THE RACAD SPEECH CORPUS OF NEW BRUNSWICK ACADIAN FRENCH: DESIGN AND APPLICATIONS

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ABSTRACT

The RACAD (*Reconnaissance automatique de l'acadien)* speech corpus contains high quality audio recordings that can be used to develop recognition systems for the regional varieties of French spoken in the province of New Brunswick, Canada. Its design is informed by linguistic analyses of Acadian French. The corpus contains sentences read by 140 speakers who were selected according to age, gender and geographical region. This paper presents a preliminary application of the corpus in automatic speech recognition research; it outlines an original global monophone recognition model that is designed to handle linguistic variability. Global phone and word recognition rates for this model are satisfactory (about 90%), but they vary considerably across geographical locations. Possible applications of the RACAD corpus in acoustic phonetic and socio-phonetic studies of dialect variation are also described in this paper.

RÉSUMÉ

Dans le but de développer des systèmes de reconnaissance automatique des variétés de français parlées dans la province du Nouveau-Brunswick, au Canada, un corpus d'enregistrements de haute qualité, le corpus RACAD (*Reconnaissance automatique de l'acadien)*, a été recueilli. Ce corpus est constitué de phrases lues par 140 locuteurs. Suivant la méthodologie employée dans les études linguistiques portant sur le français acadien, les locuteurs ont été sélectionnés d'après leur âge, leur sexe et leur appartenance géographique. Cet article décrit une première application du processus de reconnaissance automatique de la parole à partir de ce corpus; il présente un modèle monophone global qui tient compte de la variabilité linguistique dans le RACAD. Les résultats montrent que les taux de reconnaissance globale des phones et des mots sont satisfaisants (environ 90%), mais que ces taux varient entre les diverses régions géographiques. Des applications possibles du RACAD, dans des analyses de phonétique acoustique et de sociophonétique de la variation régionale, sont aussi décrites dans le présent article.

1. INTRODUCTION

Early studies involving automatic speech recognition of French tended to focus primarily on mainstream dialects of the language. In the BREF corpus of French (Gauvain *et al* 1990), all speakers are from areas in and around Paris, a region that is generally considered to speak a variety of speech that is "close" to standard or referential French. With ongoing research (Gauvin & Lamel 1992; Lamel & Gauvin 1992, 1993; Lamel *et al* 1991), the situation has evolved considerably so that present-day systems are able to accommodate different dialects of French. For example, the Microsoft® Speech Recognition engine on Windows® Vista® is available for Canadian French; Nuance®'s "Dragon Naturally Speaking" and "OpenSpeech" support standard French as well as certain dialects spoken in Québec, Belgium, Luxembourg and Switzerland. Nevertheless, the performance of these systems tends to degrade when used by French speakers from other dialect regions.

The TIMIT corpus of American English (Fisher *et al* 1986) was one of the first spoken language corpora designed for speech recognition research that took into account regional linguistic variation. This corpus consists of sentences produced by 630 speakers, both males and females, from eight different dialect regions of the United States. While the TIMIT corpus has been criticized (Keating *et al* 1994; Clopper & Pisoni 2006) because the regional labels assigned to speakers do not correspond exactly to the dialect areas identified in more recent linguistic studies of American English (Labov *et al* 2006), the corpus does provide for a wide range of regional linguistic variation. Indeed, this corpus has contributed to significant developments in speech recognition research since the 1980s. In addition, TIMIT has been used in related research areas such as perceptual dialect categorization experiments (Clopper & Pisoni 2004) and linguistic phonetic studies of the phonetic characteristics of American English, such as variation in the pronunciation of the word 'the' (Keating *et al* 1994).

The TIMIT corpus of American English served as the basis for the design of RACAD, a corpus that is developed for research on the automatic speech recognition of the regional dialects of French spoken in the province of New Brunswick (Canada). RACAD stands for *Reconnaissance automatique de l'acadien* ("Automatic speech recognition of Acadian French"). The main goal of this paper is to outline the design and applications of the RACAD speech corpus.

