SPECIALIZED LANGUAGE MODELS USING DIALOGUE PREDICTIONS

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ABSTRACT

This paper analyses language modeling in spoken dialogue systems for accessing a database. The use of several language models obtained by exploiting dialogue predictions gives better results than the use of a single model for the whole dialogue interaction. For this reason several models have been created, each one for a specific system question, such as the request or the confirmation of a parameter.

The use of dialogue-dependent language models increases the performance both at the recognition and at the understanding level, especially on answers to system requests. Moreover using other methods to increase performances, like automatic clustering of vocabulary-words or the use of better acoustic models during recognition, does not affect the improvements given by dialogue-dependent language models.

The system used in our experiments is Dialogos, the Italian spoken dialogue system used for accessing railway timetable information over the telephone. The experiments were carried out on a large corpus of dialogues collected using Dialogos.

1. INTRODUCTION

In a spoken dialogue system (SDS) a method to improve speech recognition and speech understanding is to use contextual knowledge as a constraint, both at the recognition and at the parsing level [1].

Carter [2] shows that clustering the sentences of the training corpus into subcorpora on the basis of the criterion of minimizing entropy, improves n-gram based language models. We propose that the splitting of a corpus acquired from a SDS should be done according to the dialogue point in which an utterance was given. On these subcorpora a set of more specific n-gram based language models was trained. This work extends the previous one described in [3], where first insights into the usefulness of dialogue predictions were given on a corpus acquired with an earlier version of the dialogue system, see [4].

Our use of dialogue prediction is similar to the static prediction described in [5] and is related to the dialogue-step dependent models in [6], the difference being that we also measured performance at the understanding level.

Other methods to improve SDS performances in conjunction with the use of dialogue predictions were tested. The work developed in [7] was exploited and the vocabulary-words (VW) were clustered automatically. Further improvement was obtained using acoustic models trained on a larger training-set of domain specific utterances. It's remarkable that even in those cases the improvements given by dialogue-dependent language models were not affected.

2. THE SYSTEM USED FOR THE ACQUISITION

Dialogos is an all-software, completely integrated, dialogue system which runs very close to real-time on a DEC Alpha, except for the telephonic interface and text-to-speech synthesizer which are run from a PC equipped with a D41E Dialogic board.

The acoustical front-end performs feature extraction and acoustic-phonetic decoding. The recognition module is based on a frame-synchronous Viterbi decoding, where the acoustic matching is performed by a phonetic neural network [8]. The vocabulary of Dialogos contains 3,471 words, clustered in 358 classes. 348 of them contain a single word, while the remaining 10 classes contain semantically important words, such as city names (2,983 words), station names (33 words), numbers (76 words), months, week days, and so on. During the recognition, a class-based bigram language model is used. It was trained on 30,000 sentences. The training data of the language models was partially derived from a previous trial of SDS applied to the same domain, but for the most part (86%) it was manually created.

The linguistic processor starts from the best-decoded sequence, and it performs a multi-step robust partial parsing, which is an improvement of [9]. It accepts partial solutions on the basis of their coherence with respect to the parser's linguistic knowledge and generates a task-oriented semantic caseframe.

To interpret a new utterance in the on-going interaction, the dialogue module (DM) takes into account the linguistic history and the active focus. This mechanism allows the DM to identify linguistic references, find out the correct context to apply to utterance interpretation, and decide if an utterance causes a shift or restriction of focus [10]. The result of the contextual interpretation is the choice of a proper dialogue act (DA), such as the request or the confirmation of a parameter, and the generation of a system answer. The DM makes use of pragmatic expectations about what the user would probably say in a certain dialogue state. On the basis of these contextual based expectations the DM can generate predictions.

S1> Where are you leaving from and going to?
<request: departure_city, arrival_city>

U1> From Turin to Milan.

S2> Are you leaving from Turin for Milan?
<confirm: departure_city, arrival_city>

U2> Yes tomorrow at about eight o'clock.

S3> Do you want to leave tomorrow at about eight o'clock?
<confirm: departure_date, arrival_time>

U3> Yes.

S4> I have found two connections ... Do you want other information about these connections?
<confirm: connection_information>

U4> No thanks.

S5> Thank you for the call. Good-bye.

Figure 1: Example of a dialogue interaction.

Using Dialogos a corpus[1] of near 2,000 dialogues for a total of 19,697 utterances was acquired. A dialogue example is shown in Figure 1, where for each system sentence (Si>) the DA and the parameters are given. This information can also be used for predicting a more specific language model which better represents the syntactic, semantic, and contextual constraints of the future user's answer.

3. PREDICTIONS

The concept of prediction constitutes the guessing of a future action and it is commonly used to obtain constraints in a certain point of a dialogue. In an information inquiry system the knowledge to estimate the subset of user's DA already exists. In the VERMOBIL system [11], for instance, a special module estimates the set of DAs in the next user utterance and a stochastic recovery is done when the prediction fails. In our system a certain point in a dialogue is identified by the question that the user is replying to, i.e. the DA of the system generated sentence, which is called in the following dialogue prediction (DP).

