Dropping of the Class-Prefix Consonant, Vowel Elision and Automatic Phonological Mining in Embosi (Bantu C 25)

Annie Rialland, Martial Embanga Aborobongui, Martine Adda-Decker, and Lori Lamel

The aim of this paper is two-fold: 1) to provide a new analysis of a set of phonological processes in Embosi (Bantu C 25), particularly of the dropping of the class prefix consonant, proposing that it involves dissimilatory processes and compensatory lengthenings due to an empty C position, and vowel elision at phonological word boundaries; 2) to introduce an automatic speech-to-text alignment system in Embosi (with a word dictionary) and investigate how it can be used for phonetic/phonological data mining, focusing on vowel elision and on compensatory phenomena at phonological word junctions.

Embosi is a Bantu language (C 25) spoken in Congo (Brazzaville) by an estimated number of 140000 speakers in the Cuvette Region (INS, Congo). The number of speakers in Brazzaville itself and in the diaspora is unknown. This paper is mainly based on the variety of Embosi spoken in Boundji and its vicinity.

1. Selected phonological processes in Embosi

We will first reconsider the dropping of the class prefix consonants in Embosi, proposing an analysis in terms of dissimilation, and then, considering vowel elision processes at the junctions of phonological words, we will propose that the class prefix consonant, when not realized, leaves an empty C position. This empty C position may give rise to vowel lengthening at relevant word junctures.

1.1. Consonantal dropping and dissimilation in prefixes

Consonants in prefixes are realized when the stem is vowel initial and they are not when the stem is consonant initial. For example, the plural class prefix *ba* (cl. 2) is realized *b*- in (1,2) and *a*- in (3,4).

1. ba+ásí → b-ásí « wives »
2. ba+ána → b-ána « children »
3. ba+kondzi → a-kondzi « chiefs »
4. ba+kúsu → a-kúsu « tortoises »

In general, consonants in CV prefixes alternate similarly. Thus, the singular class prefix *mo* (cl. 1) is realized *mw*- in (5,6) and *o*- in (7,8). Note that the vowel –o of the prefix does not disappear, as seen in previous examples, but is replaced by the w- glide (cf. ex. 5 and 6).

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5. mo+ásí → mw-ásí « wife »
6. mo+ána → mw-ána « child »
7. mo+kondzi → o-kondzi « chief »
8. mo+yíri → o-yíri [1] « woman »

mi (cl. 4) is realized *my*- in (9) and *i*- in (10). Note that the vowel *–i* of the prefix is replaced by the *y*-glide, as illustrated by example (9):

9. mi+ésé → my-ésé « wife »
10. mi+kili → ikili « country»

These alternations have been documented in most of the studies of Embosi (Amboulou 1998, Bedrosian 1998, Fontaney 1988, 1989). In the line of Beltzung and al (2010), we propose to analyse this consonant dropping as an extreme case of consonant dissimilation. In many Bantu languages, the prefix consonant dissimilates but this dissimilation concerns only one or two features. In the classical version of Dahl's law, as exemplified by Kikuria (Odden 1994), the dissimilation is triggered by the [±voice] feature. In Embosi, the dissimilation is extreme as it involves not only one feature but all the consonantal features, that is all the features attached to the C root in a feature geometry representation, which can be schematized as follows:

```
      Prefix            Stem
        C                 C
        |                 |
  [Root Node]       [Root Node]
        |                 |
  [C features]      [C features]
```

Figure 1. Feature geometry representation of the extreme case of consonantal dissimilation process in Embosi class-prefixes.

In this paper, we will add further arguments for this analysis and this representation, which predict that only the Feature Root Node is affected by the dissimilatory process and that the C position is left. In the following experimental section, we will show evidence for this empty C position, left untouched by the dissimilation.