We begin with an overview of regional linguistic variation in New Brunswick Acadian French and then describe the speech corpus, noting its relation to TIMIT. We present two experiments that test an original global monophone recognition model. Finally, we mention research applications of the corpus in the areas of acoustic phonetics and language variation.

2. French in New Brunswick

Approximately 32.4% of New Brunswick's total population of nearly 730,000 (Statistics Canada 2006 census figures) are francophones and, for the most part, these individuals identify themselves as speakers of a dialect known as *français acadien*, Acadian French. The linguistic structure of Acadian French differs from other dialects of Canadian French such as *français québécois*, which is spoken in the neighbouring province of Québec. Both historically and linguistically, New Brunswick Acadian French is closely related to varieties of French that are found in different parts of Atlantic Canada, namely, Newfoundland, Nova Scotia, Prince Edward Island and, to a certain extent, the Magdalen Islands and areas on the Gaspé Peninsula (in the province of Québec).

There are three main geographic regions in New Brunswick where French is either the majority language or where it has a dominant presence (Arseneault 1999). These regions are shown on the map in Figure 1: the "Northeast" is a large area that includes the Acadian Peninsula (the triangle formed by Shippagan, Néguac and Paquetville) and the central northern part of the province, sometimes referred to as the "North" (Johnson & McKee-Allain 1999), situated between the communities of Allardville and Campbellton; the "Northwest" mainly occupies the region around the city of Edmundston and includes part of the so-called "Madawaska Republic"; the "Southeast" comprises rural towns and villages in the southeastern part of the province and the urban area of Moncton/Dieppe. Other regions of New Brunswick have considerably fewer native speakers of French and are predominantly English speaking. It is noteworthy that New Brunswick is an officially bilingual (French-English) province and that this status ensures that services such as education, health and justice are offered in both French and English languages.

Regional linguistic variation in New Brunswick Acadian French has been the focus of only a very small number of studies. These studies are based on partial sociolinguistic and dialectological surveys, and they identify several regional differences. Phonetic variation of the /r/ consonant (Cichocki 2006) follows a North-Northeast-Southeast regional distribution. Speakers in parts of the Northwest region have a separate linguistic identity, called *brayon*, and impressionistic phonetic studies point to phonetic features – for example, the /wa/ glide-vowel sequence in words such as 'moi' *me*, 'toi' *you* – that distinguish it from other regions of New Brunswick (Holder *et al* 1992). Lexical research on fishing terminology (Péronnet *et al* 1998) has established the presence of a major Northeast-Southeast division. A morpho-syntactic study of the usage of prepositions and relative pronouns (Péronnet & Kasparian 1998) suggests a three-way Northeast-Northwest-Southeast breakdown.

In addition, phonetic features can vary considerably within localities. In the town of Tracadie-Sheila located on the Acadian Peninsula in the Northeast region, phonetic variation has been shown to correlate with demographic factors such as speaker age and gender (Flikeid 1984).

In general, Acadian French has a number of distinctive phonetic features (see the overview in Lucci 1973). The /r/ phoneme has at least three realizations including alveolar, uvular and retroflex pronunciations. There are affricate consonants; for example, [dʒ] occurs in the phonemic sequence /dj/ (as in 'diable' *devil* [djab, dʒab]) and in /g/ (as in 'guerre' *war* [gɛR, dʒar]). The fricative /h/, that is silent in many varieties of French, is often pronounced (as in 'hareng' *herring* [arɑ̃, harɑ̃]). The nasal vowels /ɑ̃/ and /ɔ̃/ are often neutralized (as in 'saumon' *salmon* [somõ, somɑ̃]). Noteworthy prosodic features are long nasal vowels, lengthened vowels in the penultimate position of a prosodic phrase, and frequent occurrences of level-high and rising-falling intonation contours (Cichocki 1996, 2002).

