A Rule Based Schwa Deletion Algorithm for Punjabi TTS System

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Abstract. Phonetically, schwa is a very short neutral vowel sound, and like all vowels, its precise quality varies depending on the adjacent consonants. During utterance of words not every schwa following a consonant is pronounced. In order to determine the proper pronunciation of words, it is necessary to identify which schwas are to be deleted and which are to be retained. Schwa deletion is an important step for the development of a high quality Text-To-Speech synthesis system. This paper specifically describes the schwa deletion rules for Punjabi written in Gurmukhi script. Performance analysis of the implemented rule based schwa deletion algorithm, evaluates its accuracy to be 98.27%.

Keywords: Punjabi schwa deletion, Text-to-speech synthesis, Speech synthesis, Punjabi vowels and consonants.

1 Introduction

Schwa is a mid-central vowel that occurs in unstressed syllables. Phonetically, it is a very short neutral vowel sound, and like all vowels, its precise quality varies depending on its adjacent consonants. Each consonant in Punjabi (written in Gurmukhi script) is associated with one of the vowels. Other vowels, except schwa ('ਅ' the third character of Punjabi alphabet and written as [ə] in International Phonetic Alphabet (IPA) transcription), are overtly written diacritically or non-diacritically around the consonant; however schwa vowel is not explicitly represented in orthography. The orthographical representation of any language does not provide any implicit information about its pronunciation and is mostly ambiguous and indeterminate with respect to its exact pronunciation. The problem in many of the languages is mainly due to the existence of schwa vowel that is sometimes pronounced and sometimes not, depending upon certain morphological factors. In order to determine the proper pronunciation of words, it is necessary to identify which schwas are to be deleted and which are to be retained. *Schwa deletion* is a phonological phenomenon where schwa is absent in the pronunciation of a particular word, although ideally it should have been pronounced [1]. The process of schwa deletion is one of the complex and important issue for grapheme-to-phoneme conversion, which in turn is required for the development of a high quality text-to-

speech (TTS) synthesizer. In order to produce natural and intelligible speech, the orthographic representation of input has to be augmented with additional morphological and phonological information in order to correctly specify the contexts in which schwa vowel is to be deleted or retained [2].

Mostly phonological schwa deletion rules have been proposed in literature for Indian languages. These rules take into account morpheme-internal as well as across morpheme-boundary information to explain this phenomenon [3]. The morphological analysis can improve the accuracy of the schwa deletion algorithm which is a diachronic and sociolinguistic phenomenon [1, 4]. The syllable structure and stress assignment in conjunction with morphological analysis can also be used to predict the presence and absence of schwa [5].

1.1 Punjabi Language and Schwa

Punjabi is an Indo-Aryan language spoken by more than hundred million people. Like other Indian languages, Punjabi includes segmental phonemes (vowels and consonants), but not supra-segmental phonemes (stress, intonation, juncture, nasality and tone) in its alphabet. In Gurmukhi script, which follows the *one sound-one symbol* principle, Punjabi language has thirty eight consonants, ten non-nasal vowels (ਇ, ਈ, ਏ, ਐ, ਅ, ਆ, ਔ, ਉ, ਊ, ਓ) and same numbers of nasal vowels (ਇੰ, ਈਂ, ਏਂ, ਐਂ, ਅੰ, ਆਂ, ਔਂ, ਉਂ, ਊਂ, ਓਂ).

Vowels can appear alone in orthography (known as full vowels) however consonants can appear along with vowels only. Vowels, except schwa ([ਅ]), are represented diacritically when these come along with consonants (known as half vowels), otherwise as such. The consonant sound varies according to the vowel attached to consonant. For example, consonant [ਸ] conjoined with vowel [ਈ] (having diacritic ੀ) results a single orthographic unit “ਸੀ”, having pronunciation of a consonant-vowel sequence /ਸ+ਈ/ (/si/) however when this consonant comes with vowel [ਆ] the resulting single unit [ਸਾ] will be pronounced as /ਸ+ਆ/ (/sā/).

Consonants represented in orthography without any attached diacritic, basically have the associated inherent schwa vowel that is not represented diacritically. While pronouncing the written word, the speaker retains the intervening schwa vowel associated with a consonant where required and eliminate it from pronunciation where it is not required. In Punjabi the inherent schwa following the last consonant of the word is elided. For example, Punjabi word “ਸੜਕ” ([sədəkə] means road) pronounced as \ ਸ ਅ ੜ ਕ \ (\s ə d k\) is represented orthographically with only the consonant characters [ਸ], [ੜ] and [ਕ]. Schwa following the last consonant [ਕ] is deleted as per rule said above and the deletion the schwa following the second consonant [ੜ] makes the word monosyllabic of type CVCC (Consonant-Schwa-Consonant-Consonant).