The loss of the consonant in a prefix preceding a consonant initial stem is not restricted to Embosi but is known to be an areal phenomenon. It is found in most languages of the C20 language group (in Mboko (C21), Akwa (C22), Ngare (C23), Koyo (C24), Embosi (C25) but not in Likwala (C26), likuba (C27), see Gazania & Hyman 1996, Ndinga Oba 2004),, in other C languages (Doko C30, cf. Grégoire & Janssens 1999) as well as in some B languages (Yisangu B 42 cf. Ondo-Mebiame 2000, Lempiini, Mbaana dialect B62 cf. Blanchon & Alihanga 1992, Orungu B 11b Ambouroue 2007). We refer the reader to Beltzung & al. 2010 for a first analysis in terms of dissimilation and a review of the geographical dispersion of this process. Note that compensatory lengthening is not mentioned in these studies and could have passed unnoticed in some languages as it did previously in Embosi.

Considering vowel elision at phonological word junctions, we will analyse whether and how these dropped consonants leave traces.

1.2. Vowel elision at the junctions of phonological words without/with compensatory lengthening

Vowel elision occurs at phonological word junctions when two vowels get in contact. This elision may or may not be accompanied with lengthening. At first, we will consider the regular cases of vowel

[1] y is the notation of [j]. This symbol commonly represents the sound [j] in the spelling of African language.

elisions involving short or long vowels and then, the case of vowel elision with lengthening that occurs when the second word begins with a prefix the consonant of which is dropped.

1.2.1. Regular cases of vowel elisions

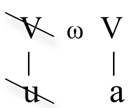
At phonological word junctions, two vowels are often in contact, as all the phonological words end with a vowel and as many phonological words begin with a vowel (see part 2, for percentages of vowel-initial words in a corpus). The last vowel of the first phonological word (V1) can be short or long while the first vowel of the second phonological word V2 is always short. In the regular cases, the last vowel of the first word or its last mora if it ends in a long vowel is elided, as shown by the following examples:

a) Examples of contacts of short vowels at phonological word junctions

11. okondzásɛri
((m)o-kondzi) ω (á-sɛr-i) ω[2]
Cl1.chief. 3sg-Past-say-Recent
« The chief said. »

12. oyúlalámbi
((m)o-yúlu) ω (á-lámb-i) ω
Cl1-woman 3sg-Past-cook-Recent
« The woman cooked. »

In this type of examples, the last vowel of the first phonological word is deleted. This deletion concerns the entire vowel (V position as well as vowel features), which can simply be represented as follows:

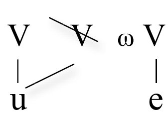


b) Examples of contact of a long and a short vowel at phonological word junctions

When the 1st word ends with a long vowel, only the final V position of that long vowel falls, as shown in (13):

13.ekuébe
(e-kuu) ω (é-bva-i) ω
cl7. door cl7.Past-fall-Recent
« the door fell »

The loss of the last V position of *kuu* can be schematized as follows:



1.2.2. Vowel elision with lengthening at phonological word junctions

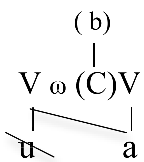
Vowel elision associated with the lengthening of the vowel of the second phonological word (V2) can be observed when the second word begins with a prefix the consonant of which is dropped due to the dissimilation process presented previously, as shown by the following examples:

[2] ω is the symbol referring to the phonological word.

14. akondzaásɛri
((b)a-kondzi)ω ((b)á-sɛr-i) ω
Cl2.chiefs Cl2.Past-say-Recent
« Chiefs said. »

15. ayúlaalámbi
((b)a-yúlu) ω ((b)á-lámb-i) ω
Cl2.women Cl2.Past-cook-Recent
« women cooked. »

In these examples (14) and (15), the prefix plural *ba* occurs four times and, each time, it is realized *a*, as, each time, it precedes a stem beginning with a consonant (*-kondzi*, *sɛr-* in (14), *yúlu*, *lámb* in (15). At the junction of the two phonological words forming these sentences, the last vowel of the first word (*i* of *(b)a-kondzi* in 14, and *u* of *(b)a-yúlu* in (15) is elided and the vowel *a* of *(b)a* is lengthened. We propose to analyse this lengthening as a compensatory lengthening, which can be schematized as follows (based on example 15):



