The 6th Intl. Workshop on Spoken Language Technologies for Under-Resourced Languages
29-31 August 2018, Gurugram, India

Implementation of Concatenation Technique for Low Resource Text-To-Speech System-based on Marathi Talking Calculator

Monica Mundada[1], *Sangramsing Kayte*[1], *Pradip K. Das*[2]

[1]Department of Computer Science and IT, Dr. Babasaheb Ambedkar Marathwada University, Aurangabad, Maharashtra, India
[2]Department of Computer Science and Engineering IIT Guwahati, Assam, INDIA

monicamundada5@gmail.com, bsangramsing@gmail.com, pkdas@iitg.ac.in

Abstract

The indulgent acquaintance of mathematical basic concepts creates the pavement for numerous opportunities in life for every individual, including visually impaired people. The use of assertive technology for the disabled section of the society makes them more independent and avoid barriers in the field of education and employment. This research is focused to design an Android-based application i.e. talking Calculator for low resource based Marathi native language. The novelty of this work is to develop both, the application and the Marathi number corpus. Marathi is an Indo-Aryan language spoken by approximately 6.99 million speakers in India, which is the third widely spoken language after Bengali and Telugu but as they lack in linguistic resources, e.g. grammars, POS taggers, corpora, it falls into the category of low resource languages. The front end part of the application depicts the screen of a basic calculator with numerals displayed in Marathi. During runtime, each number is spoken as the specific key is pressed. It also speaks out the operation which is intended to be performed. The concatenation synthesis technique is applied to speak out the value of decimal places in the output number. The result is spoken out with proper place value of a digit in Marathi. The performance of the system is measured to the accuracy rate of 95.5%. The average run time complexity of the application is also calculated which is noted down to 2.64 sec. The feedback and review of the application is also taken from real end-user i.e. blind people.

Index Terms: Visually challenged, Assertive Technologies, text-to-speech, Digital Signal Processing, Concatenative Synthesis, Unit Selection, Di-phone Synthesis.

1. Introduction

The invention of new technologies makes life easier for humans, but for disabled people it, is a blessing. The learning and understanding of Mathematical concepts cultivates thoughts and reasoning skills. The study of the subject is noteworthy in the human civilization and assigned importance from primary to secondary and higher-secondary level of education [1]. Mathematics teaches the systematic way of thinking with help of numerical and spatial aspects of the objects. But the learning of mathematics is fundamentally different than reading and writing other subjects and languages [2]. In traditional time the learning of Mathematics has been unapproachable to visually impaired and blind students because it is enriched with visually defined concepts and information. As per the World Health Organization (WHO) [3] 285 million people are considered to be visually impaired world- wide: Out of which 39 million people are blind and 246 million have low vision [4]. Calculators are the tools which are used to solve simple and complex problems faced by students, teachers, academicians and people working at home, school and industry. But the scenario is different for visually impaired people with these normal calculators [2]. It offers few or no tactile clues to permit an individual with visual impairment to acquaint him or herself to the keypad. Low resources languages (LRL) are defined for which few online resources exist. The resources of LRL include a standard digital encoding, supplies of news text, parallel text, translation dictionaries, name taggers, segmenters, and morph analyzers. Indian languages are considered as low-resource, under-studied, and exhibit linguistic phenomena problems for developing synthesizers. Also, these languages are low resource languages in terms of the availability of resources for building machine translation, synthesizers, and for various Natural Language Processing (NLP) experiments [5]. The speakers of these languages are well-educated, with many of them speaking English either natively or as a second language.

