FRISIAN TTS, AN EXAMPLE OF BOOTSTRAPPING TTS FOR MINORITY LANGUAGES

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ABSTRACT

A Frisian adaptation of a Dutch TTS system based on Festival, NeXTeNS, is presented as a case study in prototyping TTS for resource-poor minority languages. For these languages, demonstrator systems are essential to seed projects in speech and language technology. The conversion of a Dutch TTS system to a new language with minimal speech and language resources, Frisian, demonstrates that a TTS prototype can be built rapidly using existing modules and voices. An informal evaluation with native speakers of Frisian shows that such a hybrid prototype can already produce intelligible speech for demonstration purposes.

1. INTRODUCTION

A shared language is a strong binding force for communities. In the modern world, people often feel that the future of their community is linked to the future of their language (even when this is absurd, see http://www.usenglish.org/ and many others). On the other hand, the prospects of any language depend largely on its sphere of usage. Whenever a language is excluded from a domain of life, it becomes less attractive to its users. Once these exclusions progress, a language will eventually disappear, often together with the community and its defined and valuable cultural heritage.

By definition, minority languages are excluded from large domains of society. So it is no surprise that communities fight to claim as much territory as possible for their shared tongue. Focal points in their political actions are teaching and access to mass media, e.g., TV, radio and newspapers, in the native language.

With the computerization of modern societies, digital media have rapidly become mass media themselves. Exclusion from these digital media and services would be a major setback for any language community. A lot of work has been done on the creation of authoring tools (e.g., spelling and grammar checkers) and localization of digital interfaces (e.g., non-western writing systems). Currently, the localization of a full toolset for digital media is rather straightforward (e.g., http://www.kyfieithu.co.uk/ for Welsh, see also http://l10n.openoffice.org/localization_responsibilities.html). The Simputer project in India (http://www.simputer.org) and the African Speech Technology project (http://www.ast.sun.ac.za/the_project.htm) have demonstrated the importance of a fully integrated speech interface for minority languages. If community members cannot use their own language for ever more ubiquitous speech-related services, both for commerce, mass media and in teaching, this will be a disincentive for the language itself. Moreover, it will strengthen often existing feelings that their language is inadequate for the modern age.

Many communities speaking a minority language do have access to some, limited, resources for technology projects. What these resources have in common is their unpredictability and intermittence. To have any chance of success, implementing a large language application for a minority language has to be divided into small, incremental sub-projects that can be handled by small groups of volunteers or single researchers over a short time-scale. To access these resources, it is important to have an example prototype that can demonstrate the feasibility of the project. Even with a limited prototype, members of the target community can estimate the costs and benefits of a full scale system and decide whether they want to participate. This holds equally well for community volunteers as for grant agencies that try to stimulate the use of the language.

In this paper we present the results of a case study into a rapid prototyping framework for building a TTS system for a minority language, Frisian, with only minimal digital resources. First results of an evaluation of the synthesis quality are given. This study was performed as a MA-thesis of the first author who is a native speaker of Frisian. It is our intention to release the Frisian adaptations as Open Source.

2. THE FRISIAN LANGUAGE

When we speak of Frisian in this paper, we mean West-Frisian, mainly spoken in the province of Fryslân, one of the twelve provinces of the Netherlands. The Frisian language is a member of the West Germanic branch of the Indo-European language family. Several parallels have been found between Old-Frisian and Old-English, though nowadays Frisian tends to become more and more similar to Dutch [2].

2.1. Frisian and Fryslân

The total population of the province of Fryslân counts over 634,000 inhabitants, which is less than 4% of the total population of the Netherlands. Of those inhabitants 74% is able to speak Frisian. For 55% of the total population Frisian is their mother tongue, which comes down to roughly 350,000 native speakers [7]. Furthermore 94% of the population of Fryslân can understand Frisian, 65% can read and 17% can write in Frisian [5]. Language surveys from 1967, 1980 and 1994 show a small decline in the ability to speak Frisian. Also, the Frisian language becomes gradually more and more similar to Dutch due to language assimilation [2]. Our prospects are that both the decline in number of speakers and the assimilation will continue in the future.
Fryslân was traditionally an agricultural area with little industry which induced work-related emigration of younger people. This explains why the education level and income of the Frisian population is below average compared to the rest of the Netherlands. Recently there has been an increase in service-related (financial) industry which might reverse this trend [6].