In sum, an important consideration in designing the RACAD corpus was to elicit features of pronunciation that are related to regional and social variation. This design feature is intended to inform future research about the possible influence of linguistic variation on the performance of automatic speech recognition systems.

3. Corpus Design

3.1 Speakers and regions

The participants in this project were 140 speakers from the three main francophone regions of New Brunswick. Sampling numbers reflect overall francophone population sizes in these regions. To include social variation, the corpus was designed to represent gender and age: there are equal numbers of males and females, and there are two age groups, younger speakers between 18 and 24 years of age and older speakers between 41 and 55 years of age. Speakers come from a variety of socioeconomic backgrounds; no particular social group – such as teachers or professional speakers – was targeted. Table 1 shows the number of speakers by region, with a breakdown by locality, gender and age.

Figure 1. Map of New Brunswick showing the three main regions and eleven localities surveyed in the RACAD speech corpus

The total number of speakers (140) was determined by the requirements of the protocol for selecting speech materials (see below) and by the time constraints needed for travel for on-site data collection and for in-laboratory segmentation and labeling. While a corpus such as TIMIT has more speakers (630), it represents a considerably larger population and a greater geographic area. In this respect, it is felt that a sample of 140 speakers is sufficient to represent the francophone population of New Brunswick and, at the same time, to meet the requirements of research in automatic speech recognition.

In order to ensure a representation of regional linguistic differences, all participants are native speakers of Acadian French and all had grown up in or near one of the localities selected for this research. The map in Figure 1 locates the communities studied with respect to the three main francophone regions. Each region is represented by more than one locality. The recent in-migration from the northern areas of New Brunswick to the Southeast, in particular to the urban Moncton-Dieppe area, was excluded from the research design. While this in-migration is of current social and economic interest (Beaudin & Forgues 2006), its inclusion would have required a more detailed sampling design than was possible in this study.

Table 1. Distribution of speakers in the RACAD speech corpus by age, gender, region and locality

Region and locality	younger females	older females	younger males	older males	total
Northeast					65 (46.4%)
Acadian Peninsula Shippagan	4	4	4	3	15 (10.7%)
Paquetville	4	3	4	4	15 (10.7%)
Néguac	2	3	2	3	9 (6.4%)
North Allardville	3	4	4	4	15 (10.7%)
Campbellton	3	2	3	3	11 (7.9%)
Northwest					26 (18.6%)
Edmundston	6	6	5	5	22 (15.7%)
St-Quentin	1	1	1	1	4 (2.9%)
Southeast					49 (35.0%)
Bouctouche	2	2	2	2	8 (5.7%)
Richibouctou	1	2	2	2	7 (5.0%)
Cap-Pelé	3	2	2	3	10 (7.1%)
Moncton/Dieppe	6	6	6	6	24 (17.1%)
Total	35 (25%)	35 (25%)	35 (25%)	35 (25%)	140 (100%)

3.2 Speech materials and recording conditions

The text material in the RACAD corpus consists of 212 read sentences. Selection of these materials mirrors the protocol used in the TIMIT corpus of American English. Two "calibration" or "dialect" sentences, which were meant to elicit specific dialect features, were read by all 140 speakers. These sentences are given in (1):

(1) a *Je viens de lire dans «L'Acadie Nouvelle» qu'un pêcheur de Caraquet va monter une petite agence de voyage.*

(1) b *C'est le même gars qui, l'année passée, a vendu sa maison à cinq Français d'Europe.*

The remaining 210 sentences were selected from published lists of French sentences, specifically the lists in Combescure (1981) and Lennig (1981). These sentences are not representative of particular regional features but rather they correspond to the type of phonetically balanced materials used in coder rating tests or speech synthesis applications where it is important to avoid skew effects due to bad phonetic balance. Typically, these sentences have between 20 and 26 phonemes each. The relative frequencies of occurrence of phonemes across the sentences reflect the distribution of phonemes found in reference corpora of French spoken in theatre productions; for example, /a/, /r/ and schwa are among the most frequent sounds. The words in the corpus are fairly common and are not part of a specialized lexicon.

