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Short Paper

A Layered Approach to the Polysemy Problems in a Chinese to Taiwanese TTS System*

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This paper proposes a novel approach to the polysemy problems in a Chinese to Taiwanese TTS (text-to-speech) system. Polysemy means there are words with more than one meaning or pronunciation, such as "不"(no), "上"(up), and "下"(down), and so on. The correct pronunciation of a word affects the comprehensibility (or intelligibility) and fluency of Taiwanese speech. We applied our approach to solve the polysemy problems of the above mentioned three words. These words are difficult polysemy cases since they have many (6, 3, and 4, respectively) possible pronunciations. Results show that the proposed layered approach is over some language models and decision list classifier. Our approach has high accuracy and it can be extended when more training data is available.

Keywords: layered approach, polysemy, Chinese to Taiwanese, word sense disambiguation, confidence measure

1. INTRODUCTION

Most of the people in Taiwan speak Taiwanese. Taiwanese is the most widely spoken dialect in Taiwan. There are more and more people in Taiwan learning and speaking Taiwanese. Teaching Taiwanese is also an important teaching activity in all levels of schools, especially in the elementary schools. Many universities set up new departments or research centers in popularizing the culture and language of Taiwanese.

Researchers such as those in [1, 5, 8, 10, 14] have had outstanding results in developing Mandarin text-to-speech (TTS) systems in the past years. The researchers of information science in Taiwan have made some efforts in developing speech recognition systems and text to speech systems for Taiwanese in recent years [3, 4, 11]. In contrast to Mandarin which is officially used in Taiwan, there are no formal characters for Taiwanese. Consequently, many researchers have focused on Chinese to Taiwanese (C2T) TTS systems. This means that the input of a so-called Taiwanese TTS system is Chinese text. In 1999, Y. C. Yang [11] developed a method based on machine translations to help solve this problem. Since there are differences between Mandarin and Taiwanese, a C2T

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TTS system should have a text analysis module that can solve the problems specific to Taiwanese. For example, the word "你"(you) has two pronunciations in Taiwanese, namely /li/ and /lin/. The first pronunciation /li/ of "你"(you) means "you", while the second pronunciation /lin/ of "你"(you) means "your".

In general, a C2T TTS system should contain four basic modules. They are (1) a text analysis module; (2) a tone sandhi module; (3) a prosody generation module; and (4) a speech synthesis module. Text analysis in a C2T TTS system should have functions other than that in a Mandarin TTS system, such as phonetic transcription, digit sequence processing [7], and polysemy resolution [6]. Among these works, the polysemy problem in Taiwanese is a complex and difficult one. There is little research about solving the polysemy problem. Polysemy means that a word has two or more meanings hence it may have different pronunciations. The correct pronunciation of a word affects the comprehensibility (or intelligibility) and fluency of Taiwanese speech. We think that to solve the polysemy problems in a C2T TTS system is a fundamental task.

The remainder of this paper is organized as follows: In section 2 we will describe the polysemy problem in Taiwanese. We will focus on the polysemy problems of the word "不"(no) with six different kinds of pronunciation, the word "上"(up) with three different kinds of pronunciation, and the word "下"(down) with four different kinds of pronunciation in this paper. To decide the correct pronunciation of these three words is more complex than that on other words. We will first apply language models to determine the pronunciations of these three words in section 3. A layered approach for determining the proper pronunciation is proposed in section 4. In section 5, we compare our results with the results applying the decision list classifier used in [12, 13]. The decision list classifier worked very well in solving the word sense disambiguation problems. The results show that the accuracies of using the layered approach are over that of using language models and decision list classifier. Finally, in section 6, we summarize our major findings and outline some future work.

2. THE POLYSEMY PROBLEMS IN TAIWANESE

Compared with Chinese, the polysemy problems in Taiwanese are more complex and difficult. The number of words with polysemy problems in Taiwanese is also greater than that in Chinese.

As shown in [6], the polysemy problem in Taiwanese is very common and complex. Ex 1 shows the pronunciations of the word "我"(I) and "你"(you) in Taiwanese. The two pronunciations of "我"(I) are /ghua/ with the meaning of "I" or "me", and /ghun/ with the meaning of "my". The two pronunciations of "你"(you) are /li/ with the meaning of "you" and /lin/ with the meaning of "your". If one chooses a wrong pronunciation, it will result in wrong meanings of the speech.