Marathi is a low resource language which trails in the online corpus, Part of Speech Tagging (POS) and building of lexicons [6]. The primary aim of this research article is to survey alternatives which can advance the computational facilities of the visually impaired related to Marathi language. A text-to-speech (TTS) system converts normal language text, into speech [7]. The aim of speech synthesis is to project the design of a machine having an understanding and natural sounding voice for communication [8]. Speech synthesis systems leads with the conversion of the input text into its corresponding linguistic or phonetic representations and then synthesize the sounds corresponding to those representations [9]. With the input being a plain text, the generated phonetic representations need to be augmented with information about the intonation and rhythm that the synthesized speech should have. Here for ease, the speech corpus developed consist of only numbers [10]. Using the concatenation synthesis technique in Android platform, we have developed a low resource based Marathi Talking calculator [11]. So this Marathi talking calculator speaks out each number key as it pressed. It also speaks the operation to be executed and the result in Marathi with the correct digit place value. It also has two important key functions i.e. clear and go-back along with voice feedback. So this gives perfect indication about the overall procedure of the application. The synthesized voice is accepted and correct, which is verified with the subjective Mean Opinion Score (MOS) test [12]. The application is also verified and feedback is applied with real blind students. This research article focuses to perform the basic calculation in Marathi language with important concept of voice. This will help rural illiterate people and also visually impaired people to

10.21437/SLTU.2018-16

derive the basic mathematical functions .The average run time complexity of the application is calculated as 2.64 sec.

2. Database Corpus for Numbers

Most Indian languages are phonetic in nature [13]. Marathi consists of Devanagari script and spoken mainly in Maharashtra, India [14]. There are about 12 vowels and 32 consonants [15]. The peculiarity of this language is that it retains the pronunciation of some Sanskrit alphabets. The arrangement of phonemes is according to place and manner of articulation of the native script [16]. The database is designed for low resource Marathi language with total size of 121 recordings. This includes Marathi numerals from 1 to 100, place values of digits, and the four arithmetic operations. This also includes recording for clear and go back in Marathi. The database is developed at a professional recording studio, Silver Oak Advertisers, Aurangabad. The transcribing and labelling of each speech file phonetically is done using the Wave Surfer. This tool is enriched with features like playback of speech file with variable length delay between repetitions. It also adds phonemic, orthographic, tone and annotations to transcription in an interlinear format. It can also plot waveform, pitch plot, spectrogram, spectrum and various F1 vs. F2 displays [17]. Figure 1 shows the transcription files of speech input number *"Ek"*. Fgure 2 decipts the Marathi numerals with pronunciation and arithematic operators.

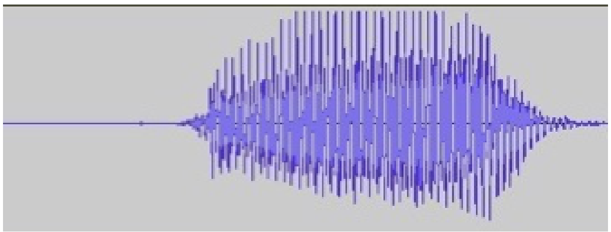


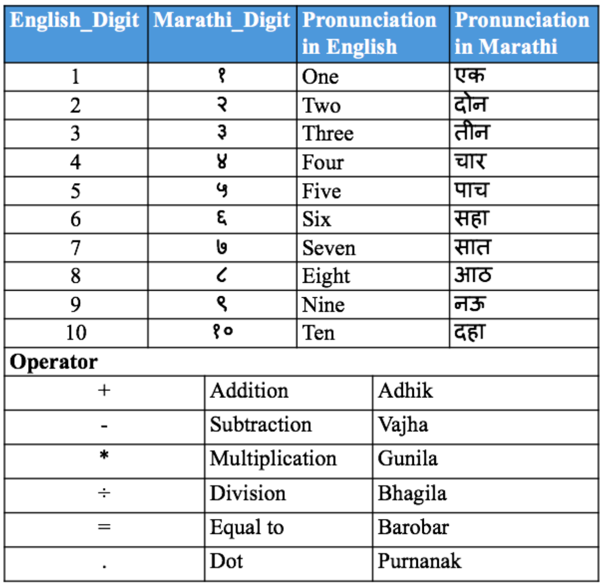
Figure 1: *Transcription file for speech input number "Ek"*

2.1. Literature Survey

A lot of research and study is focused for developing synthesizers for Marathi language using various techniques. The Blizzard challenge 2015 [18] [19] covers the synthesis for various Indian languages including Marathi. Also research is going in institutes like IIT-M, C-DAC, TIFR, IIIT Hyderabad, IIT-Bombay, IIT-Kharagpur and various universities related to Marathi language for building of corpus, POS taggers, online-synthesizers [20]. The novelty of this research is intended to build application oriented systems, which is small and easily accessible to common people using Marathi language [21].