Of these 210 sentences, 70 so-called shared sentences were each read by 14 speakers and the remaining 140 sentences were read by a single speaker. Assignment of sentences to speakers was made randomly. Thus, each speaker read 10 different sentences: the two dialect sentences, seven of the shared sentences, and one individual sentence. The entire corpus has a total of 1400 sentences.

Prior to the recording, the interviewer explained the purpose of the RACAD speech corpus and gave each participant a written description of the study, including name and contact information in the case of concerns, complaints or consequences. Everyone participated in the reading task on a voluntary basis and provided only basic demographic information about their locality of residence, gender and age. All speakers signed a consent form acknowledging their willingness to participate in the study.

The interviewer was a young female student from New Brunswick who is a native speaker of Acadian French. It was decided that interviews should be carried out by someone who is an "insider" in order to avoid the so-called "outsider" effect, whereby speakers may modify their speech to accommodate (by convergence to or by divergence from) a speaker (interviewer) who speaks a dialect different from their own dialect (Flikeid 1997; Giles & Powesland 1998).

Speakers were recorded individually in the field, that is, in their home locality. A quiet location, familiar to the speaker, was chosen for the recording. Speakers read the stimulus sentences from cards that were arranged in random order. Where there were hesitations or repetitions, the interviewer requested a new reading of the sentence. Total duration of each speaker's recording varied between 55 and 90 seconds. To obtain high quality audio recordings, equipment used included a portable Sony digital recorder and a Shure unidirectional microphone; the sampling rate was 16 kHz.

Table 2. List of phones used in the RACAD speech corpus

Phone	Example	Phone	Example
sp	*(short pause)*	d	*dans*
	(silence)	n	*nom*
a	*patte*	s	*sans*
aa	*pâte*	z	*zone*
ax	*justement*	l	*long*
eh	*seize*	sh	*champ*
eu	*deux*	zh	*gens*
ey	*ses*	nj	*oignon*
iy	*si*	ng	*camping*
oe	*neuf*	y	*ion, pierre*
oh	*comme*	w	*coin*
ow	*gros*	k	*quand*
uy	*du*	g	*grand*
uw	*doux*	r	*rond*
p	*pont*	hy	*juin*
b	*bon*	a^	*vent*
m	*mont*	ey^	*vin*
f	*femme*	oe^	*brun*
v	*vent*	ow^	*bon*
t	*temps*		

3.3 Speech Database

The corpus of digital speech samples is organized largely according to TIMIT protocol. A hierarchical file structure identifies each audio file by locality, speaker and sentence number. Associated with each speaker's realization of a sentence are a wave file and two transcription files: a time-aligned orthographic word transcription, and a time-aligned phonetic transcription. Segmentation used in the phonetic transcription followed standard acoustic phonetic criteria. The corpus can be searched by segment, word or sentence as well as gender, age and region.

The phonetic transcriptions are broad and are given in the (standard) French SAPI (Speech Application Programming Interface) phone set. The phone set used in labeling the corpus consists of 39 of the possible 46 phones found in recognition systems from Microsoft® Corporation. The list of phones is given in Table 2.

4. A Speech Recognition System for the RACAD corpus

As noted in the introduction, materials from the RACAD corpus are intended primarily for the development of original recognition systems for New Brunswick Acadian French. In this section, we outline one such system and then discuss two experiments that gauge how well the system performs with respect to regional variation. Both the automatic speech recognition system (described below) and the parameterization method were designed by using the Hidden Markov Model Toolkit (HTK) which runs on a Linux platform (Cambridge University, 2007). The HTK toolkit is a general-purpose tool designed for the creation of Hidden Markov Models (HMM). It lends itself perfectly to the creation and evaluation of automatic speech recognition engines.