Ex. 1: 『我/ghua/過一會兒會拿幾本有關台語文化的書到你/lin/家給你/li/, 你/li/可以不必到我/ghun/家來找我/ghua/拿。』(I will bring some books about Taiwanese culture to your house for you later. You need not come to my home to get them from me.)

We have shown that using language models and their combined approaches can achieve high accuracy rates [6]. The abovementioned words have two different kinds of pronunciation. There are some words with more than two kinds of pronunciations in Taiwanese. These words are also used commonly. We will describe three such words in this paper. They are "不"(no), "上"(up), and "下"(down).

The first word is "不"(no). The word "不"(no) has six different kinds of pronunciation. They are /bhuaih4/, /bho5/, /m7/, /bhei7/, /but4/, and /mai3/. Exs. 2-7 are examples for these pronunciations.

Ex. 2:『你爲什麼**不/bhuaih4/**快點抓住呢？』(Why don't you catch it quickly?)
Ex. 3:『一般人並**不/bho5/**容易看出它的重要性。』(It is not easy for a person to see its importance.)
Ex. 4:『**不/m7/**知浪費了多少國家資源。』(We do not know how much national resources are wasted.)
Ex. 5:『讓人聯想**不/bhei7/**到他與機械的關係。』(It cannot remind the relationship between him and machines.)
Ex. 6:『華航使用之航空站交通已**不/but4/**如從前方便。』(The traffic to airport is not as convenient as before for China Airlines.)
Ex. 7:『我希望**不/mai3/**傷她的心。』(I hope that it will not hurt her mind.)

The second word is "上" (up). The word "上" (up) has three different kinds of pronunciation. They are /ding2/, /siong7/, and /jiunn7/. Exs. 8-10 are some examples of pronunciations of the word "上"(up). The meaning of the word "上"(up) in Ex. 8 is the sense of "previous". Ex. 9 shows the sense of "on" of the word "上"(up). We also find that it means the sense of "get up" of "上" (up) in Ex. 10.

Ex. 8:『我**上/ding2/**個月花了好多錢去買有關台語的教科書。』(I spent much money in buying Taiwanese textbooks last month.)
Ex. 9:『我是在這地圖**上/siong7/**的哪裡？』(Where am I on this map?)
Ex. 10:『我**上/jiunn7/**了公車後才發現我搭錯車了。』(I find that I took the wrong bus when I get in the bus .)

The third word we want to discuss is the word "下"(down). The word "下"(down) has four different kinds of pronunciation. They are /ha7/, /ao7/, /loh8/, and /ei7/. Exs. 11-14 are some examples of pronunciations of the word "下"(down). The meaning of the word "下"(down) in Ex. 11 is the sense of "close" or "be over". Ex. 12 shows the sense of "next" of the word "下"(down). Ex. 13 is the sense of the verb "falling". We also find that it means the sense of "next" of "下"(down) in Ex. 14.

Ex. 11:『我今天將在十點**下/ha7/**課。』(I will finish class at ten o'clock today.)
Ex. 12:『台中**下/ao7/**星期有甚麼音樂會？』(What concerts are scheduled for next week in Taichung?)
Ex. 13:『彰化已經開始**下/loh8/**大雨了。』(It has begun to rain hard in Chung-Hua.)
Ex. 14:『請問**下/ei7/**一班火車何時開出？』(Please tell me when will the next train depart?)

As we see in the above examples (Exs. 2-14), it is not easy to determine the proper pronunciation for each word. The abovementioned words (“不”(no), “上”(up), and “下”(down)) have at most two kinds of pronunciation in Mandarin. Yet they have more kinds of pronunciation in Taiwanese. We think that it is a fundamental task to solve the polysemy problems in a C2T TTS system. The correct meaning of the synthesized speech cannot be determined if this problem is not solved properly. We can have fluent synthesized Taiwanese speech only after we get the correct pronunciation of each word in Taiwanese.

Though we had good results in our previous research [6], we found that it can still be improved. The improvement is done by giving priority to the case that many facts occur simultaneously. For instance, consider the sentence “讓人聯想不到他與機械的關係”. By using the co-occurrence of the preceding word “聯想”(think of) and the following word “到”(reached) of “不”(no) (or you can treat “聯想 + 不 + 到” as a pattern), we will read “不”(no) as /bhei7/. We no longer treat “聯想” and “到” as individual cues in determining the pronunciation of “不”(no).

