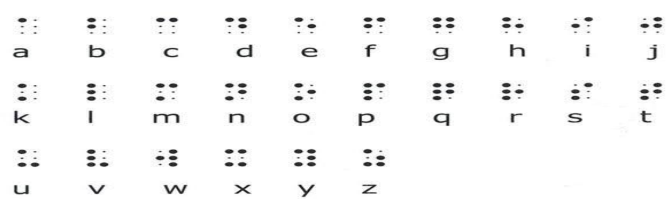

Fig. 1. Braille Alphabet

format of braille letter generation which is being followed all over the world. The vision is to give our system the instruction which will make it recognize the braille letters so that it can give the proper output as this standard format. A visually impaired person mostly faces the communicating problem with others. This is the primary reason for developing EBCS which is independent, autonomous and user friendly. The main focus of this paper is to enhance the rate of communication amongst visually challenged people and also between normal and visually impaired people. Our main contributions are as follows

1) EBCS has the uniqueness of taking voice as input and generates braille letter in paper by embossing in real time with higher accuracy.
2) EBCS is a compact package of hardware and software design for printing braille letter on paper.

The rest of this paper is organized as follows. Literature Review is given in Section II. Section III introduces the proposed methodology where the method of our project got highlighted. In Section IV, the experimental setup is shown. The ultimate result of the project is provided in Section V, and finally the conclusion and the future work is given in Section VI.

II. LITERATURE REVIEW

Expert Braille Communicating System (EBCS) has been an important research area from last few decades. Researchers have been trying to improve the braille system day by day. Tirthankar Dasgupta et al. in 2008 presented a transliteration system from Indian language's text to braille format. In a vision of removing the gap between a sighted and visually impaired person they took the step to make such a device. It needs braille keyboard and stuff like that which is very hard for a the visually impaired person to perform [9].

Melissa Ramírez et al. in 2016 made an automated speech recognition system which will help the visually impaired children to learn braille. Their paper introduced a new training algorithm for the device and tested the device which positively resulted in approximately 89%. The device receives command through a mic and provides the command as text format [10]. Shaheena Sultana et al. in 2012 worked with speech to text conversion. This paper worked with speech application program interface (SAPI). Although the paper mostly represented Bengali letters and all but it is also very useful for the people who are working with speech to text recognition [11]. Sadaoki Furui et al. in 2004 made the automatic speech into talks, presentations, speech to speech conversion and speech to text conversion also. The authors followed two stage summarization method and investigated about speech sentence recognition. This paper focused on speech to speech and speech to text conversion which is helpful for the others who are working on any topic related to this kind of work [12].

W.Chou et al. in 1992 introduced a new training algorithm based on hidden markov model (HMM). This algorithm recognizes the speech using Viterbi decoding. The cause of the algorithm's recognition of almost every speech which was trained using conventional training methods [13]. Swagat Das et al. in 2019 worked on an automated device which will detect obstacles around it's 50cm area. This device even works properly in a crowded place. When the device finds any kind of obstacle it beeps or vibrates to aware the user [14]. Joyce Siqueira et al. in 2016 introduced a very innovative idea which is the braille text entry on smartphone. The paper focused on the future and assumed that most of the phone users will shift to the touchscreen smartphone, that's how the idea came up [15]. Rohit Rastogi et al. in 2015 approached to make a device or gadget which will be able to eliminate the communication gap between the three kind of differently abled people like visually impaired, dumb and deaf. The researchers primarily trying to use data entry glove and multi modal interfaces. The gadget will take the input message from the differently abled person and covert that message to be transformed as per the requirements. After getting transmitted the message will reach to the receiver and will be delivered as per the requirement [16]. Farig Yousuf Sadeque et al. in 2013 made an artificial voice tool that converts text document to speech. Also, they used syllabic method of unit which made it easier to use. But in this paper the problem is text format has to give by the user. The artificial voice will convert that text into speech [17].

Although, there are several researches have undergone for improving braille letter generation both in software and hardware fields. Our research combines the both effort into one for solving the limitation of previous research works.

III. PROPOSED METHODOLOGY

Main methodology of this paper starts with training the voice data into the system. While training the voice data, uttered alphabets have been trained separately. Alphabets will be generated in text format accordingly using HMM [18]. The

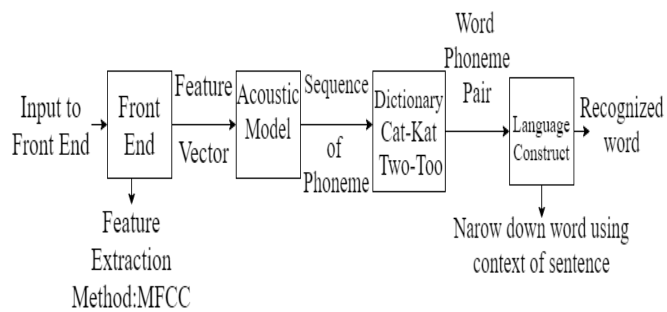

Fig. 2. Speech to Word conversion

total process from speech to word conversion is shown in Fig. 2.