2 Schwa Deletion Algorithm

Schwa vowel is not explicitly represented in orthography, so the schwa deletion algorithm basically turns to be *schwa insertion* at the morphological processing grounds in the text analysis component of the TTS system. The developed algorithm for schwa deletion basically consists of the two tasks: *vowel-consonant pattern generation* and *schwa deletion (/insertion) in vowel-consonant pattern.* These modules of the developed system have been discussed in the following subsections.

2.1 Module I: Vowel-Consonant pattern generation

This module generates the Vowel-Consonant pattern of the input word. It locates the full/half vowels (nasal or non-nasal) and the consonants positions; and hence identifies the schwa locations in the word. The output sequence corresponding to the input word consists of a string of symbols: C, V, v and n for the consonants, full-vowels, half-vowels and nasal-morphemes (bindī [ਂ] / tippī [ੰ]) respectively. This sequence of symbols will be helpful for marking the schwa positions. For example, the vowel-consonant pattern for the word "ਕਿਤਾਬ" ([kitāb] means book) is CvCvC and that of "ਅਧਿਆਪਕ" ([adiāpək] means teacher) is VCvVCC.

The further processing of the input word emphasises on finding the presence or absence of the schwa vowel sound during word's pronunciation. For example, the vowel-consonant pattern for the Punjabi word "ਮਰਦ" ([mərəd] means man) is CCC. Grammatically, there must be schwa vowel following each consonant in Punjabi but the word's pronunciation specifies the existence of schwa [ə] /ਅ/ sound after the first consonant only. So, schwa following the first consonant [ਮ] will be retained, however schwa vowels following the second [ਰ] and third [ਦ] consonants will be deleted.

2.2 Module II: Schwa deletion (/insertion) in vowel-consonant patterns

As already discussed the schwa is not represented orthographically. For the processing of the input text, schwa needs to be represented symbolically like other vowels. So, the schwa deletion process is taken up as schwa insertion and rules have been developed for the same. These rules are based on mainly three parameters: grammatical constraints, inflectional rules and morphotactics of Punjabi.

For these rules, let Σ = {V, v, C, S, b} be the set of all the symbols, where V = set of full vowels, v = set of half vowels, C = set of consonants, S = schwa vowel and b = blank space. A set of eleven rules has been designed and are discussed below. The underlined symbol in the following rules represents the current consonant that is under consideration.

Rule I: VC<u>C</u>C → VC<u>CS</u>C. If a consonant is preceded by VC syllable and followed by a single consonant (C), then schwa is inserted after that consonant. For example, in

word “ਇਕਦਮ” ([ikdəm] means immediate) schwa is inserted after consonant ‘ਦ’ ([d]) as per this rule, however not after ‘ਕ’ ([k]) and ‘ਮ’ ([m]) being at the syllable and word boundary respectively. In terms of schwa deletion we can say that schwa vowels after the consonants ‘ਕ’ and ‘ਮ’ are being deleted and that after ‘ਦ’ is being retained.

Rule II: VCC<u>C</u>C → VCC<u>CS</u>C. If a consonant is preceded by VCC syllable and is followed by single consonant (C), then schwa is inserted after that consonant. For example, in word “ਆਕਰਸ਼ਨ” ([ākərəshən] means attraction) schwa is inserted only after the consonant ‘ਸ਼’ ([sh]). No schwa after consonants ‘ਕ’ [k] and ‘ਰ’ [r] is inserted (being at syllable and word boundary respectively) and thus making this word disyllabic.

Rule III: <u>C</u>CCv(Σ - b) → <u>CS</u>CCv(Σ - b). If a consonant at word starting position is followed by a consonant cluster (CC), a half vowel (v) and one more character except the word boundary (Σ - b), then schwa is inserted after that consonant. For example, in word “ਹੜਤਾਲ” ([hədtāl] means strike), the schwa is inserted after consonant ‘ਹ’ ([h]) as per this rule, however not after ‘ੜ’ being at syllable boundary.

Rule IV: <u>C</u>CCC(Σ - b) → <u>CS</u>CCC(Σ - b). If a consonant at the word starting position is followed by consonant triplet (CCC) and one more character except the word boundary (Σ - b), then schwa is inserted after that consonant. For example, the consonant ‘ਗ’ ([g]) in word ਗਰਦਨਾਂ ([gərdnā]) satisfies this rule and so schwa is inserted after this consonant.

Rule V: <u>C</u>CΣ(V/b) → <u>CS</u>CΣ(V/b). If a consonant cluster at word starting position is followed by any character (V, v or C) and a full vowel or word boundary, then schwa is inserted after the consonant at first position. For example, in the words “ਕਹਿਆ” ([kəhiā] means said), “ਰਹੇ” ([rəhe] mean doing), “ਤਰਨ” ([tərn] means swimming), “ਕਰ” ([kər] means do), schwa is inserted after the first consonant of each word.