The empty C, left behind by the dropped *b*, avoids the contact between the two V positions. Thus, it protects the V position of the 1st vowel and the vowel *a* fills the V position left by the elision of the first vowel *u*. This process, consisting in filling a position left by an elided element, is typically a compensatory lengthening. Note that we assume a disymmetry, which is common, between an empty C position with no weight or duration and an empty V position with a duration.

An optional coalescence process can be observed, which merges a vowel *a* and a vowel *i,* occurring in this very order at phonological word junctions. The result is either a vowel *e* or a vowel *ɛ* depending on vowel harmony, as shown by the following example (16).

16. sɛɛ́kangá/ siíkangá
(sá) ω ((m)i-kangá) ω
loc cl4.racines
« in roots »

Note that all of our examples of coalescence at phonological word junctions involve a morpheme with a floating consonant and, therefore, with an empty C marked by a compensatory lengthening.

For a more detailed study of these vowel elisions, coalescences and compensatory lengthening phenomena in Embosi, we refer the reader to Embanga Aborobongui (2013).

1.3. Intermediate conclusions: a revised analysis of the dropping of class prefix consonants

These alternations in class prefixes, depending upon the nature of the first segment of the stem, were previously observed. We propose to analyse this dropping as a case of consonantal dissimilation. We showed that in this process, the consonant is not totally deleted but it leaves behind an empty C position, revealed by compensatory lengthenings occurring at phonological word junctions. In the second part of this paper, we will introduce an Embosi text-to-speech alignment system designed for phonological data mining, including a study of vowel elision and compensatory lengthening.

2. An Embosi text-to-speech alignment system for phonological/phonetic data mining

In the following, we start describing our Embosi spoken material before introducing the automatic speech alignment system adapted to Embosi. We then propose to make use of automatic speech alignment and data mining techniques to examine the acoustic realizations of the previously formulated Embosi elision rules at word junctions. We will show how these elision rules can be automatically investigated by introducing pronunciation variants dealing with optional elisions, following a methodology developed by Adda-Decker & al. 1999, 2005, 2013. This method will also enable us to provide a first quantification of compensatory lengthenings.

2.1. Embosi linguistic resources

Embosi has very little written material and no officially agreed upon writing conventions. To highlight the paucity of written sources, we may note that the Bible which is available in hundreds of different languages, has only been partially translated in Embosi. Embosi speech recordings can be rather easily collected either by fieldwork or by using recordings from the local TV: Alima TV in Boundji. This TV channel broadcasts programs in French, Lingala, Embosi and in Teke-lima and has an important function both in revitalizing the languages/cultures of the region and in preserving cultural heritage. The production of corresponding speech transcripts represents a major bottleneck due to the lack of writing conventions and related knowledge of the language.

To study Embosi, we have created a first transcribed speech corpus consisting of three read folktales (Obenga, 1984) recorded in a quiet room totalling ten minutes of speech:

1) ndéngé yáádiá tsɛ́sɔɔmwɛnɛ́ «The hare and the elephant »
2) ɛbɔ́ɔ bá lɔɔnɔɔ « The hand and the mouth»
3) lekú áyaá laayúlu «The death and the woman»

The recorded data were manually transcribed in IPA (with tones and bracketed floating consonants) by M. Embanga Aborobongui.