2.2. Dialects

There are three main dialects of Frisian: Klaaifrysk, Wâldfrysk, and Súd-Westhoeksk [6] and several smaller dialects, mostly mixtures of Dutch and Frisian. In general, all dialect variants are mutually comprehensible. The accepted standard Frisian language is mostly based on the Klaaifrysk forms of Frisian.

2.3. Domains

In 1995 there has been a socio-linguistic survey [5] which concluded that family, work and the village community are the strongest domains for Frisian.
Since its recognition in 1970 by the Dutch government, the position of Frisian has improved, although slowly. Now, for example, Frisian has equal goals in education as for Dutch, and it is allowed to use Frisian in court and in the correspondence of public administrations. Though the amount of Dutch used in those formal domains is still considerably larger [2].
There are two daily newspapers in Fryslân, which produce < 3% Frisian texts and one special Frisian page every week. Furthermore there is a small number of Frisian (literary) journals and magazines [6]. Together, these give only a limited amount of digital text to work upon for language technologies.

3. CHANGING AN EXISTING FESTIVAL TTS SYSTEM TO PROCESS A NEW LANGUAGE

The approach we chose for rapid prototyping was to take an existing implementation of the Festival TTS system and adapt it piecewise to generate Frisian speech. Given historic influences, we chose to use a Dutch implementation of Festival, NeXTeNS [10], which was adapted to process Frisian instead of Dutch text.

3.1. Festival and the NeXTeNS-project

The Dutch NeXTeNS project aimed to produce a Dutch TTS for research purposes [10]. NeXTeNS is built upon the common Festival system. The waveform synthesizer operates on the MBROLA diphone synthesizer and it uses the Dutch nl3-voice. It is freely available for research purposes.

The architecture of NeXTeNS is derived from the standard Festival system architecture:
- Token Module: tokenisation
- POS Module: Part-Of-Speech tagging
- Syntactic Module: syntax parsing
- Phrasing Module: phrase break prediction
- Intonation Module: accent placement
- Tune Module: tune choice needed for ToDI
- Word Module: lexicon, letter-to-sound rules, building prosodic structures
- Pauses Module: pause insertion
- Postlexical Module: assigning postlexical rules and phone mapping
- Duration Module: determination of segment and pause durations
- Fundamental frequency control: apply ToDI to utterance
- Waveform synthesis: sending TTS-information to MBROLA-voice

For our Frisian prototype TTS system, many of the advanced features, e.g., POS tagging, NP chunking and ToDI labeling, are not available as they could not be re-trained for Frisian without adequate training corpora.

3.2. Language resources and tools

For Frisian as an official language of the Netherlands, there exists a language research infrastructure. Most research for Frisian has been coordinated and hosted by the Fryske Akademy ("Frisian Academy"). The linguistic information needed for creating letter-to-sound rules and intonation and duration modules was largely provided by the Academy.

There are several associations that provide language information and resources. LDC (http://ldc.upenn.edu) and ELRA (http://www.elra.info) distribute large annotated corpora, and are parent associations for lots of initiatives (e.g., the LREC conferences). Cocosda (http://www.cocosda.org) tries to coordinate language resources and tools. The IMDI-project of EAGLES/ISLE collects data on existing corpora (http://www.mpi.nl/IMDI/ and/or http://www.mpi.nl/ISLE/). Organizations working on minority and endangered languages are SALTMIL (http://isl.ntf.uni-lj.si/SALTMIL/) and DOBES (http://www.mpi.nl/DOBES). Other initiatives are the Foundation

for Endangered Languages (http://www.ogmios.org), the Endangered Language Fund (http://sapir.ling.yale.edu/~elf/), and the International House for Endangered Languages (http://www.tooyoo.l.u-tokyo.ac.jp/ichel/ichel.html).