3. Speech Synthesis for Marathi Numerals using Concatenation

Concatenative synthesis uses different length pre-recorded samples derived from natural speech [22]. This method is categorized into two types i.e. Unit and di-phone synthesis [23]. Diphones are defined as speech units that initiate in the middle of the stable state of a phone and end in the middle of the following one. The number of di-phones is determined by the possible combinations of phonemes in a language [24]. In di-phone synthesis, only one example of each di-phone is contained in the speech database. The quality of the resulting speech is generally not as good as that from unit selection but more natural-sounding than the output of formant synthesizers [25]. Diphone synthesis suffers from the robotic-sounding quality [26]. Unit selection synthesis uses unit as database for speech synthesis. This method requires large recording of database [27]. The unit selection technique gives naturalness due to the fact that it does not apply digital signal processing techniques to the recorded speech, which often make recorded speech sound less natural [28]. Figure 3 represents the block diagram of unit selection method.



English_Digit	Marathi_Digit	Pronunciation in English	Pronunciation in Marathi
1	१	One	एक
2	२	Two	दोन
3	३	Three	तीन
4	४	Four	चार
5	५	Five	पाच
6	६	Six	सहा
7	७	Seven	सात
8	८	Eight	आठ
9	९	Nine	नऊ
10	१०	Ten	दहा
Operator			
+	Addition	Adhik	
-	Subtraction	Vajha	
*	Multiplication	Gunila	
÷	Division	Bhagila	
=	Equal to	Barobar	
.	Dot	Purnanak	

Figure 2: *Marathi numerals with pronunciation and arithematic operators*

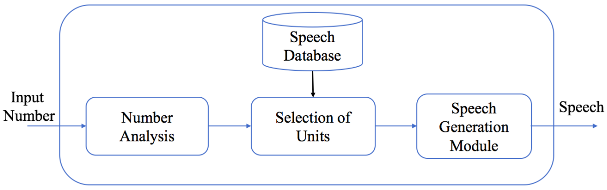


Figure 3: *Block diagram of unit selection text- to-speech (TTS) synthesis. After [29].*

4. Building of Marathi Talking Calculator

TTS system can be used to speak text messages from emails, SMS, web pages, news, articles, blogs, talking books and toys, games, man-machine communications, etc. Internet revolution made phones smart which became a fundamental part of life. There are number of speech driven applications available on smart phones [30]. Android operating system is gaining lots of attention as it provides access to various features of the phone like location sensor, TTS and many more. Android being open source delivers free development tools, which encourages

people to use the android system [31]. These features of Android attracted developers to build systems which can be easily accessible to common people and also for low resource

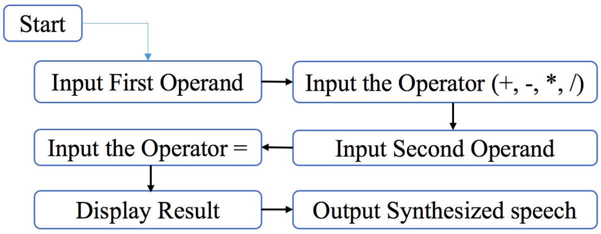


Figure 4: *Workflow for the Android-based Marathi talking calculator*

languages. A talking calculator has a built-in speech synthesizer [32] that reads aloud each number, symbol or operation key a user presses in Marathi. Figure 4 describes the workflow for Android-based Marathi talking calculator. The main feature of the application is the ability to talk in Marathi. The attractive feature of APP is it contains two special buttons for clear and go back which again speaks out when pressed. This again gives the clear instruction to the user for performing the particular operation. The minimum system specification for implementing Marathi Talking calculator Android operating system with any version and 512MB RAM. The size of developed application is 7 MB. The front end of the application is designed like a basic calculator, the numerals are presented in Marathi along with the basic arithmetic operation i.e. Addition, Subtraction, Multiplication and Division. A real time image of the application is shown in Figure 5.