4.1 Parameterization Model

The parameterization method developed is a single-Gaussian global model. Mel-frequency cepstral coefficients (MFCCs) are chosen as the basis for data parameterization. The model uses MFCCs, delta coefficients (D) that are the derivatives of the MFCCs, and logarithmic energy. Speech is sampled at 16 kHz. A Hamming window is used every 30 msec. For each 10 msec frame, 12 MFCCs and 12 delta vectors are computed. The latter represent the first order regression for each MFCC and are calculated by equation (2), where d_t is the delta coefficient at time t and $c_{t\pm\Theta}$ represents the static coefficient at instant $t \pm \theta$. The value of the delta window θ was set to 3.

$$d_t = \frac{\sum_{\Theta=1}^{\Theta} \theta(c_{t+\theta} - c_{t-\theta})}{2\sum_{\Theta=1}^{\Theta} \theta^2} \qquad (2)$$

A log energy parameter is computed for each type of parameter: one for the 12 MFCCs, one for the 12 delta vectors. These represent the log of the sum of the squares of the parameters. They are calculated using equation (3), where E represents the log energy and s_n represents the n^{th} vector for n=1 to N. This gives a total of 26 parameters per window. Intensive cross-validation experiments were carried out in order to determine the optimal number of parameters.

$$E = \log \sum_{n=1}^{N} s_n^2 \qquad (3)$$

4.2 Speech Recognition Platform

The model was trained using 93 speakers, for a total of 911 sentences from the RACAD corpus. The rationale for determining this number of speakers follows the general practice among speech recognition researchers to use a greater number of speakers for training a system than for testing it. In the present research, we selected two-thirds of the speakers for training (93 from the pool of 140 individuals) and one-third for testing (47 out of 140). It is noteworthy that the technical quality of the data is the same in both the training and testing subsets of the corpus.

Thirty-nine HMM models were created to represent each of the French phones. The optimization of the HMMs was then performed through nine Baum-Welch re-estimations as well as through an alignment of speech data after the seventh re-estimation using the Viterbi algorithm. During the training phase, a bigram and a word network, estimated from the entire corpus, were created in order to improve speech recognition accuracy.

4.3 Two Experiments: Model Efficiency and Regional Variation

We carried out two experiments to test the proposed global model. The first experiment assessed the model's general performance. The second investigated the impact of regional variation on the model by testing it in three different localities.

In the first experiment, the parameterization engine was tested using data from the 47 speakers that had not been used to train the model. This gave a total of 469 sentences for testing. The global phoneme recognition rate for the model was 93.23%, which is a satisfactory recognition performance. In addition, testing the engine for word recognition showed a recognition rate of 89.29%. These results show that the proposed global model is satisfactory for the purposes of automatic speech recognition of the French spoken in New Brunswick.

The second experiment asked the following question: Does the global model "understand" one region better than another? Three localities were selected for this study: Shippagan (in the Northeast), Edmundston (in the Northwest), and Moncton/Dieppe (Southeast). These cities are located near the geographic extremities of New Brunswick, and they represent what are perceived as different regional varieties of New Brunswick Acadian French.

The engine was tested using data from the testing subset of the corpus, that is, the one-third of the data that had not been used in training the engine. The following numbers of speakers had been selected (randomly) in each locality: 5 out of 15 in Shippagan (49 sentences), 7 out of 22 in Edmundston (70 sentences), and 8 out of 24 in Moncton/Dieppe (80 sentences). The number of sentences tested varies from region to region because the number of speakers is not constant across regions.

Table 3. Word recognition rate globally and by locality

Global	Shippagan (Northeast)	Edmundston (Northwest)	Moncton/ Dieppe (Southeast)
89.29%	91.61%	81.37%	81.82%

As shown in Table 3, the results indicate considerable variation among the three localities. Shippagan received a much better recognition rate (91.61%) than either Edmundston (81.37%) or Moncton/Dieppe (81.82%). Furthermore, the size of the difference in the rates between Shippagan and the other two localities – about 10% – suggests that recognition differences are not due to random error.