At the recognition level, we make use of the information that the DM can provide, by creating specific LMs for each DP. The most specific LM is obtained from a training-set which only contains replies given in a certain DP. However, some questions very rarely appear and for them the information contained in the training DB is not enough to obtain a robust LM.

3.1 Question classification

The system questions were classified in a natural way. At first they were divided into groups according to the type of DA: request for (***Ri***) and confirmation of (***Ci***) a parameter ***i***, and listing of train information (***Info***). Then these groups were separated into DAs involving one or more parameters, and, finally, a distinction was made between the different parameters dealt with by the questions, such as departure city (***p***), arrival city (***a***), departure time (***t***), and departure date (***d***). For example, ***Cp*** is the confirmation of the departure city, ***Rt*** the request of the departure time, and ***Rp & Ra*** the request of both the departure and the arrival cities through a single sentence. In Figure 2 the various classes are shown together with the frequencies of occurrence in the acquired corpus.

Bearing in mind these distinctions, a specific training-set for each class was obtained. The utterances of a specific training-set include all the instances of different user's answers in that point of the dialogue, for instance in the ***Cp*** training-set there are both positive and negative confirmations.

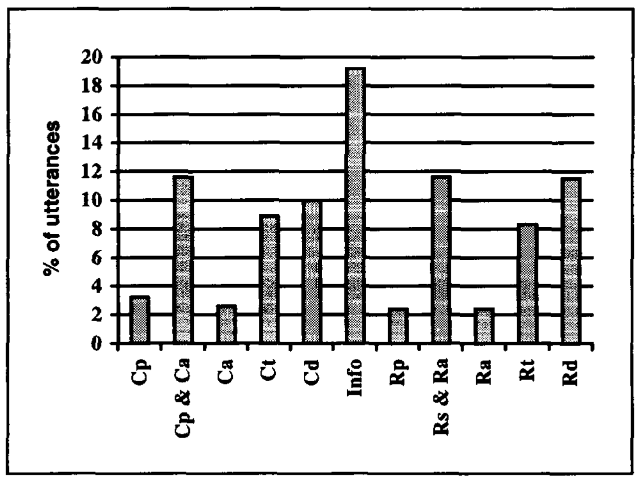

Figure 2: Relative frequencies of the classes.

3.2 Creation of the models

After obtaining the training-sets for each specific class, different models were created with the same algorithm used for a single context-independent model. All the results presented in this paper were obtained using both a bigram model during the acoustic decoding and a trigram one for the rescoring of the 25 n-best sequences.

4. EXPERIMENTAL RESULTS

We carried out two sets of experiments using either a single model for all utterances or a set of specific models that takes into account the predictions described before.

[1] A part of this corpus collected from 493 naive users (1,363 dialogues, 13,123 utterances) is reported in [12], where the evaluation results of the system are given.

Both the context-independent and the specialized models were trained on the same material, 15,575 user utterances, and tested on 2,040 ones. The two sets were disjunctive.

Performance is measured at both recognition and understanding levels. Recognition performance is measured in terms of sentence accuracy (SA) and word accuracy (WA), and understanding one in terms of sentence understanding (SU[2]) and concept accuracy (CA).

4.1 Single context-independent models

Table 1 shows the comparison of the performance of the LM used during the acquisition (*baseline*) and a single dialogue-independent LM obtained with the whole training-set (*ALL_INT*). The baseline model was mainly trained on manually created data, which some of them are unusual in a dialog interaction, and so this model shows a poor level of specificity. The ALL_INT model, on the other hand, is far more specific, as it only includes utterances occurred through the user dialogues, and so it reflects the distribution of the utterances in a real setting. Both at the recognition and the understanding levels the ALL_INT model gives a better performance.

	SA	WA	SU	CA
baseline	69.4	68.8	76.1	66.4
ALL_INT	70.9	71.1	77.6	68.5
ALL_PRED	71.2	73.1	79.4	72.2
FINAL	71.5	73.4	79.8	72.5

Table 1: Results of single models and models with DP.

4.2 Language models with dialogue predictions

A set of two models with DP were tested. The first one, ALL_PRED, was created as described in Section 3.2. Another one, FINAL, takes for each class the best between the single model (ALL_INT) and the model with DP (ALL_PRED), according to the SU metric. For classes containing a few utterances the ALL_INT model was preferable, for instance, in the class "confirmation of departure city" (***Cp***), so in this case it was selected.

The results for the models with DP are also given in Table 1. They show that the use of DP almost double the improvement obtained with the ALL_INT model alone. The error rate reduction between ALL_INT and FINAL is near 10% for WA and SU, and over 20% for CA. These improvements are encouraging because they compare favorably with the ones reported in [6].