3. LANGUAGE MODEL APPROACH TO THE POLYSEMY PROBLEM

In this section we will describe the experimental data and our earlier language model approach [6]. Note that a major feature of this language model approach is that the words in the window are treated individually. Their co-occurrence patterns are not utilized. We will make some descriptions of our experimental data in section 3.1.

3.1 Description of Experimental Data

We use Academic Sinica Balanced Corpus 3.0 (ASBC 3.0) as our experimental data. ASBC is a well-known Chinese corpus with segmentation information. We select all the data (sentences) with the single-character word “不”(no), “上”(up), and “下”(down) from ASBC. Note that some data with the words like “不要”(don’t want), “不行”(not allowed), “上升”(to rise), …, and so on, are not included in our experimental data, since there is only one pronunciation for such multi-character words. There are 38,930 samples with single-character word “不”(no) selected, 2,1297 samples with single-character word “上”(up) selected, and 6,843 samples with single-character word “下”(down) selected. We determined the pronunciation for the above samples manually.

The ratio of training data and testing data is about 9:1. In other words, there are 35,037 samples of “不”(no), 19,168 samples of “上”(up), and 6,159 samples of “下”(down) for training. And there are 3,893 samples of “不” (no), 2,129 samples of “上”(up), and 684 samples of “下”(down) for testing. In our experimental data, the ratios of the most frequent pronunciations of the words “不”(no), “上”(up), and “下”(down) are 41.3%, 81.2%, and 69.6%, respectively.

3.2 Results of Using WU

We applied WU (word-based uni-gram model) for training data to find the best observation window (*m*, *n*) for each word. Where *m* means the window size in words on the

left side, and *n* is the window size in words on the right side. Twenty four (5 * 5 – 1 = 24) different window sizes are applied in the analysis using WU model. The best inside test result achieved was 79.74% and the best range is 1 word on the left side of "不" (no) and 1 word on the right side of "不"(no). The best inside test result achieved is 94.40% whose best range is 0 word on the left side of "上"(up) and 1 word on the right side of "上"(up). And the best inside test result achieved is 96.53% with the best range 0 word on the left side of "下"(down) and 1 word on the right side of "下"(down).

We apply the above best ranges of the three words in WU to the testing data. Fig. 1 is a comparison between the accuracy of baseline (choosing the most frequent pronunciation in training data) and the accuracy applying WU for each word. We find that WU works not well in determining the pronunciation of the word "上"(up) (81.2% vs. 76.33%).

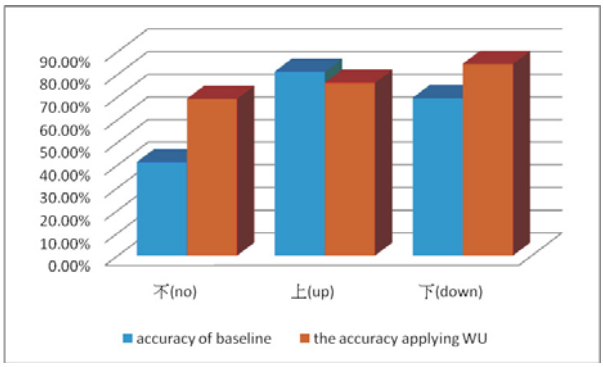


Fig. 1. A comparison of the accuracy of baseline and the accuracy of applying WU to the three target words.

4. A LAYERED APPROACH TO THE POLYSEMY PROBLEM

We will propose a layered approach for solving the polysemy problem in Taiwanese. The main drawback of using the approach mentioned in section 3 is that the importance of higher gram patterns is the same as that of lower ones. We think that the importance of a higher gram should surpass that of a lower one. We will first bring up our layered approach in subsection 4.1. Subsection 4.2 is the experimental results applying the layered approach. We will use confidence measures to the layered approach in subsection 4.3.

4.1 Proposed Layered Approach

According to our previous researches [6], we find that to decide the correct pronunciation of a word with polysemy problem needs to take considerations of its neighborhood words. We find that there are some drawbacks in using WU. An example is that the importance of the higher gram patterns and the lower ones are the same. Our proposed layered approach can overcome such a drawback. For example, consider the fragment "聯想不到"(cannot associate with something in thinking) with 3 grams, the word "不" (no) can be pronounced as /bho5/. If there are only bi-gram patterns, such as（不, 到),

the word "不"(no) may have two kinds of pronunciation, /bho5/ or /bhei7/. It shows that the higher gram patterns are more important than the lower gram patterns.