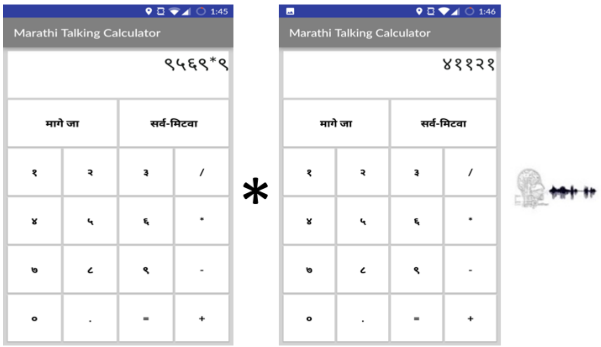
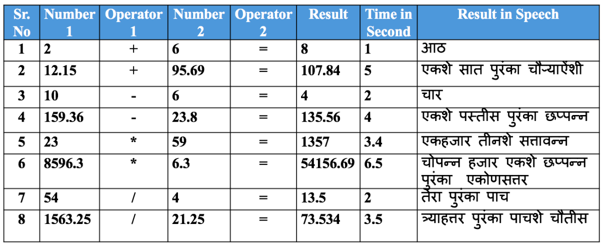


Figure 5: *Android-based Marathi talking calculator application*

5. Experimental Analysis

The implementation and GUI of the application is designed using Android studio and Java script environment [33]. The system is trained with the Marathi recorded number corpus. The concatenation technique is applied for the generation of output speech. The run time analysis of the application is calculated as the time taken for each operation to be performed from the initial state to the final calculated and synthesized output. We have calculated the run time analysis for each of the basic operation i.e. Addition, Subtraction, Multiplication and Division. Total 50 readings are stored for the same. The average run time analysis for the overall application execution along with the result output speech synthesized in Marathi is 2.64 sec. Figure 6 depicts the run time complexity of input numbers, operation and the output result.



Sr. No	Number 1	Operator 1	Number 2	Operator 2	Result	Time in Second	Result in Speech
1	2	+	6	=	8	1	आठ
2	12.15	+	95.69	=	107.84	5	एकशे सात पुरंका चौऱ्याऐंशी
3	10	-	6	=	4	2	चार
4	159.36	-	23.8	=	135.56	4	एकशे पस्तीस पुरंका छप्पन्न
5	23	*	59	=	1357	3.4	एकहजार तीनशे सत्तावन्न
6	8596.3	*	6.3	=	54156.69	6.5	चोपन्न हजार एकशे छप्पन्न पुरंका एकोणसत्तर
7	54	/	4	=	13.5	2	तेरा पुरंका पाच
8	1563.25	/	21.25	=	73.534	3.5	त्र्याहत्तर पुरंका पाचशे चौतीस

Figure 6: *Run time complexity for the Android-based Marathi speech talking calculator*

5.1. Performance Evaluation

The performance of the synthesized speech system is evaluated in terms of naturalness and intelligibility parameters [34]. There are various performance evaluation parameters i.e. subjective and objective, but here we opted the Mean Opinion Score (MOS) parameter for the evaluation of the synthesized speech. MOS is a test that has been used for decades in telephony networks to obtain the human users view of the quality of the output. It is calculated for the synthesized speech produced after the production from the application. It was counseled to the volunteers that they have to provide score ranging from 1 to 5 (Excellent 5, Very good 4, Good 3, Satisfactory 2 and Not understandable 1) for understandability. We have applied MOS test for all the four operations in the application i.e. addition, subtraction, multiplication and division using 100 subjects. The performance of the system is found to have an accuracy rate of 95.5% with the MOS test observations. The real-end user of this Marathi Talking calculator are blind people. So our intention of designing of this application is to benefit such sections of the society. The research study shows that visually impaired people have a good sense of hearing as compared to people with other disabilities. So we have also reviewed our application from such a cluster of people. We have tested our application with Blind students from classes 5-9 at Tarawati Bafna Blind School, Aurangabad. These students are well aware of handling mobiles and its operations. We have performed MOS tests with such group of 10 students for basic operations. So the accuracy of the application as per the visually impaired people is 93.25%.

