A Mobile Phone based Speech Therapist

Vinod K. Pandey
TCS Innovation Lab
Tata Consultancy Services
Thane, India
vinod.pande@tcs.com

Arun Pande
TCS Innovation Lab
Tata Consultancy Services
Thane, India
arun.pande@tcs.com

Sunil K. Kopparapu
TCS Innovation Lab
Tata Consultancy Services
Thane, India
sunilkumar.kopparapu@tcs.com

ABSTRACT

Patients with articulatory disorders often have difficulty in speaking. These patients need several speech therapy sessions to enable them speak normally. These therapy sessions are conducted by a specialized speech therapist. The goal of speech therapy is to develop good speech habits as well as to teach how to articulate sounds the right way. Speech therapy is critical for continuous improvement to regain normal speech. Speech therapy sessions require a patient to travel to a hospital or a speech therapy center for extended periods of time regularly; this makes the process of speech therapy not only time consuming but also very expensive. Additionally, there is a severe shortage of trained speech therapists around the globe in general and in developing countries in particular. In this paper, we propose a low cost mobile speech therapist, a system that enables speech therapy using a mobile phone which eliminates the need of the patient to frequently travel to a speech therapist in a far away hospital. The proposed system, which is being built, enables both synchronous and asynchronous interaction between the speech therapist and the patient anytime anywhere.

Keywords

Remote speech therapy, low cost mobile therapy, articulation disorder.

Categories and Subject Descriptors

H.5.2 [**Information Interfaces and Presentation**]: Miscellaneous

General Terms

System Architecture

1. INTRODUCTION

Nearly 6% of the population suffer from some kind of articulation and language disorders [1]. Articulation disorders can be due to cleft lip, cleft palate, cleft lip and palate, autism, cerebral palsy, hearing impairment to name a few. Several studies have been conducted to understand social, emotional and behavioral problems of these patients [2], [3], [4]. While surgery is not always required to correct articulatory defects, but almost in all cases the patient needs to undergo extensive speech therapy to rectify articulation disorder to regain normal speech.

Speech therapy is critical for continuous improvement in the patient speech. The goal of speech therapy is to develop good speech habits as well as to teach how to produce sounds correctly. Conventionally, speech therapy sessions are face to face and require a patient to travel to a hospital[1] or a speech therapy center for extended periods of time and frequently; this makes the process of speech therapy not only time consuming exercise in terms of travel for the young patient but also very expensive in terms of stay for extended duration near the speech therapy centers. Additionally, there is a severe shortage of trained speech therapists around the globe in general and in developing countries, like India, in particular. The severity of the problem increases for the rural patients affected by articulation disorders. Any form of speech therapy, which does not require frequent travel, but is monitored as effectively as a physical visit to a speech therapist is not only welcome but is an urgent requirement in all developing countries.

In this paper, a work in progress, we propose a system architecture which could be used effectively by patients with articulation disorders to undergo speech therapy under the speech therapist guidance to regain normal speech. The approach takes advantage of the proliferation of the mobile phone and the advances in speech signal processing to facilitate patients undergo speech therapy sessions without (a) the actual physical presence of the speech therapist, which essentially means the patient can avoid travel and (b) the patient and the speech therapist need not be available on this platform at the same time, meaning a speech therapist can assist a lot more patients. The proposed system also permits verbal and/or textual communication between remotely located patient and a speech therapist. The system uses the mobile phone to capture the speech of the patient and the analysis of the speech is done on a remote server. While this system is intended for speech therapy sessions, it can however also be used for practicing speech lessons. The proposed system addresses the issue of imparting speech therapy effectively, economically and remotely using available and to be developed state of the art technology. We present an approach to make speech therapy affordable and sustainable for use by masses. The rest of the paper is organized as follows. In Section 2 we browse through related literature and describe our approach in Section 3. In Section 4 we discuss some experiments carried out on normal and speech with articulation disorders. We discuss out interaction with speech therapist in 5 and conclude in Section 6.