The main concept of the proposed layered approach is as follows: There are four layers in this approach. The highest layer, Layer 4, uses the information of 4-gram for each pronunciation, while the lowest layer, Layer 1, uses the information of uni-gram for each pronunciation. For a testing sentence with polysemy problem, it will first go through Layer 4. If there are pattern (w_{-2}, w_{-1}, w_{+1}, w_{+2}) found for some kinds of pronunciation P_j, we can output the pronunciation with highest score (or frequency) and terminate the predicted process. Otherwise, the prediction process will go down to Layer 3. The notation of w_{-1} means the preceding word, and w_1 is the succeeding word, and so forth. The patterns (w_{-2}, w_{-1}, w_{+1}) and (w_{-1}, w_{+1}, w_{+2}) will be used in this layer. The decision process is like that in Layer 4. The patterns to be considered in Layer 2 are (w_{-2}, w_{-1}), (w_{-1}, w_{+1}), and (w_{+1}, w_{+2}). The patterns which will be used in Layer 1 are ($w_{-(i+1)}$, w_{-i}), $i > 1$, (w_{-1}), (w_{+1}), and (w_{+j}, $w_{+(j+1)}$), $j > 1$. If we cannot decide the pronunciation with these four layers, we will output the default pronunciation of that word, which is the most frequent pronunciation in the training data. For instance, the default pronunciation of the word "不" (no) is /bho5/.

For further illustration, we use Ex. 15 to make a description about how the layered approach works. Fig. 2 shows the process of predicting the pronunciation of the word "不"(no) in Ex. 15.

Ex. 15: 體驗出 (VC) 一 (Neu) 種 (Nf) 說 (VB) 不 (D) 出來 (VB) 的 (DE) 感覺 (Na) experienced a kind say no out of feeling (Somebody experienced a kind of feeling that one cannot say.)

In Fig. 2, there are four layers designed in our layered approach. Here (w_{-2}, w_{-1}, w_{+1}, w_{+2}) is (種, 說, 出來, 的). The first pattern, (種, 說, 出來, 的), will be Checked in Layer 4. Since there is no such pattern found in Layer 4, we cannot decide the pronunciation of "不"(no) with this pattern in Layer 4. We then use two patterns, (w_{-2}, w_{-1}, w_{+1}) for (種, 說, 出來) and (w_{-1}, w_{+1}, w_{+2}) for (說, 出來, 的), as input of Layer 3. We cannot find any pattern in training data which tallies with these two patterns, the pronunciation cannot be decided in this layer either.

There are three patterns used in Layer 2. They are (種, 說), (說, 出來), and (出來, 的).

And we find that the pattern (種, 說) appeared in training data. The frequencies are 63 for pronunciation /bhuaih4/, 189 for pronunciation /bhei7/, and 0 for other pronunciations. The pattern (出來, 的) also appeared in training data. The frequencies are 15 for pronunciation /bhuaih4/, 106 for pronunciation /bhei7/, and 0 for other pronunciations. The scores for each possible pronunciation of "不" in Ex. 15 are 78 for /bhuaih4/, 295 for /bhei7/, and 0 for others. We can conclude that the predicted pronunciation of "不" is /bhei7/ in this layer.

Compared with language models in section 3, the main advantage of layered approach is that we can keep up to 4-gram words information for training data. There is no data sparsity problem in our approach. In the layered approach, we also keep lower n-gram information. If there is no pattern found in higher layer, we go down to the lower layer. This is the concept of back-off strategy.