Many voices for speech synthesis are available on the MBROLA website (http://tcts.fpms.ac.be/synthesis/mbrola.html).

4. STEP BY STEP PROCESSING

4.1. Phoneme set

First of all, a computer-readable phoneme set was created. For Frisian we created a phone set based on the SAMPA set used by the Fryske Akademy. However, instead of SAMPA we used the Worldbet-annotation [8] because it codes each IPA symbol uniquely and over all languages. Moreover, Worldbet allows transparent coding of complex sounds (e.g., triphthongs, nasalized diphthongs) and transitions between narrow and broad transcriptions. For Frisian this was needed when dealing with nasalized vowels (e.g., nasalized diphthongs) and triphthongs, who go beyond SAMPA's two characters codes.

These Frisian phonemes were inserted between the Dutch ones in the phoneme file in NeXTeNS. Because we continued using the Dutch voice (see also 4.13.), it was important that the Dutch phonemes remained in the phoneme file. At the bottom of the file with postlexical rules, the Frisian phonemes were mapped to their Dutch counterparts. So, if these Dutch phonemes were absent in the phoneme file, Festival would give an error.

After referring NeXTeNS to use an empty lexicon and letter-to-sound-rules file, a basic synthesizer was created.

4.2. Token Module

Tokenisation is necessary to change unknown tokens like abbreviations, numbers, symbols, acronyms and dates into words. A standard file in NeXTeNS was completed with the language-specific details. To avoid most problems we only implemented abbreviations (from an older Frisian-Dutch dictionary [14]) and a number-to-word conversion. The latter was done by copying the number-to-word conversion for the Spanish el-voice and by changing the order of pronunciation to the order in Frisian (and Dutch). For instance, instead of converting the number "31" to "treinta y uno" (lit. "thirty and one") as in Spanish, it was converted to the Frisian "ienentritich" (lit. "one-and-thirty").

Due to lack of time less attention has been paid to symbols, acronyms and dates. Examples of these implementations are given in the English version of Festival, though. This version contains a huge variety of token-to-word conversions.

4.3. POS Module

Part-of-Speech tagging is mainly used for accent and break assignment. Since there is no Part-of-Speech tagging for Frisian, we decided to make use of the simple function and content word division by using the guess_pos-function. Hence, the automatic POS tagging function was not operational in NeXTeNS (at the time of writing), so a separate list of function words was made by copying the function words from a Frisian grammar [13] and by inserting translated missing words from a Dutch function word list [12]. Both guess_pos-list and this separate list of function words were located in the tokenisation file.

An alternative for creating a Frisian POS file would be to translate a Dutch one into Frisian.

4.4. Syntactic Module

Since there is no syntax parser for Frisian the default option of no syntax method was chosen.

4.5. Phrasing Module

In this module breaks are predicted by means of punctuation. Breaks can be heavy or medium. The default option is a punctuation cart tree, which we chose. Alternatives are assigning breaks by means of POS (if POS-tagging is available).

4.6. Intonation Module

In NeXTeNS nouns, adjectives and verbs (except auxiliary verbs) get sentence accent. Since we used a simple function/content word division, this rule was replaced by one that gives accent to every word that is not a member of the function word list (see also 4.2. and 4.3.). Furthermore in a group of accents every second accent was removed.

4.7. Tune Module

In this module sentence accents and breaks are replaced by ToDI-values, which are necessary for the fundamental frequency control (see also 4.12.). The values %L and L% are assigned to the beginning and the end of each utterance, respectively. In case of a medium or heavy break (see also 4.5.) the module refers to the %-value. Sentence accents are usually replaced by H*L-values. This source code was written by Marsi & Kerkhoff [10]. For more information about these ToDI-values see http://todi.let.kun.nl/ToDI/home.htm. At the time of writing not all options could be reached by the code, because in some cases the POS was needed to assign a ToDI-value, e.g., in the case of H*LH, which was assigned in special cases after a verb.