2. RELATED LITERATURE

[1] at least in developing countries like India

The issue of imparting speech therapy has been discussed in literature sparsely and most of them are found in terms of patents. A miniaturized device for remote speech therapy to overcome stuttering problem is reported in [5]. The described system acquires patients medical history and speech samples to perform automatic diagnosis of the speech disorder and connects with a therapist for teleconferencing. Based on the diagnostic information, patient can select a pre-programmed therapy session for speech training. The system also permits playing reference sound, storing patients speech samples and retrieving previously stored speech samples for play back and/or speech analysis. This is more of a web based system, which requires the speech therapist to be online when the patient is using the system; further unlike what we propose, the words that the patient is asked to speak is static and does not depend on the progress of the patient.

A system for providing speech therapy and speech assessment by capturing tongue movement of patient is described in [6], however this is not intended for conducting remote speech therapy. The system uses a special instrument, palatometer for acquiring labial, linguadental, lingapalatal contacts along with the voice samples. The system provides feedback on a PC, connected to the palatometer, by displaying contacts of lips, tongue etc for the spoken utterance. Simultaneously, lingual movements (contacts of lips, tongue etc) are displayed on the screen for the reference speech. A scoring, based on the timing between the sensor and the lingual movement, is used to judge the closeness of the spoken utterance with the reference. In [7] a method for enhancing the fluency of persons who stutter while speaking is addressed. They use frames of eyeglasses to visually display the articulatory movements of a patients mouth and normal person's mouth to enable the patient observe the difference£. The patient can refer to the display at desired times to enhance the fluency of the speech. The system described in [8] presents to a user a symbol representative of a word, which the patient has to to pronounce into a microphone, the therapist hears the pronounced word and enters the phonetic representation of the user pronunciation. The system then automatically determining whether an error exists in the user pronunciation; and if an error exists, it categorizes the error. This system reported in [8] always requires the speech therapist to be present when the patient is undergoing speech therapy. Ratio between therapist to patients are very low and hence it may not always be feasible that a therapist is present when the patient is taking speech training sessions.

Movement of tongue is used for providing speech therapy and speech assessment in [9]. The system uses a sensor plate, similar to [6], for acquiring labial, linguadental, lingapalatal contacts along with the voice samples. The system determines a set of parameters representing a contact pattern between the tongue and the palate during the patients utterance and compares them with a set of parameters from normal speaker in terms of deviation and accuracy scores. Additionally, the system also displays contact location between tongue/ palate and sensor plate for the patient utterance and the normal speaker. Nasal airflow acquired simultaneously with the speech of the patient is used in [10]. Variations in nasal airflow and speech signal with timestamps are used as a visual assessment of the patient condition by therapist. This approach is not automated and requires presence of the therapist for the analysis.

Almost all the systems described in literature specifically consider the fact that the therapist and the patient be present at the same point of time even if they are not in face to face contact. This can not address the issue of the lop sided ratio in terms of therapy needing patients and the therapist. Our approach is one of enabling a speech therapy session happen without requiring the patient and the therapist to be present at the same time [11].

3. PROPOSED SOLUTION APPROACH

It is well known that for producing different speech sounds, articulators such as jaw, tongue, teeth, lips etc move from one position to another. The configuration of these articulators effectively change the shape of the vocal tract which usually ends at the lips for some sounds and at the nose for some sounds. This position change in articulators is exhibited in some form in the acoustic signal produced by the human speech. Typically a speech signal is represented by several parameters such as energy, pitch, formats, jitter, shimmer, spectral tilt, spectral balance, spectral moments, spectral decrease, spectral slope and its roll-off.

Different types of articulation disorder may need different dictionary words, phrases and sentences that need to be practiced by the patient. For example, therapy in case of cleft patients may involve speaking more words with nasal sounds. A database of words, phrases and sentences which have sounds embedded in them which are typical of being wrongly produced by patients with certain articulation disorders is maintained. These words, could also be phrases or sentences, are (a) chosen in consultation with the speech therapist along with (b) details of the order in which these words need to be presented to the patient and additionally (c) the manner in which the spoken words are to be analyzed to identify the improvement in articulation post a speech therapy session. Typically references of normal speech is stored in terms of the speech parameters such as energy, pitch, formats, jitter, shimmer, spectral tilt, spectral balance, spectral moments, spectral decrease, spectral slope and its roll-off etc in a database. These speech features can be used to compute the closeness of the patient speech and the reference speech. This closeness metric can also be also used to (a) judge the progress of the patient and (b) as a guide during speech therapy session.