The major components of a large vocabulary continuous speech recognizer are illustrated in the equation (1). The input audio waveform from a smartphone is converted into a sequence of fixed size acoustic vectors $Y_{(1:T)} = y_1, \ldots, y_T$ in a process called feature extraction. Mel-frequency cepstral coefficient (MFCC) are used to analyze the feature vectors in every 10ms using a window of 25ms. In addition to the cepstral coefficients, first order (delta) and second-order (delta–delta) regression coefficients are often appended in a heuristic attempt to compensate for the conditional independence assumption made by the HMM-based acoustic models.

$$\Delta y_t^s = \frac{\sum_{(i=1)}^{n} w_i (y^s_{(t+i)} - y^s_{(t-i)})}{2 \sum_{(i=1)}^{n} w_i^2} \tag{1}$$

If the original (static) feature vector is Δy_t^s., then the delta parameter, Δy_t^n. is given by where n is the window width and w_i are the regression coefficients. Each spoken word w is decomposed into a sequence of K_w basic sounds called base phones. This sequence is called its pronunciation $q^{(w)}_{(1:K_w)} = q_1, \ldots, y_{(K_w)}$. To allow for the possibility of multiple pronunciations, the likelihood $p(Y|w)$ can be computed over multiple pronunciations where the summation is over all valid pronunciation sequences for w, Q is a particular sequence of pronunciations,

$$P(Q|w) = \Pi^{L}_{(i=1)} P(q^{wl}|wl) \tag{2}$$

In equation (2) where each $q^{(w_l)}$ is a valid pronunciation for word w_l[18]. This method achieves higher accuracy in case of large volume of vocabulary than the smaller vocabulary dataset. Melissa et al. [10], Sadaoki et al. [12], Tirthankar et al. [9] attains less accuracy for smaller dataset.

In testing phase, the device will take voice as input via smartphone. The voice will be converted into text format using HMM[18]. A bluetooth module will be connected between smartphone and Arduino UNO. After converting into text Cosine Similarity (CS) used to check the similarity. If a word is articulated, our system checks the angles between the uttered word and trained word using cosine similarity where *x* is the vector of uttered word and *y* is the vector for trained word [19,20]. The formal definition of cosine similarity is stated as follows in equation (3).

$$cos(x, y) = \frac{x \cdot y}{||x||||y||} = \frac{\sqrt{\sum_{i=1}^{N} x_i y_i}}{\sqrt{\sum_{i=1}^{N} x_i^2}\sqrt{\sum_{i=1}^{N} y_i^2}} \tag{3}$$

If it matches with the trained alphabet, the EBCS will emboss the letter on paper as a braille standard format. While taking voice input EBCS will look for spaces between words and sentences to separate distinguish words and sentences respectively. We trained the EBCS device with 1 epoch. The characters are familiar with EBCS because of the training given to it with the accuracy of 97.6%. The following Fig 3. is depicting the flowchart of braille training and testing parts of EBCS.

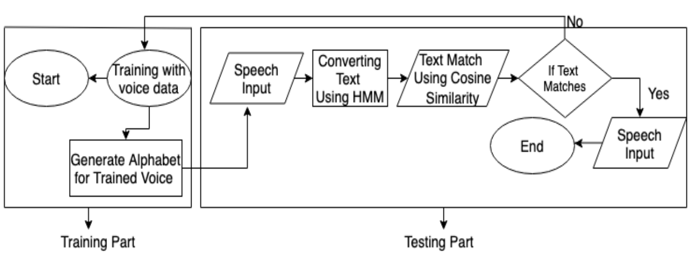

Fig. 3. Training Voice with EBCS

IV. EXPERIMENTAL SETUP

The device is consisted of Arduino Uno, two types of motors, Bluetooth module, embosser and many additional small structural units that assembled together to form a complete circuity that is capable of taking voice as input, converts them into text format inside the system and finally printing them into braille format on the paper. Arduino is the base-station. It mainly combines the software and hardware together. Stepper and servo motors are also being used along with Bluetooth module. In Fig. 4 an x-axis stepper motor is used to rotate the pen for making the dots and the servo motor to roll the paper. Servo motor 360-degree rolls the paper to write on it. It maintains the paper's line updating format.

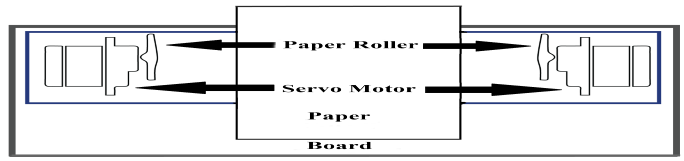

Fig. 4. Rolling paper with Servo Motor

Servo and stepper motor are attached with each other in Fig. 5 to maintain the formation of paper with pen.