4.8. Word Module

In the Word module, the graphemic word is transformed into a phonemic one. This happens by means of a pronunciation lexicon. When a word does not occur in this lexicon it is built up by letter-to-sound rules (LtS). After the lexicon lookup or LtS, the prosodic structure of the word is built up.

4.8.1. Letter-to-sound rules

LtS rules can be written by hand, or automatically. In the Frisian language, there is a relatively strong relationship between the letters in a word and its pronunciation. For languages like this it is often easier to write the rules by hand. The LtS can be built from existing examples from the Festival distribution. The Spanish example that we used contained a conversion to lower-case letters, a grapheme-to-phoneme conversion, a conversion into syllables, and a definition for assigning lexical stress to the word in question. The definition to change certain vowels into weaker ones, needed for Spanish LtS, was removed. For practical reasons, syllabification was put before the actual LtS. A separate definition for assigning the nasal feature to vowels was given later on. So first the word was set to lower-case letters, then a division into syllables took place. The hyphen sign was used as symbol for the syllable break. When two identical consonants occurred a syllable break was given between those consonants. When a consonant was surrounded by vowels a syllable break was given before the consonant. Furthermore, all possible consonant clusters were listed [4] together with their breaks. Breaks that occurred at the wrong place were for the most part corrected in the next definition, the actual LtS, in which graphemes were changed into phonemes. Next, a default stress was given to the first syllable of the word unless this syllable contained a schwa vowel. If necessary the feature nasal was assigned to the vowels in question.

The LtS rules have the following form [1]:

$$(LC [alpha] RC = beta)$$

Some examples are:
(1)   ([y] = i)
(2)   (VOWEL [- g] VOICEDC = - G)

Example (1) is a simple LtS conversion The sound [y] is assigned to the letter <i>. In case of example (2) a voiced [G] is given whenever <g> is placed between vowels (left side) and voiced consonants (on the right). As mentioned earlier, the hyphen sign is the annotation for a syllable break.

LtS rules could also be constructed automatically. Black and Lenzo [1] give instructions how to do this. In the NeXTeNS-version with Dutch, the TreeTalk method was used to create such rules. TreeTalk is a self training method which can be trained on a set of samples. Since TreeTalk needs more than a hundred thousand words with pronunciation and since our dictionary "only" contained about 70,000 words it was decided to use hand-written rules.

At the end of the LtS file the word was built up like the pronunciation part of the word entry of a lexicon (see also 4.8.2.). For example, the output of the LtS file for the word "hynder" (horse) looks like this:

$$((((h i n) 1) ((d \& r) 0)))$$

4.8.2. Pronunciation lexicon

However, there are still words with irregular pronunciation, or with an irregular stress pattern. Therefore it is advantageous to use a pronunciation lexicon. In general, if an extensive digital pronunciation dictionary is available, this should be converted to the standard Scheme form. A recurrent problem here is the incompatibility of the phoneme sets used in the dictionary and that necessary for TTS. If necessary, the dictionary transcription has to be "augmented" by special LtS rules to disambiguate the incompatible words. When no digital dictionary is available, it can be built starting with an automatic transcription of a (large) word list with the LtS and syllabification rules. Volunteers can then correct this transcription for known problems and check and correct the rest. Such work can easily be distributed over the internet, and includes proofreading and other management tasks (see the project Gutenberg, http://www.gutenberg.net).