The improvements became clearer if we separate the test utterances into requests for and confirmations of a parameter, as shown in Table 2. Through the use of DP (the FINAL model) a general improvement for the request utterances of 2-4% was achieved. This was slightly reduced for the confirmations, because about 70% of them are utterances of only one word ("Yes", "No", "Okay", and so on), which are always correctly recognized.

		SA	WA	SU	CA
request	ALL_INT	60.8	74.6	67.4	60.6
request	FINAL	62.8	78.9	71.3	66.3
confirm	ALL_INT	77.3	71.9	84.6	76.5
confirm	FINAL	76.9	71.3	85.4	78.1

Table 2: Results for requests and confirmations.

5. PREDICTIONS VS. OTHER IMPROVEMENTS

It is interesting to test if the increment of performance brought by the use of DP is affected by the use of other methods. Two methods were tested, such as: the automatic clustering of vocabulary words (ACVW) and the use of acoustic models trained on a larger set of domain specific utterances.

5.1 Language models with automatic clustering of vocabulary words

Word clustering is commonly used to reduce number of parameters of a LM. This could increase the statistical robustness and reduce the size of the model itself.

At first, most of the classes (348 from 358) had one single word, and these classes were clustered again in automatic way using *Maximum likelihood* method[3], as described in [7]. The final number of classes was 120.

Two models FINAL-clust, and ALL_INT-clust were trained on the same database as FINAL, and ALL_INT described above, but the word classification was changed from 358 to 120 classes.

5.2 Use of more specific acoustic models

All experimental results till now, have used an acoustic model (M1) trained on a set of two DBs. The first is a domain independent one, which contains phonetically balanced data produced by 1,136 speakers, 4,875 utterances (with an average length of 6 words) and 3,653 isolated words. The second one is domain dependent, and it includes 3,580 utterances (with an average length of 2 words) from 270 speakers. It came from an older SDS acquisition.

A new acoustic model (M2) was created by adding 13,929 utterances (with an average length of 2 words), from the corpus described in Section 2, to the domain dependent DB part of M1.

[2] SU is obtained comparing for each sentence the caseframe generated by the parser with a manually corrected one. The CA takes into account substitution, insertion, and deletion of concepts, i.e. attibute-value pairs in the caseframe. The CA formula is similar to the WA one, see [13].

[3] In [7] several clustering methods were compared through the perplexity values and they gave similar results. In this work the choice of the best automatic clustering method was made experimentally.

5.3 Final comparison

Table 3 shows WA and SU results for the LMs with autoclassification using both M1 and M2 acoustic models. Autoclassfication only (M1 columns) improved both the single model and the DP one, compared to the results in Table 1, and, as expected, the M2 acoustic models furtherly increment the recognition and understanding results. In any case these improvements does not alter the advantage obtained by the use of DP.

	WA		SU	
	M1	M2	M1	M2
ALL_INT-clust	71.9	73.8	79.0	81.4
FINAL-clust	73.4	75.6	80.8	83.5

Table 3: Comparison between models with ACVW.

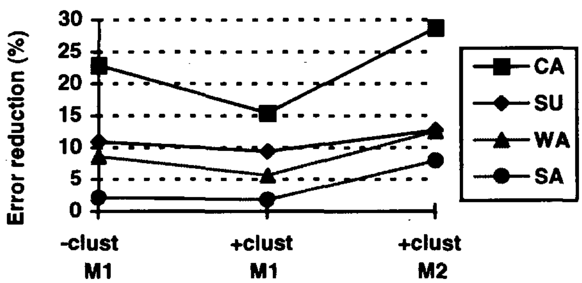

Figure 3: Error reduction among all the experimental settings.

The diagram in Figure 3 represents the error rate reduction values between ALL_INT and FINAL LMs, for three different experimental settings, which are: without ACVW using M1 (-clust/M1); with ACVW still using M1 (+clust/M1); and with ACVW but using M2 (+clust/M2).

The diagram shows clearly that in each case the LMs which use DP give better recognition and understanding results (all the error rate reduction values are positive). It's also remarkable that the use of DP, in conjunction with other methods, could even increase the improvement. All the values of +clust/M2 are greater then the -clust/M1 ones, so for SU it goes from 10.9% (for -clust/M1) to 12.7% (for +clust/M2), and from 22.9% to 28.7% for CA. However in +clust/M1 the error reduction is the smallest, because the ACVW improve above all the single model (ALL_INT-clust).

6. CONCLUSIONS

It has been shown that more specific models (created exclusively with replies given at a certain point of the dialogue) improve globally the performance of SDS. On the other hand, in some cases the specific models are not robust enough (i.e. very rare, but appropriate utterances). The trade-off between specificity and robustness should be better studied in future.

The improvement of the performance for requests suggests a proportional general improvement of the whole system, because it implies a higher number of positive replies to the following confirmation and the reduction of the number of turns in the dialogue for some unnecessary recovery. Moreover the use of DP is useful in conjunction with other methods, such as the autoclassification of vocabulary words and the use of more specific acoustic models. These kind of dialogue-dependent LMs have been already integrated into Dialogos system.

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