Rule VI: <u>C</u>CvC → <u>CS</u>CvC. If a consonant at word starting position is followed by a CvC syllable, then schwa is inserted after that consonant. For example in word “ਸਵਾਲ” ([səwāl] means question) schwa is inserted after the first consonant ‘ਸ’ ([s]).

Rule VII: (V/v)C<u>C</u>CC → (V/v)C<u>CS</u>CC. If a consonant is preceded by full or half vowel and one consonant and is followed by a consonant cluster, then schwa is inserted after that consonant. For example, in words “ਅਸਚਰਜ” ([aschərj] means strange), schwa is inserted after the consonant ‘ਚ’ ([ch]).

Rule VIII: CvC<u>C</u>CCvC → CvC<u>CS</u>CCvC. If a consonant is preceded by a CvC syllable and is followed by CCvC syllable, then a schwa is inserted after that consonant to make the word tri-syllabic. For example in word “ਰਾਸ਼ਟਰਵਾਦ” ([rāshtərwād] means nationalism), the consonant ‘ਟ’ ([t]) is at the position that satisfies the above said rule, so schwa is inserted after that consonant making the

word tri-syllabic having syllables ਰਾਸ਼ (CvC), ਟਰ (CvC, where ‘v’ is schwa ‘ə’) and ਵਾਦ (CvC).

Rule IX: (V/v/S)C<u>C</u>CCv(V/b) → (V/v/S)C<u>CS</u>CCv(V/b). If a consonant is preceded by the VC or CvC syllables and is followed by consonant cluster, half vowel and (/or) full vowel, then a schwa is inserted after that consonant. For example, the schwa insertion in words “ਤਿਲਕਣਗੀਆਂ” ([tilkəngiyā] means to be slipped) and “ਉਸਰਨਗੀਆਂ” ([usrəngiyā] means to be constructed) after the consonants ‘ਕ’ ([k]) and ‘ਰ’ ([r]) respectively.

Rule X: <u>C</u>CCvC → <u>CS</u>CCvC. If a consonant at the word starting position is followed by the CCvC syllable, schwa is inserted after that consonant. For example, in the word “ਤਕਰਾਰ” ([təkrār] means argument) the consonant ‘ਤ’ ([t]) at the word starting position, satisfies the above said rule and so schwa is inserted after this consonant.

Rule XI: (V/Cv)C<u>C</u>CC → (V/Cv)C<u>CS</u>CC. If a consonant is preceded by VC or CvC syllable and is followed by consonant cluster (CC), then schwa is inserted after that consonant. For example, in words “ਉਪਕਰਣ” ([upkərn] means instrument) and “ਨਾਮਕਰਣ” ([nāmkərn] means naming), schwa is inserted after the consonant ‘ਕ’ ([k]) in both words.

2.3 Algorithm

The schwa deletion algorithm that has been basically implemented as schwa insertion can be described briefly as below.

Input: vowel-consonant pattern of the input word.
Output: vowel-consonant pattern with inserted (/deleted) Schwa.
Algorithm:

i. Set variable *CVpattern* to consonant-vowel pattern of the input word.
ii. Set *currSymbol* to first symbol of the *CVpattern*.
iii. Repeat steps (iv) and (v) while *currSymbol* < > “”
iv. If *currSymbol* is a consonant then
    (a) Seach rule base for the *currSymbol.*
    (b) If the *currSymbol* satisfies any of the rules then insert schwa after that consonant in the word.
v. Set variable *currSymbol* to the next symbol of *CVpattern*.
vi. Return current word.

3 Performance Analysis

The developed algorithm has been tested on ten thousand most frequently used words of Punjabi. These words have been selected from a Punjabi corpus having 104425741

total and 232565 unique words. The set of most frequently used words have been generated on the basis of their frequency of occurrence in the above said corpus. Output of the algorithm for these words has been checked manually. Out of ten thousand, 173 words have been found with wrong schwa insertion. This results the accuracy of the algorithm to be 98.27%. It has been observed that most of the words for which the algorithm is giving wrong results are those containing *addak* (ੱ) specifying gemination in Punjabi and the words having *consonant conjuncts* those appear at bottom of the barer consonant.

4 Conclusions

Schwa plays an important role in the correct pronunciation of a language and hence for the development of a high quality TTS system. The decision for retention or deletion of schwa is very much obvious for a native speaker, but for machine processing purpose this decision will be based on language specific rules. A set of eleven rules have been developed and discussed in this paper for Punjabi. These rules are based on grammar rules, inflectional rules and morphotactics for Punjabi. The algorithm developed on the basis of these rules has good accuracy which will definitely improve the quality and hence naturalness of the output speech.

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