We were fortunate to have access to a digital version of the "Frysk hânwurdboek"-dictionary from the Fryske Akademy, for which we are grateful. The lemma, which contained lexical stress in the form of an apostrophe before the stressed syllable, and its pronunciation had to be converted into a Scheme file. Each word was converted separately with help of a Perl script. First, the phonetic signs used by the Fryske Akademy were replaced by the Worldbet annotations. Then a syllable division took place on the pronunciation. This was based on sonority, which provided a reasonably accurate syllable division. The number of nuclei before the apostrophe in the lemma part were counted and in this way a lexical stress was assigned to the correct syllable in the pronunciation part. As a last step, the apostrophe was taken out of the lemma. Because the dictionary contained only the primary accent placement, our synthesis was limited to primary accents as well. As we followed the NeXTeNS-project and as such the architecture of the KUNLEX-lexicon, we assigned 'nil' to the POS information. One could also assign a Part-of-Speech tag to it, to get a better chance for the correct pronunciation in its context.

A word entry in the final lexicon should contain, next to the orthographic word, POS information, and a phonetic realization of the word in question, including syllable boundaries and lexical stress marking (when appropriate) [1]. The result of the word "bjusterbaarlik" (miraculous) looks like this:

("bjusterbaarlik" nil
        ((((b j Y s) 0) ((t & r) 0) ((b a: r) 1) ((l & k) 0))))

The lexicon should contain not only the base forms of a word, but all their morphological variants as well. These variants are usually not available in a dictionary. Including all those variants is a large but realistic job. However, it becomes unrealistic when dealing with languages with extensive word compounding or agglutinative languages like Finnish, or Turkish. In that case Black and Kenzo [1] advise to develop a proper morphological

analyser to intercept this problem (see also [11]). This was outside the scope of our prototype.

When there is no LtS, and a word does not occur in the lexicon, Festival can give feedback that it does not know the word or it can spell out the word. The recipe for this implementation is found in [1]. Since we do have LtS, this has not been implemented.

4.8.3. Building the prosodic structure of the word
The word was built up from the level ProsWord1 (whole word) down to ProsWord2 (in case of compounds), Foot, Syllable, SylPart (Onset, Nucleus, Coda) and Segment (phonemes) in the relation ProsTree. In NeXTeNS compounds were divided at the level of ProsWord2. For Frisian we were not able to accomplish this, so for Frisian ProsWord2 is equal to the ProsWord1 level. This explains the two pairs of brackets around the whole word in the pronunciation part of the lexicon. All code is implemented by Marsi & Kerkhoff [10].

4.9. Pauses Module

This Pause module inserts the actual pauses. It inserts a silent segment at the beginning and end of the sentence, and wherever the Phrasing Module contains a heavy or medium break.

4.10. Postlexical Module

Postlexical rules are applied for when assimilation occurs between word boundaries and inside words. Also in this module phones are mapped to their Dutch counterparts (see also 4.13.). At the time of writing, we made use of the Dutch postlexical rules. These are mostly the same as for Frisian. Though, we still have to implement some for Frisian as well.

4.11. Duration Module

In this module the duration of every phoneme is defined and special rules can shorten the default duration or lengthen it, e.g., shortening in a consonant cluster. Another option is the default duration module in Festival, where every phoneme has the same length. In our prototype we made use of the duration file as used by NeXTeNS.

4.12. Fundamental frequency control

For F0 assignment NeXTeNS uses the ToDI-intonation (http://todi.let.kun.nl/ToDI/home.htm). Not much research has been done on the prosody and intonation of Frisian. Most grammars assume the Frisian intonation to be the same as in Dutch [4] [13]. One of the few studies on Frisian intonation has been done by Hoekstra [9], who concentrates on sentence accents. He claims that lexical and specific functional prepositions are more frequently stressed in Frisian than in Dutch, and less than in English.
Because of the so-called similar intonation structure in Dutch and Frisian, we used ToDI for the time being and are curious to see if the intonation is good enough for Frisian.