2.2. Automatic speech-to-text alignment system in Embosi

Speech-to-text alignment consists in automatically locating words and phone segments in the speech signal by making use of a reference transcription and a speech recognition system. The alignment process produces acoustic time-stamps of linguistic units (word and phone segment boundaries). Speech alignment is carried out by using an automatic speech recognition system in *alignment mode*, which means that the recognizer gets as input not only the acoustics, but also the *corresponding transcription*: the recognizer's search space is thus reduced to the *solution*, i.e. to the actually produced word string. If the system includes pronunciation variants for a given word, the alignment process will be able to select the most likely one (given the acoustic models on the one hand and the acoustic input to be aligned on the other hand). Speech-to-text alignment may thus produce - beyond the boundary information - the best-matching pronunciation. Both these features will be taken advantage of in the following.

The LIMSI French recognition system (Gauvain & al. 2005, Candea & al. 2013) was adapted to align Embosi speech. Preliminary steps to process a new language comprise the definition of the new language's phonemic inventory, the design of an acoustic phone model set, where each sound is modeled by a 3-state HMM (Hidden Markov Model) and of a pronunciation dictionary including all words occurring in the manual transcripts (Adda-Decker & al. 2011).

The Embosi sound inventory includes seven vowels (/i/, /e/, /ɛ/, /a/, /ɔ/, /o/, /u/) and 24 consonants (phonemes and main variants). All vowels and most consonants have close counterparts in French. Specificities of the Embosi consonantal inventory (w.r.t. French) consist in a bilabial fricative /β/ and a series of prenasalized consonants (e.g. /mb/, /ndz/).

Given the relative closeness of the Embosi sound inventory to the French one, an acoustic model set to process Embosi speech can be rather straightforwardly defined using the French models. The Embosi vowel inventory being fully covered by the French vowels, the relevant French vowel models were selected. The same was done for the consonantal subset covered by the French consonants (p, b, t, d, k, m, n, ɲ, f, s, l, w, j). For the bilabial fricative /β/, the French /w/ model was used. The prenasalized consonants are modeled as sequences of nasal /n/ or /m/ acoustic models followed by either a stop or a fricative model. In the same vein, affricates (/ts/, /dz/, /ndz/, /bv/, /mbv/) are modeled as sequences and long vowels are modeled as sequences of two short vowels. Tones are not modelled.

Figure 2 gives some insight in how the alignment system builds the acoustic models of the input speech transcription. On the top, the Embosi speech transcript corresponds to a « lexical line » with words including tones and floating consonants ((m)o yúlu). With the help of the pronunciation dictionary a « phonemic » symbol sequence is generated (Figure 2, second box), each symbol pointing to an acoustic model borrowed from French (third box). During the text-to-speech alignment procedure, these acoustic models (in terms of weighted acoustic vectors) are statistically compared with the vectors resulting from the acoustic analysis of the Embosi speech (Figure 2, bottom). Alignment results (word and phone boundaries) are stored in a Praat (Boersma & Weenink, 2013) compatible format for visualization and manual alignment result checking.