We note that no statistical analyses were carried out to test these between-locality differences. The recognition rates are based on Hidden Markov Models that model and capture all of the variation present in the data; thus, these models produce the same recognition rates and leave confidence intervals of zero. Future experiments, in which different subsets of speakers can be selected for training and testing the model, will allow us to determine whether the between-locality differences observed in this preliminary study are indeed statistically significant.

The variability in the recognition rates among the three localities raises several questions about the role of linguistic variation in speech recognition. Some of these questions are linguistic: Which phones contain variations that are too large for the model to take into account? How different are these "difficult" phones in the pronunciation of Moncton/Dieppe and Edmundston speakers from the pronunciation of Shippagan speakers? Are there fewer of these "difficult" phones in the region that is most easily understood?

Other questions are of a sociolinguistic nature: Do recognition rates correlate with speakers' age, gender, region or locality? For example, are recognition rates for females speakers' data better than those for males speakers' data? Are older speakers more easily "understood" than younger speakers? Is there greater phonetic variation within larger localities such as Moncton/Dieppe than in the more rural areas such as the Northeast and Northwest?

The main implication of the results of the second experiment described here is that regional linguistic variation appears to be an important consideration in designing speech recognition systems.

5. Other Research Applications of the RACAD Speech Corpus

The RACAD corpus has several strengths: it contains recordings that are of a high quality, these recordings were made by a reasonably large number of speakers, the choice of speakers represents differences due to region, age and gender, and the dialect is a minority variety that differs from mainstream varieties. The speaker demographic features and the presence of considerable regional variation provide an interesting set of perspectives for speech science applications, such as automatic speech recognition, to this variety of French.

The attention to recording quality and to demographic factors makes the RACAD corpus attractive to other areas of speech research. One of these is the acoustic phonetic analysis of New Brunswick Acadian French. The phonetic characteristics of the realizations of certain phonemes in Acadian French can be compared with those found in other dialects, including mainstream varieties.

A second area of application is in studies of linguistic variation. Because it contains speech samples of many speakers who are from well-defined regional, age and gender backgrounds, the corpus can provide data for sociolinguistic and dialectological studies that examine the fine phonetic details of speech variation. Increasingly, instrumental socio-phonetic studies are paying particular attention to vocalic, consonantal and prosodic variation (Foulkes & Docherty 2006; Thomas 2002), allowing researchers to pursue questions about the relation between phonetic detail and social and geographical information. As well, materials from the corpus are well suited for perceptual dialect categorization experiments and automatic dialect classification studies.

Other research applications of the RACAD corpus in linguistics are limited. One weakness of the corpus is the small amount of speech data recorded for each speaker. This limits studies of variation within one speaker's production. Nor does this allow detailed phonetic studies that focus on minimal pairs or that examine a large number of specific environments of a particular phoneme (that is, specific combinations or sequences of phones). A second weakness is the absence of stylistic variation. Speakers in the corpus had only one task, reading sentences, this to the exclusion of other styles such as reading a longer text or the kind of casual, spontaneous speech that is often of interest in sociolinguistic research. Nevertheless, the data are naturalistic because they were obtained in the field as opposed to a laboratory setting.

6. CONCLUSION

The RACAD speech corpus contains recordings of 140 native speakers from the three main francophone regions of New Brunswick. The design of the corpus was informed by linguistic studies of Acadian French based in sociolinguistics and dialectology. The major application for this corpus is in research on automatic speech recognition. The preliminary global monophone speech recognition model described in the present study is successful at both phone and word recognition tasks; however, success varies across geographical regions. Data from the RACAD corpus are a potential resource for acoustic-phonetic and socio-phonetic studies that examine dialect variation.

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