6. Conclusion

This research study is intended for the development of low resource Marathi talking calculator which benefits visually impaired people to perform basic calculations in their native language. Using Concatenation method, the result of output speech is synthesized. The assertive devices will be beneficial if the synthesized voice sounds more natural. The study also focused to develop Marathi numerals database for low resource Marathi language which will be useful in many applications where numerical values are used. The developed application will be beneficial to illiterate mass of Maharashtra for calculations. The application is available in Play Store as Marathi Talking Calculator. There are numerous user-end applications for various devices with respect to the handicapped who could benefit from the use of such a relatively small and limited vocabulary voice capability. The development of a speaking capability for calculator thus opens the door to a wide variety of other promising applications. The assertive devices build using these techniques will be of great usage to visually disabled people and also benefit other researchers to progress in low resource languages. The feedback we received from blind students is to develop a multilingual calculator.

7. Acknowledgements

We are thankful to Dr. Bharti Gawali Department of Computer Science and IT, Dr. Babasaheb Ambedkar Marathwada University, Aurangabad for providing the guidance for the research. We also show our gratitude for School authorities and students of Tarawati Bafna Blind School, Aurangabad for providing their valuable co-operation and support for performing MOS tests.

8. References

[1] P. Agarwal, "Higher education in India: The need for change," Working paper, Tech. Rep., 2006.

[2] M. Niss, "Mathematical competencies and the learning of mathematics: The danish kom project," in 3^{th} *Mediterranean conference on Mathematical education, Athens, Greece*, 2003, pp. 115–124.

[3] W. H. Organization, *The world health report 2000: health systems: improving performance*. World Health Organization, 2000.

[4] W. H. Organization *et al.*, "Who releases the new global estimates on visual impairment," *World Health Organization. http://www. who. int/blindness/en/. Accessed*, vol. 10, 2011.

[5] M. Post, C. Callison-Burch, and M. Osborne, "Constructing parallel corpora for six Indian languages via crowdsourcing," in 7^{th} *Workshop on Statistical Machine Translation, Montreal, Canada*. Association for Computational Linguistics, 2012, pp. 401–409.

[6] B. B. Ali and F. Jarray, "Genetic approach for Arabic part of speech tagging," *arXiv preprint arXiv:1307.3489*, 2013.

[7] T. Dutoit, *An introduction to text-to-speech synthesis*. Springer Science and Business Media, 1997.

[8] R. T. Sataloff, "The human voice," *Scientific American*, vol. 267, no. 6, pp. 108–115, 1992.

[9] I. G. Mattingly, "Phonetic representation and speech synthesis by rule," in *Advances in Psychology*. Elsevier, 1981, vol. 7, pp. 415–420.

[10] Y. K. Muthusamy, R. A. Cole, and B. T. Oshika, "The OGI multi-language telephone speech corpus," in 2^{nd} *International Conference on Spoken Language Processing, Banff, Alberta, Canada*, 1992.

[11] S. Gaikwad, B. Gawali, and S. Mehrotra, "Design and development of Marathi speech interface system," in *Advanced Computing and Systems for Security*. Springer, 2016, pp. 3–20.

[12] A. Kain and M. W. Macon, "Spectral voice conversion for text-to-speech synthesis," in *IEEE International Conference on Acoustics, Speech and Signal Processing, Seattle, WA, USA*, vol. 1, 1998, pp. 285–288.

[13] S. P. Kishore and A. W. Black, "Unit size in unit selection speech synthesis," in 8^{th} *European Conference on Speech Communication and Technology, Geneva, Switzerland*, 2003.

[14] W. Bright, "The devanagari script," *The worlds writing systems, Oxford University, Press New York, NY*, pp. 384–390, 1996.

[15] J. Liljencrants and B. Lindblom, "Numerical simulation of vowel quality systems: The role of perceptual contrast," *Language, JSTOR*, pp. 839–862, 1972.

[16] W. D. Whitney, *Sanskrit grammar*. Courier Corporation, 2013.

[17] K. Sjölander and J. Beskow, "Wavesurfer-an open source speech tool," in 6^{th} *International Conference on Spoken Language Processing, Beijing, China*, 2000.