At a very high level architecture of the proposed system is one of a web service. The system connects the patient and the speech therapist without both of them being available on the system at the same time. A typical scenario would require the mobile phone, with the proposed remote speech therapy application, be with the patient who wishes to undergo speech therapy. Fig. 1 shows instances of the application running on the patients mobile phone. As is normal in any hospital, there is a registration process where in several details of the patient are captured, like name, age, gender, medical history, nature of articulatory disorder, name of the speech therapist etc. Registration details serve two purposes, (a) it determines the speech therapist who can view the progress of the patient and (b) determine the nature of therapy that is required for the patient. The application on the mobile phone is controlled by the server to utter a certain word or a phrase. The set of words and the sequence in which they need to be presented to the patient is controlled by the server and is based on the articulatory

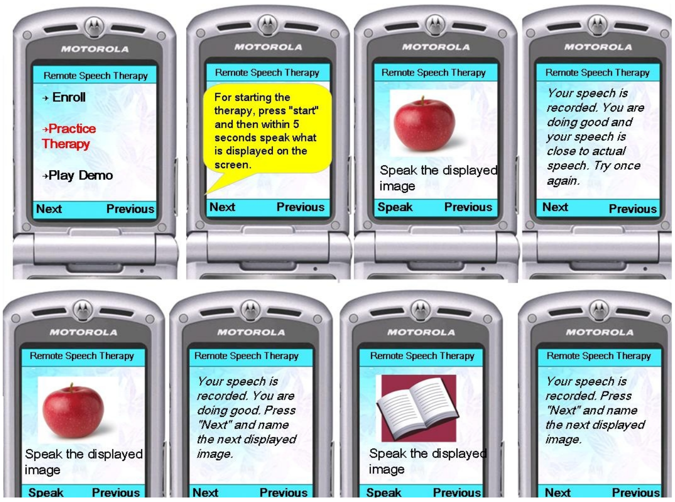


Figure 1: Instances of the application running on patient mobile phone.

disorder of the patient. Additionally, the set of words and the sequence of the words that need to be uttered by the patient can be changed, if desired, by the speech therapist on the server offline. This word the patient has to speak is elicited by presenting an image, displayed on the mobile screen or as a spoken speech sample. The patient is expected to speak the word when prompted by the system. The patient spoken speech is then processed on the server and then compared with the reference normal spoken speech. The method of comparison is based on what a therapist would normally look for in a face to face session. For example, if a certain vowel in a word is what is to be observed then the comparison would be based on the identification of the vowel in the spoken speech followed by vowel comparison with reference vowel. The comparison, enables identification of the disorder and in case of post speech therapy the degree of improvement in speech. The deviation, if any, from the normal spoken speech is presented as a feedback to the patient. The feedback could be in the form of either (a) graph and presented to the patient in a manner that might assist the patient to improve the articulation and thereby rectify the disorder or (b) as a reference sound to enable the patient to *learn* the sound. This process of the patient uttering a sound and the system identifying the existence of the disorder and displaying a feedback to assist the patient is repeated with out the actual presence of the speech therapist on the other side of the system at the same time.

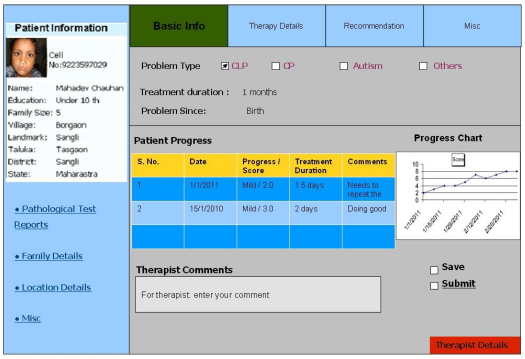
The speech therapy sessions taken by the patient can be examined at the therapist convenience periodically. Patients speech files and other performance details of the patient are presented as a dash board view (an expert console) for the therapist to browse the activity of the patient. therapist on using a personal computer connected to the Internet. Fig. 2 shows different instances of the dash board as viewed by the therapist. Fig. 2(a) is the speech therapist view which displays details such as personal information of patient, nature and date of surgery, speech therapy sessions taken by the patient and the current state of the patient responding to the speech therapy, Fig. 2(b) shows details of all the speech therapy sessions taken by the patient while Fig. 2(c) shows a view where in the speech therapist can play the actual speech uttered by the patient and review the performance. Additionally the speech therapist can get to view the amount of time spent by the patient in training or using the speech therapy system. This dash board would evolve with discussions with speech therapist and would strive to give a good picture of the progress made by the patient as desired by the speech therapist. Speech therapist can also use this dash board to communicate offline with the patient if desired; typically as a voice instruction, which the patient will hear when he uses his mobile phone to take his/her next therapy session.