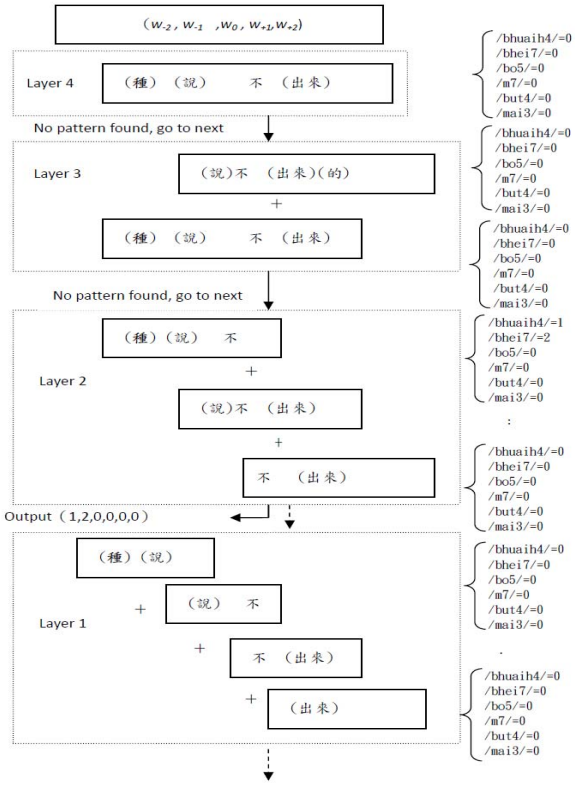


Fig. 2. An example applying layered approach.

4.2 Results of Using Layered Approach

We use the outside testing data mentioned in subsection 3.1 in applying the layered approach. The accuracy in predicting the pronunciation of "不"(no) is 73.49%. The accuracy in predicting the pronunciation of "上"(up) is 87.93%. And the accuracy in predicting the pronunciation of "下"(down) is 91.08%. Such results show that the accuracies that apply the layered approach are higher than that using WU.

4.3 Layered Approach with Confidence Measure

Theoretically, the higher layer should have higher priority than the lower layer in our layered approach. That is, if we can determine the pronunciation of a word in a higher layer, we will not use the answer of the lower layer. There may be the drawback that the result of a lower layer is better than that of a higher layer, especially when the probability of making a correct decision in the lower layer is high. We use the concept of confidence measure to measure the confidence of these four layers [15]. The final predicted pronunciation is that with the highest confidence.

The main idea of using confidence measure is that for any layer, if the difference in the scores of top 1 and top 2 is higher, the predicted pronunciation by that layer is more

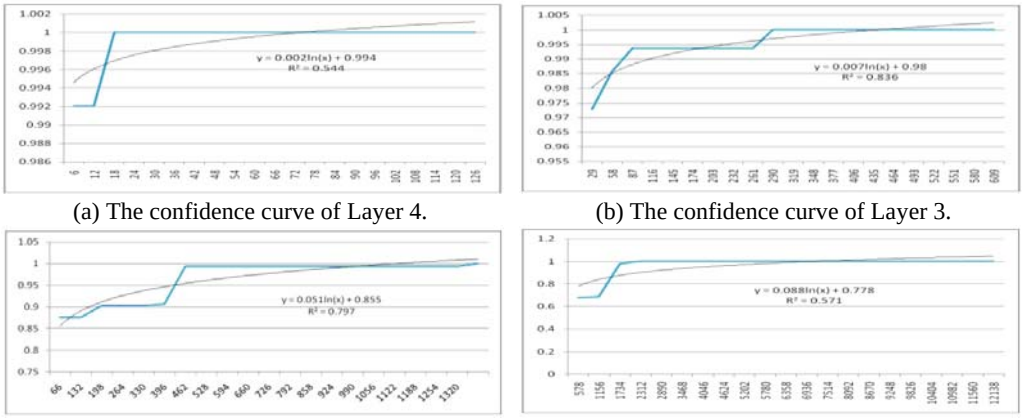
likely to be correct. Based on the concept, we measure the accuracy for each division and use a regression form involving ln(x) to estimate the confidence measure.

Fig. 3 shows the confidence curves of the four layers of "不"(no). These confidence curves are used to measure the confidence for each layer. We will choose the pronunciation predicted by the layer with the highest confidence.

Consider Fig. 3 which is derived from the training data. The x axis is the difference between the top 1 and top 2 scores. The y axis is the percentage of making correct decisions. In Fig. 3 (b) for Layer 3, we can see that when the difference is higher than 290, the probability of getting the correct pronunciation is 1. But when this difference is below 58, the accuracy goes under 0.975. Hence the probability is called confidence.