[18] S. Takamichi, K. Kobayashi, K. Tanaka, T. Toda, and S. Nakamura, "The NAIST text-to-speech system for the blizzard challenge," in *Proc. Blizzard Challenge workshop, Dresden Germany*, 2015, pp. 1–4.

[19] A. Pierre, C. Jonathan, D. Guennec, G. Lecorv, and D. Lolive, "The IRISA Text-To-Speech system for the blizzard challenge 2016," in *Blizzard Challenge 2016 workshop,Cupertino, United States*, 2016, pp. 1–7.

[20] R. Kumar, S. Kishore, A. Gopalakrishna, R. Chitturi, S. Joshi, S. Singh, and R. Sitaram, "Development of Indian language speech databases for large vocabulary speech recognition systems," in 10^{th} *International Conference Speech and Computer (SPECOM), Patras, Greece*, 2005, pp. 1–4.

[21] P. P. Shrishrimal, R. R. Deshmukh, and V. B. Waghmare, "Indian language speech database: a review," *International Journal of Computer Applications, New York, USA*, vol. 47, no. 5, pp. 17–21, 2012.

[22] B. Duggan and M. Deegan, "Considerations in the usage of text to speech (TTS) in the creation of natural sounding voice enabled web systems," in 1^{st} *international symposium on Information and communication technologies,Trinity College Dublin*, 2003, pp. 433–438.

[23] D. O'Shaughnessy, L. Barbeau, D. Bernardi, and D. Archambault, "Diphone speech synthesis," *Speech Communication, Elsevier*, vol. 7, no. 1, pp. 55–65, 1988.

[24] J. F. Werker and R. C. Tees, "Phonemic and phonetic factors in adult cross-language speech perception," *The Journal of the Acoustical Society of America*, vol. 75, no. 6, pp. 1866–1878, 1984.

[25] R. A. Clark, K. Richmond, and S. King, "Festival 2–build your own general purpose unit selection speech synthesiser," *Edinburgh Research Archive, 2004*, pp. 1–6.

[26] S. Kayte, "A text to speech system for Marathi using English Language," *International Journal of Engineering Science and Generic Research*, vol. 1, no. 1, pp. 1–12, 2015.

[27] A. J. Hunt and A. W. Black, "Unit selection in a concatenative speech synthesis system using a large speech database," in *IEEE International Conference on Acoustics, Speech, and Signal Processing, Atlanta, GA, USA*, vol. 1, 1996, pp. 373–376.

[28] J. J. Godfrey, E. C. Holliman, and J. McDaniel, "Switchboard: Telephone speech corpus for research and development," in *IEEE International Conference on Acoustics, Speech, and Signal Processing, Atlanta, GA, USA*, vol. 1, 1992, pp. 517–520.

[29] M. Beutnagel, A. Conkie, J. Schroeter, Y. Stylianou, and A. Syrdal, "The AT&T next-gen TTS system," in *The Journal of the Acoustical Society of America*, vol. 1, 1999, pp. 18–24.

[30] A. S. M. Mosa, I. Yoo, and L. Sheets, "A systematic review of healthcare applications for smartphones," *BMC medical informatics and decision making*, vol. 12, no. 1, p. 67, 2012.

[31] J. Higginbotham and S. Jacobs, "The future of the android operating system for augmentative and alternative communication," *Perspectives on Augmentative and Alternative Communication*, vol. 20, no. 2, pp. 52–56, 2011.

[32] L. M. G. Duhaney and D. C. Duhaney, "Assistive technology: Meeting the needs of learners with disabilities," *International Journal of Instructional Media*, vol. 27, no. 4, p. 393, 2000.

[33] M. Palmieri, I. Singh, and A. Cicchetti, "Comparison of cross-platform mobile development tools," in 16^{th} *IEEE International Conference on Intelligence in Next Generation Networks (ICIN), Berlin, Germany*, 2012, pp. 179–186.

[34] S. N. Kayte, M. Mundada, S. Gaikwad, and B. Gawali, "Performance evaluation of speech synthesis techniques for English Language," in *Proceedings of the International Congress on Information and Communication Technology*. Springer, 2016, pp. 253–262.