The proposed system facilitates both real time online communication and offline communication between the patient and the speech therapist. In an online mode, a human speech therapist is available during the speech therapy session, guiding the patient in real time. This is more like a remote speech therapy, except that the patient and the therapist are not at the same location. However, in an offline mode, the word uttered by the patient and the reference word stored on the server are used for comparison and giving automatic feedback. In this scenario the patient and the therapist need not be present on the system at the same time. Details of the online and offline speech therapy sessions along with the spoken speech samples are stored on the server and are available for a speech therapist to review and take necessary corrective measures to speed up or slow down the therapy sessions.

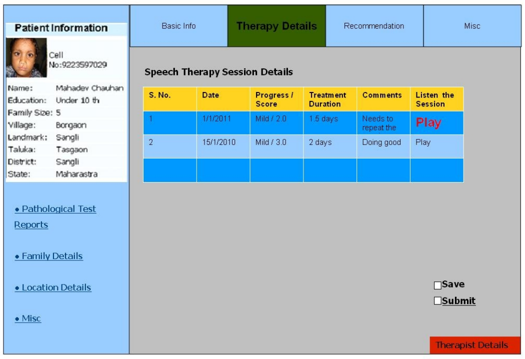
4. PRELIMINARY ANALYSIS

We conducted some preliminary experiments to analyze if there were identifiable differences between normal and a person with articulation disorder. Speech signals from normal speaking and cleft palate children were analyzed to observe visible differences in their characteristics. A total of four speech samples (2 normal and 2 cleft palate) were analyzed; the spoken speech was that of English numerals from *one* to *ten*. A visual difference between normal and cleft palate speech especially for some speech features, namely, pitch contour, formant, and signal intensity was observed. Fig 3 shows speech waveform, spectrogram, and pitch contour for the normal female subject for spoken utterance */three/*. Fig 4 shows the speech waveform, spectrogram, and pitch contour for a female subject with cleft palate (CP) for the same spoken utterance */three/*. Visual observation of some features shows that

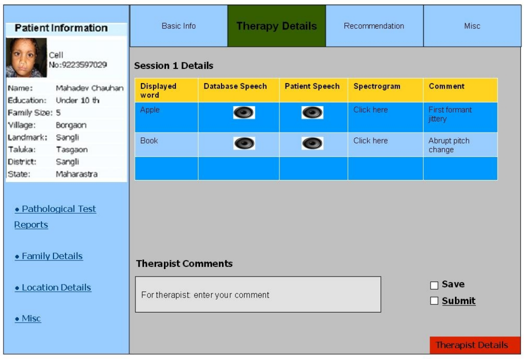
- the pitch contour for the CP female subject has abrupt changes, specially for spoken word: */three/* and */four/*.
- For the male group (age: 6 years), the pitch contour for the normal male subject was more continuous than the pitch contour for the CP affected male subject, which had a lot of discontinuities.
- Duration of the spoken numeral was smaller for the CP female subject compared to the normal speech.
- However, there was no noticeable difference in duration of spoken words for the normal male and CP male subject.
- Mean value of the first formants for the CP male and female subjects were lower as compared to the mean



(a) Patient Details.



(b) All Therapy Sessions.



(c) Particular Therapy Session.

Figure 2: Speech Therapist Console.