4.13. Waveform synthesis

One of the aims of a TTS prototype system is to create an incentive to construct a language specific voice (diphone set). So no attempt was made yet to create a Frisian diphone-database, the Dutch nl3-database of MBROLA was used instead. The Frisian phonemes were mapped to their closest relatives in Dutch. A similar approach was used by Campbell [3] in creating multilingual TTS. He produced speech in another language (English) than that of the database speaker (being Japanese), though the quality of the resulting speech by mapping alone was not considered good enough. He improved this by using the cepstral information of similar speech of a native speaker of the target language in producing speech with the segments of the prestored voice. For our prototype, this procedure was too involved and was not used.
The Frisian phoneme inventory has more vowels, diphthongs and nasal vowels than Dutch. Most Frisian diphthongs end in a schwa sound. These diphthongs were more or less created by inserting a second vowel (mostly schwa), representing the second part of the diphthong. To allow the correct processing of the inserted segments, this has to be done close to the Word Module, where the grapheme-to-phoneme conversion takes place. All diphthongs except for one (viz. [I&]), are represented in this way. The triphthong (viz. [U>_i]) was not mapped by three phones because this did not improve the quality of the output. Instead it was mapped to the Dutch diphthong [Ui].
Nasal vowels, which also are an important feature in Frisian, are not present in the nl3-database at all. So these vowels had to be restored to their original form again (non-nasal counterpart plus [n]), awaiting a possible Frisian database in the future. In the phone mapping section they were coincided with the nasal again, because otherwise we would loose the nasal aspect in the output; it would sound less like Frisian.
Of course by synthesizing texts the synthesizer will run into diphone-combinations which are not available in the nl3-database. There is no solution for this problem yet and thus an error message will occur.

5. EVALUATION

Eleven native speakers of Frisian were asked to judge 20 sentences, harvested from internet sources as newspapers, party manifestos, internet editions of literature magazines and publications of several youth associations. The subjects had to indicate the intelligibility, general quality and acceptability of the stimuli, each on a 7 point scale. As for acceptability we asked the question whether the synthesized sentences were acceptable as a

first attempt for speech synthesis. During this first evaluation, the pronunciation lexicon was not ready, so pronunciation and lexical stress were retained by LtS only. Subjects were informally selected from the contacts of the first author. We want to stress that this is only a pilot study and the results should be seen as indicative only. A formal evaluation is currently prepared.

Three subjects were excluded from the results, because they aborted the test. One of the remaining eight listeners judged only 18 of the 20 sentences in a second attempt. His first trial was not included in the results, because he aborted the test after eight sentences. This means that the total number of responses comes down to 158. The utterance length varied between 9 and 19 words and included Frisian features where synthesis would go wrong, e.g., nasality of vowels (this lacked in the output, see 4.13.), wrong placement of (default) lexical stress (see 4.8.1.), and the feature breaking where vowel change takes place in derived forms, which cannot always be gathered from the spelling.

A division was made between long (>13 w) and short utterances (<=13 w). Both the long and the short set contained 10 stimuli. The averages of the judgements are shown in Table 1.

Table 1: Mean judgements and standard error (between brackets) scale judgements 1-7, higher is better.

	short (N=78)		long (N=80)		total (N=158)	
intelligibility	3.94	(0.21)	4.00	(0.18)	3.50	(0.14)
quality	3.67	(0.17)	3.78	(0.16)	3.38	(0.12)
acceptability	3.12	(0.16)	3.31	(0.15)	3.13	(0.11)

As expected, the synthesis quality of the Frisian TTS is not stellar. Average judgements are actually below the centre of the scale (4). Six sentences were next to incomprehensible which reduces the scores. The low scores can be attributed to the problems with missing phonemes/diphones and bad modelling of morphological processes. Overall, the fact that the scores are not minimal and even better for some of the utterances shows the potential for improvement, which is the main aim of producing this prototype.

6. CONCLUSIONS

We have demonstrated that it is possible to develop a base-line prototype TTS system for a minority language with minimal speech and language resources. This framework of prototyping TTS allows the fast bootstrapping of speech synthesis. Hopefully, decision makers can then be convinced to spend more money on synthesis. A functioning prototype allows them to estimate the efforts needed for a full scale implementation. Moreover, the organization of the work follows quite logically from the structure of the Festival modules in the prototype.

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