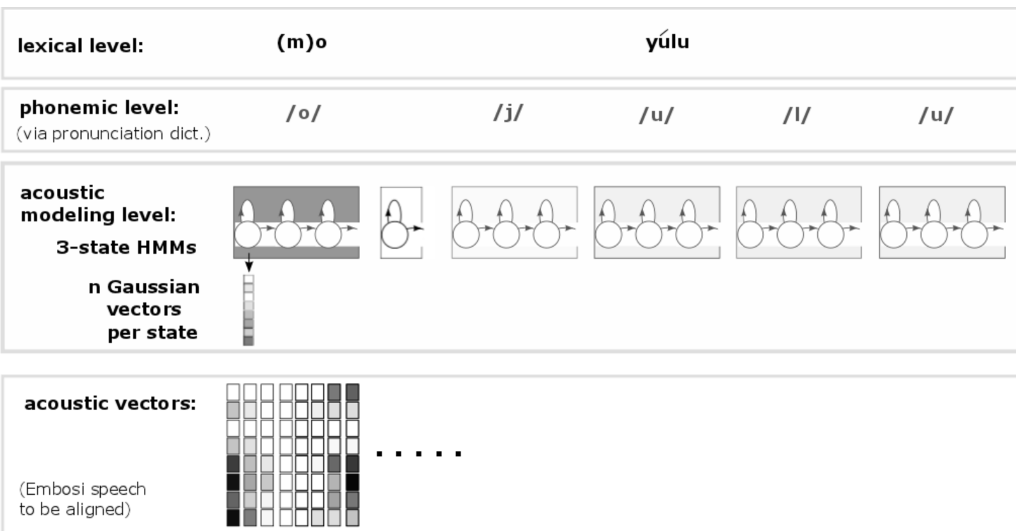


Figure 2. Schema of the levels involved in the text-to-speech alignment procedure: Embosi speech transcripts (lexical level) linked to corresponding acoustic models via a pronunciation dictionary (phonemic level) on top (dashed boxes), Embosi speech represented as acoustic vectors at the bottom.

The Embosi pronunciation dictionary (Table 1) is limited to the words occurring in the three folktales. A first pronunciation dictionary was created in which each lexical entry is described by its full (canonical) pronunciation. A second pronunciation dictionary version was designed to include pronunciation variants accounting for the Embosi dissimilation and vowel elision rules.

Word types	Canonical forms in the pronunciation dictionary	Variants in the pronunciation dictionary
ibáá	ibaa	ibaa, (i)baa, iba(a)
tsέsi	tsεsi	tsεsi, tsεs(i)
(m)oyénga	ojenga	ojenga, (o)jenga, ojeng(a)
ngá	nga	nga, ng(a)

Table 1. Embosi pronunciation dictionary giving for each word type (left column) a canonical pronunciation form (mid column) and variants (right column) with elidable vowels between brackets.

Tones and floating consonants were not included in the forms of the pronunciation dictionary, as floating consonants are not realized and as this text-to-speech alignment system does not refer to tones. Variants were generated from the canonical forms, omitting the first or the last vowels.

Figure 3 exemplifies a text-to-speech alignment obtained with the canonical form dictionary for an utterance which does not involve any elision process:

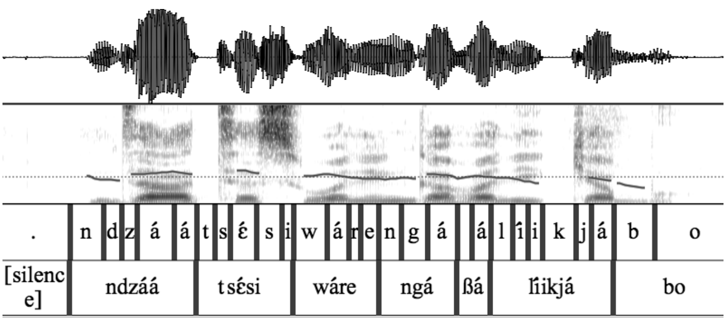


Figure 3. Text-to-speech alignment of the utterance: *ndzáá tsέsi wáre ngá βá líikjá bo* «but hare wonders how to do it » based on a canonical form dictionary. Tones were restored in the phone tier according to the transcription.

Figure 4 compares two text-to-speech alignments of an utterance in which elision processes occur: an alignment based on the variant dictionary (uppermost tier of the PRAAT visualization) and an alignment based on the canonical form dictionary (intermediate tier of the PRAAT visualization):