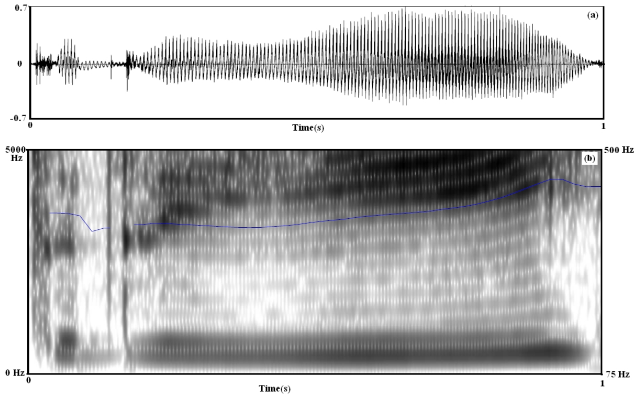


Figure 3: (a) Speech waveform, (b) spectrogram and corresponding pitch contour, for English numeral */three/*, spoken by a normal female subject (age: 6 years). Time axis: normalized to 1.

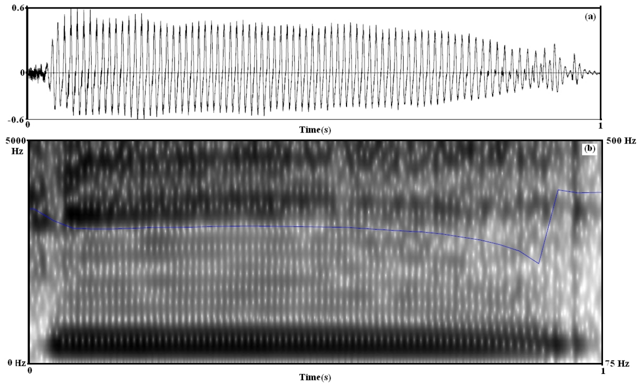


Figure 4: (a) Speech waveform, (b) spectrogram and corresponding pitch contour, for English numeral */three/*, spoken by a CP female subject (age: 5.8 years). Time axis: normalized to 1.

of the first formant for the normal male and female subjects.

Some of these features can be used for discriminating normal speech and speech from patients with articulatory disorder.

5. DISCUSSION

While some observation can be derived from the small set of analyzed data, this in no way suggests that (a) these observations are comprehensive, (b) these speech feature set are complete and sufficient. We are in process of recording large speech data from different patients with different articulation disorder. It is proposed to identify a small set of articulatory disorders and set up a complete speech therapy session in consultation with a speech therapist. We plan to run a pilot by distributing the mobile based application to some patients of the institute for the hearing handicapped to carry out speech therapy remotely. The patient will be directed to speak certain words, and the presentation of the next word or phrase will be based on the closeness of the patient spoken word to the normal spoken word. If the patient spoken word is articulated wrongly, the system would prompt the patient to repeat the word by giving a feedback on where s/he misarticulated. All therapy session will be logged and the speech files stored on the server. The dash board will enable the speech therapists to retrieve and listen to the patient speech samples, and also see the analysis results at a later time convenient to the speech therapist. The dash board will also provide facility to the speech therapist to modify the therapy program (sequence of words to be presented to the patient) depending on the speech therapist analysis of the progress of the patent; this provides the speech therapist an option to override the system analyzed option. The actual success of the proposed remote speech therapy system will be based on the feedback provided by the patients and also the speech therapists which will give an idea if this method of speech therapy can reduce the number of visits of the patient to the speech therapist thereby making the remote speech therapy (a) cheap and making speech therapy accessible to more patients. We also plan to monitor the reduced number of trips to the therapist and the reduced time and travel cost.

5.1 Discussion with Speech Therapist

Initially, we approached a hearing impaired institute in Mumbai and spoke to several speech therapist in the institute and suggested the concept of developing a mobile phone based remote speech therapy aid. During initial interactions, the therapists had hesitation in viability of the tool for speech therapy. They were convinced with the proposal after a short demonstration of the proposed system. This helped us in being able to get audience with the patient when the speech therapy was in progress. Several observations that will be of use to build the system came up. Like, a therapist initially checks if the patient is familiar with sustained sounds (like *'t'*, *'d'*, *'k'* and *'p'* etc), commonly used words, counting numbers, phrases (mostly stories, rhyme etc) before prescribing a therapy. A therapist often concentrates on speech parameters like pitch, loudness, and frequency (spectrogram) for differentiating patient speech and normal speech.