Take the example sentence "在簡訊上登一個小小啓事". Its confidences are 0 in Layer 4 (no choice), 0.982 in Layer 3 (choosing /ding2/), 0.886 in Layer 2 (choosing /jiunn7/), and 0.991 in Layer 1 (choosing /siong7/). Since the confidence in Layer 1 is the highest, we adopt prediction /siong7/ to be our answer.

The accuracy of using the modified layered approach with the confidence measures to predict the pronunciation for "不"(no) is 74.47%. We find that the layered approach with confidence measure works better than the layered approach in predicting the pronunciation of "不"(no) (74.47% vs. 73.49%). The accuracies are 90.42% vs. 87.90% and 94.30% vs. 91.08% for "上"(up) and "下"(down), respectively. We find that using the layered approach with confidence measure can achieve higher accuracies.



(a) The confidence curve of Layer 4. (b) The confidence curve of Layer 3.

(c) The confidence curve of Layer 2. (d) The confidence curve of Layer 1.

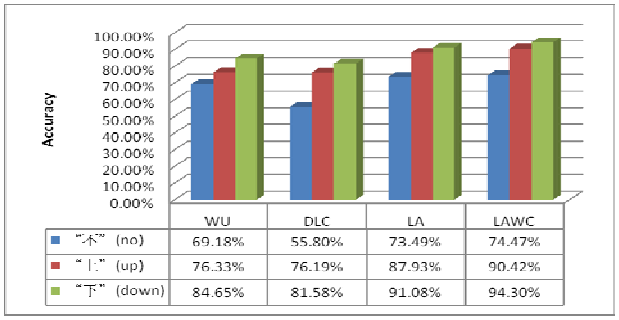
Fig. 3. The confidence curves of the four layers in processing "不"(no). The x-axis in each graph means the difference between the scores of top 1 and top 2 candidates. The values in y-axis are the confidence.

5. A COMPARISON WITH DECISION LIST CLASSIFIER

As we know, there are few researchers working at the polysemy problem in a C2T TTS system except our proposed language models [6]. In this paper, it is treated as a problem of word sense disambiguation. The example problem treated in this paper is to determine the pronunciation of the word "不"(no), "上"(up), and "下"(down) in Taiwanese.

There are a number of papers that have dealt with word sense disambiguation in recent years [2, 9, 13]. In 1997, Yarowsky built a decision list classifier (DLC) using the local context cues within a 20-word window for the target word. A log-likelihood ratio is generated, which stands for the strength of each clue of local context. The decision will be made for matching sorted ratio sequence to decide the sense of a target word. The accuracy reached over 96% on a wide variety of binary decision tasks. The decision list classifier proposed by Yarowsky is among the best in solving the problem of word sense disambiguation. We will apply the decision list classifier in determining the correct pronunciations of the word "不"(no), "上"(up), and "下"(down), and then compare the accuracy with our three approaches.

We tried twenty contextual widths of windows in our experiment. They are ± 20-words, ± 19-words, …, ± 1-words. We use the experimental data mentioned in section 3.1. The accuracies of using DLC are 55.80% for "不"(no), 76.19% for "上"(up), and 81.58% for "下"(down), respectively. As shown in Fig. 4, the results of using DLC are not better than the above two proposed approaches. Fig. 4 is a comparison in accuracy of the approaches used in this paper. Experimental results show that the layered approach with confidence measure performs the best.



	WU	DLC	LA	LAWC
"不" (no)	69.18%	55.80%	73.49%	74.47%
"上" (up)	76.33%	76.19%	87.93%	90.42%
"下" (down)	84.65%	81.58%	91.08%	94.30%

Fig. 4. A comparison in accuracy of the approaches WU, DLC, LA, and LAWC. Where WU is word based uni-gram model, DLC is for decision list classifier, LA and LAWC stand for layered approach and layered approach witch confidence, respectively.

6. CONCLUSION

We proposed an elegant approach, layered approach, to determining the pronunciation of the words with polysemy problems in a C2T TTS system. Experimental results show that the models used achieve higher accuracies than the decision list classifier and some language models. We think that our layered approach made a very good use of the neighboring information of the target words. Its performance is expected to be improved by adding higher layers if we had more training data. We can try the unsupervised approached since we can use the labeled data as our testing and developing set.

The polysemy problems in translating C2T are very common and it is imperative that they should be done in a C2T TTS system. We will continue to focus on other words with polysemy problems in a C2T TTS system in the future.

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