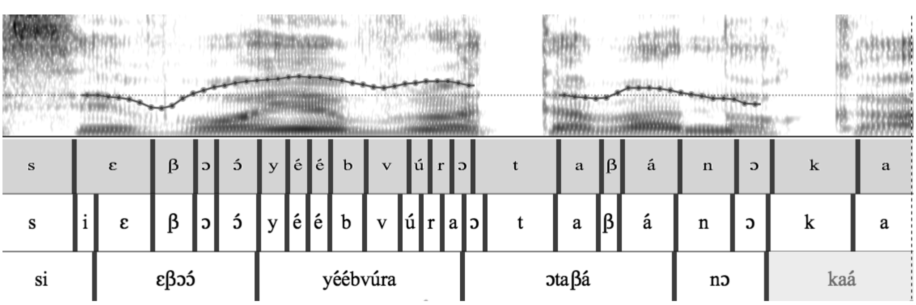


Figure 4. Two text-to-speech alignments of the utterance: *(nɔ odí ɔdzá la eyia) si εβɔɔ́ yéébvúra ɔtaβá nɔ kaá* « No secret will exist for you », with pronunciation variants allowing for vowel elision (uppermost tier of the PRAAT–visu) and without pronunciation variants (intermediate tier of the PRAAT visu).

In this utterance, elision processes occur twice : *si+ εβɔɔ́* → *sεβɔɔ́* and *yéébvúra +ɔtaβá* → *yéébvúrɔtaβá*. The alignment with variants (uppermost tier of the PRAAT notation) could refer to the pronunciation variants *s(i)* of *si* and *yéé bvur(a)* of *yéébvura* and provides a correct alignment, while the alignment based on canonical forms only (intermediate tier) tried to align the elided vowels (*i* of *si* and *a of yéébvura*) and gave them a minimal duration, creating artifactual segments.

On the basis of the automatically aligned pronunciation variants, a detection of the elision processes could be performed, as vowel elisions could be detected automatically. We manually checked the accuracy of the alignment in vowel contacts of one third of the corpus (1 folktale, 134 vowel contacts). The agreement rate between the manual and the automatic alignment is 92 %. We found that the discrepancies come from irregularities which were not yet implemented in the system (and not yet discovered for some of them) such as the non elision of the vowel of a monosyllabic root, a coalescence instead of an elision in some contexts, the irregular behavior of the long vowel *aa* (*káa+édí* realized kéedí has been «aligned » *ká +edí*, for example). This alignment procedure appears to be a reliable tool in order to perform a scan of the elisions, at least in our sample of recorded Embosi speech and we found it particularly effective in the search of exceptions and irregularities.

2.3. A text-to-speech alignment system for phonological mining: a quantitative perspective on elision and compensatory lengthening

This speech-to-text alignment can be used for phonetic and phonological mining, enabling the phonologist to scan large corpora for various phonological phenomena and get a quantitative perspective on these phonological phenomena.

As a background of our study of elision at word junctions with/without compensatory lengthening, some relevant characteristics of the corpus can be quantified, such as the number and percentage of words with initial V or (C)V and with a final V in our corpus (see Table 2).

	Total	with an initial V or (C)V	with a final V
Number of words	1142	459 223V+236 (C)V	1142
Percentage of words	100%	40%	100%

Table 2. Number and percentage of words with initial V or (C)V and with a final V in our corpus

Elisions are located by detecting differences in the two alignment tiers (canonical vs variant forms) which arise from phonemes which are not aligned on the speech signal at word junctions when using the pronunciation dictionary allowing for vowel elisions. Table 3 presents the number of V1ω V2 word contacts and of V1ω (C)V2 word contacts as well as the percentage of V1 elisions in each case:

	V1ω V2 word contacts	V1ω (C)V2 word contacts
Number of word contacts	188	198
Percentage of V1 elisions	85%	83.3%

Table 3. Number and percentage of V1ω V2 and V1ω (C)V2 word contacts and percentage of V1 elisions in our corpus

Table 3 indicates that the percentage of V1 elision is roughly the same for V1ω V2 and V1ω (C)V2, which was expected as the floating (C) does not block vowel elision. The non elision of V1 is due to the following causes : the presence of a pause between the two words, monosyllabic roots which do not undergo elision, and exceptions involving long vowels. There are also some false detections of elisions due to coalescence, which was not taken into account in the text-to-speech alignment system.