The therapists were of the opinion that the proposed system can definitely reduce the number of visit of the patient to the therapy centers. Personalization and design flexibility of the dictionary for different languages was another aspect that came out. The therapists suggested that it might be meaningful to have a facility on the proposed platform that can enable communication with the patients, as a SMS or MMS for giving instructions and prescriptions, replying to patients query. They felt that the remote speech therapy system could possibly enhance the pace of the therapy.

6. CONCLUSIONS

Patients with articulation disorders needs guidance from a speech therapist to regain their normal speech. The ratio of the speech therapist and the patients that need speech therapy is poor. Several visits to actual speech in progress therapy session suggests that it is feasible to provide a platform that can bridge the gap between the number of patient that need speech therapy and the speech therapist by reducing the actual number of physical visits of the patient to the speech therapist. This would enable the speech therapist to *see* more patients. The central idea of the proposed system is to enable speech therapy with out requiring a speech therapist being physically available during an actual in progress therapy session. This would in many cases result in avoidance of the need of the patient to travel to a speech therapist at a distant location / hospital. In brief, this mobile based system will enable putting the patient and the speech therapist in a virtual room though they are physically separated geographically. With appropriate user interface and tested usability of the software, mobile phone can be a robust device in the hands of the patients to undergo speech therapy sessions and interact with the therapist remotely. Patients can take speech therapy sessions at their convenience. This will be useful specially for young kids. This device can also be used to display multi media information in the form of audio clips, video clips for the purpose of training.

Acknowledgment

Several members of the TCS Innovation Labs - Mumbai have been instrumental in contributing to the conceptualization and building the system. Special thanks to faculty members and speech therapist at Ali Yavar Jung National Institute for the Hearing Handicapped, Mumbai, India for simulating discussions which enhanced our understanding of how speech therapy actually happens on ground.

7. REFERENCES

[1] J. Boyle, B. Gillham, and N. Smith, “Screening for early language delay in the 18 - 36 month age-range: the predictive validity of tests of production and implications for practice,” *Child Language Teaching and Therapy*, vol 12, pp 113-127, 1996.

[2] D. Aram, B. Ekelman, and J. Nation, “Preschoolers with language disorders: 10 years later,” *Journal of Speech and Hearing Research*, vol 27, pp 232-244, 1984.

[3] H. W. Catts, “The relationship between speech-language impairments and reading disabilities,” *Journal of Speech and Hearing Research*, vol 36, pp 948-958, 1993.

[4] N.J. Cohen, D.D. Vallance, M. Barwick, N. Im, R. Menna, N.B. Horodezjy, and L. Issacson, “The interface between ADHD and language impairment: an examination of language, achievement and cognitive processing,” *Journal of Child Psychology and Psychiatry*, vol 41, pp 353-362, 2000.

[5] A. Czyzewski, S. Henryk, and K. C. Bozena, “Therapy system and device for speech articulation,” WIPO Patent Application 0239423, Filed 13 Nov. 2000, Published 16 May 2002.

[6] F. L. Fletcher, “Method for utilizing oral movement and related events,” US Patent 6971993, Filed 14 Nov. 2001, Issued 6 Dec. 2005.

[7] J. Kalinowski, A. Stuart, and M. Rastatter, “Methods and devices for enhancing fluency in persons who sttuter employing visual speech gesture,” US Patent 7031922, Filed 20 Nov. 2000, Issued 18 Apr. 2006.

[8] J. E. Hartt, B. Bernhardt, and V. S. Albert, “Speech analysis and therapy system and method,” US Patent Application 2002099546, Filed 25 Jan. 2001, Published 25 Jul. 2002.

[9] S. G. Fletcher, D. J. Lee, J. D. turpin, “Providing speech therapy by quantifying pronunciations accuracy of speech signals,” US Patent Application 2009138270, Filed 26 Nov. 2007, Published 28 May 2009.

[10] W. G. Selley, R. A. Ellis, and F. C. Flack, "Speech therapy method and equipment," Great Britain Patent 1588217, Filed 22 Aug. 1977, Published 15 Apr. 1981.

[11] Arun Pande, Sunil Kumar Kopparapu, Vinod Kumar Pandey, "A system and method for providing speech training", Indian Patent application *1584/MUM/2011*