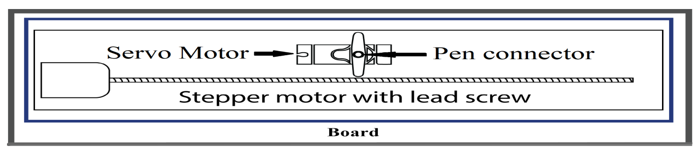

Fig. 5. Stepper Motor attached with servo motor

Servo motor maintains the paper rolling and stepper motor maintains the pen's up-down. Servo motor is connected with a pen and it punches the paper with it's 0.10mm pin to make dots on the paper.

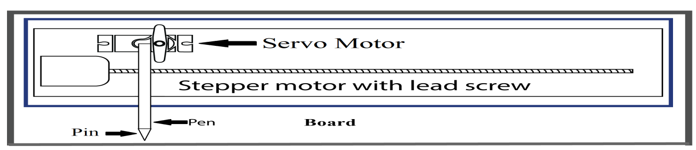

Fig. 6. Stepper Motor with pen

In Fig. 6, Stepper motor rotates servo motor along with the pen towards x-axis to generate braille letters by making dots on the paper.

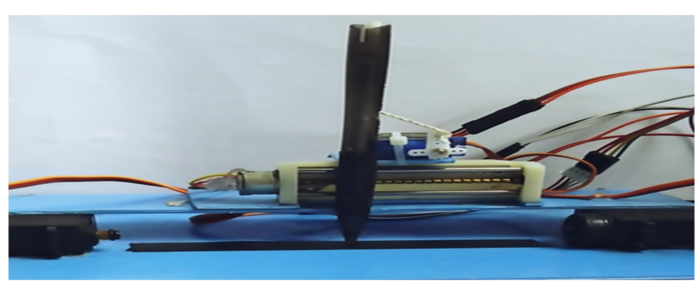

Fig. 7. EBCS Device

All the components are assembled which is shown in Fig.7.

V. RESULT

To evaluate the performance of the proposed system, the system checks how many letters are printed correctly on the paper from voice. The printed braille letters on paper (A4) are shown in Fig. 8. For each uttered word, EBCS prints a braille letter on the paper using a pen with a pin. By following the standard format of braille system each and every letter are printed. Therefor, when user gives an input voice like "Braille Hello", EBCS will print the letter in standard braille format in paper. Only word "Braille Hello" takes one line of the paper, after that the Servo 360 will roll the paper and stepper motor will move left to write the "Braille Hello" word in the paper.

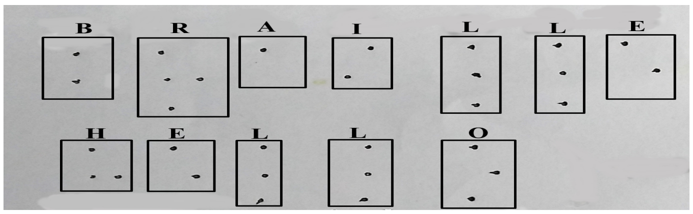

Fig. 8. Printed braille letter on paper

The accuracy of the generated braille letters on paper can be evaluated using cosine similarity. Single training epoch shows the accuracy of 97.6%. Fig. 9. shows the comparison of our results with existing research works.

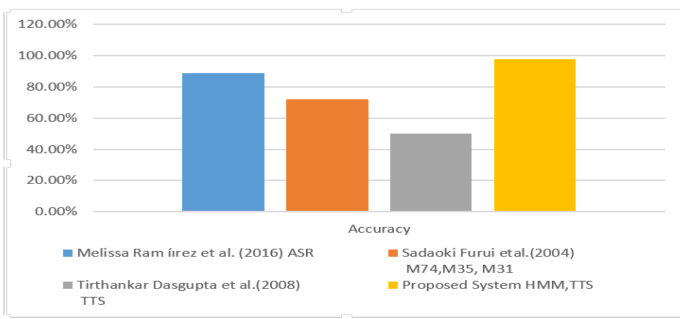

Fig. 9. Comparison of Accuracy Chart with EBCS

VI. CONCLUSION

In this paper, a combination of hardware and software system is being proposed to help the visually impaired people to write braille letter using the imprinted braille paper as their medium of communication. This device trains with a voice data from the human and transform the voice data into text form using HMM. Spectral Subtraction method along with HMM helps the proposed system to attenuate the noises as well as production cost. However, the result shows that 97.6% words are imprinted correctly after one iteration of training. In future, more compact version of device will be designed to better portability.

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