The Embosi text-to-speech alignment system also allows us to measure the duration of short and long vowels (Table 4) as well as the duration of resulting vowel(s) at word junctions (Table 5). Results are shown in the following tables:

	V (whole corpus)	VV (whole corpus)
Number of vowels	1738	343
Mean duration	70 ms	120 ms

Table 4. Number and mean duration of short (V) and long (VV) vowels in our corpus.

Within the whole corpus, long vowels are 70% longer than short vowels.

	V1ω V2	V1ω (C)V2
Number of word contacts	188	198
Percentage of V1 elision	85%	83.3%
Mean duration of V2	80 ms	100 ms

Table 5. Number of V1ω V2 and V1ω (C)V2 word contacts, percentage of V1 elision and mean duration of V2 in our corpus.

At word junctions, the elision of V1 in V1 ω V2 contact leaves V2 as the only vowel. The mean duration of this vowel is basically the same as the mean duration of a short vowel (80 ms instead of 70 ms). The mean duration of V2 in V1ω (C)V2 context as resulting from the elision process is longer than the mean duration of V2 in V1ω V2, which is predicted by compensatory lengthening. . However, it is shorter than the mean duration of long vowels in the corpus (100 ms instead of 120 ms), while our proposed analysis of compensatory lengthening would have predicted the duration of a long vowel. It would be necessary to confirm this finding on a larger corpus. If this result holds, we might question the nature of the compensatory lengthening itself, as the lengthening could be related to the empty C position directly and not to an empty V.

2.4. Intermediate conclusion: an Embosi text-to-speech alignment system with a variant dictionary

This paper presents an attempt at providing an automatic text-to-speech alignment (including variant recognition) for a Bantu language, based on the adaptation of a system designed for French. This system involves a pronunciation dictionary with variants which enables us to perform phonological data mining, focusing on elision phenomena at word junctions. Transcripts were used, allowing the system to refer to floating consonants and provide data for the study of vowel elision and compensatory lengthening.

First quantative results were obtained for Embosi, in particular : 1) proportion of V-initial (40%) and V-final words (100%), number of V1ω V2 contacts (188, 16.5% of all word contacts) and V1ω (C) V2 contacts (198, 17.5% of all word contacts); 2) overall average short V duration (70ms), long V durations (120ms); 3) V2 mean duration in V1ω (C)V2 contacts 40% longer than short V overall average duration, highlighting the compensatory lengthening effect.

This study was carried out on a small corpus of three read popular tales. The corpus has to be increased to confirm the quantitative results that we presented in this paper. Larger corpora will also enable us to train Embosi acoustic models without relying on French counterparts thus resulting in a full alignment system for the Embosi language.

3. Conclusion

We revisited some phonological phenomena in Embosi. We analyzed the loss of the class prefix consonant before a root beginning with a consonant as being a dissimilation targetting the root node (which all the consonantal features are directly or indirectly attached to). This total dissimilation is an areal feature of the C20 Bantu zone and neighboring languages in the C and B Bantu zones. We showed that the C position of this class prefix consonant is kept in Embosi, and is signaled by a compensatory lengthening associated with vowel elision processes at word junctions.

We also showed how a speech-to-text alignment system designed for one language (French) can be adapted to an unrelated one (Embosi) and be used for phonological/phonetic mining. With the help of a pronunciation dictionary including variants for vowel elision, the resulting alignments could be scanned for vowel elisions at word junctions. The accuracy of the elision detection was checked manually on a third of the corpus: it reached 92%. The errors came from irregularities which were not encoded in the system. Thus, they concerned monosyllabic roots which do not undergo elision and vowel coalescence at word junction. The automatic alignment system provided quantitative data for the study of elisions with/without compensatory lengthening at word junctions. A compensatory V2 vowel lengthening of 40% could be measured on V1ω (C)V2 contacts.

The results presented in this study are based on a relatively small annotated corpus, the first one in Embosi (to the best of our knowledge). Larger annotated corpora are needed to confirm these results. We are currently planning annotations of TV broadcast news and shows in Embosi.

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