

Towards Automatic Scoring of a Test of Spoken Language with Heterogeneous Task Types

Klaus Zechner and Xiaoming Xi

Educational Testing Service
Rosedale Road, Princeton, NJ 08541, USA
{kzechner, xxi}@ets.org

Abstract

This paper describes a system aimed at automatically scoring two task types of high and medium-high linguistic entropy from a spoken English test with a total of six widely differing task types.

We describe the speech recognizer used for this system and its acoustic model and language model adaptation; the speech features computed based on the recognition output; and finally the scoring models based on multiple regression and classification trees.

For both tasks, agreement measures between machine and human scores (correlation, kappa) are close to or reach inter-human agreements.

1 Introduction

As demand for spoken language testing and cost of human scoring have increased in recent years, there is a growing interest in building both research and industrial systems for automatically scoring non-native speech (Bernstein, 1999, Zechner and Bejar, 2006, Zechner et al, 2007).

However, past approaches have focused typically only on one type of spoken language, or on a range of types similar in linguistic entropy. Entropy in this context can be seen as a measure for how predictable the language in the expected spoken response is: Some tests, such as SET-10 (Bernstein 1999), are focused mostly on the lower entropy aspects of language, using tasks such as “reading” or “repetition”, where the expected sequence of words is highly predictable. Other assessments, such as the TOEFL® Practice Online Speaking test, on the other hand, focus on more

spontaneous, high-entropy responses (Zechner et al., 2007).

In this paper, we describe a spoken language test with heterogeneous task types, ranging from read speech to tasks that require candidates to give their opinions on an issue, whose goal is to assess communicative competence (Bachman, 1990; Bachman & Palmer, 1996); we call this test THT (Test with Heterogeneous Tasks). Communicative competence, in this context, refers to a speaker's ability to use the language for communicative purposes. The effectiveness of the communication typically consists of a few aspects including comprehensibility, accuracy, clarity, coherence and appropriateness, and is evident in a speaker's pronunciation, fluency, use of grammar and vocabulary, development of ideas, and sensitivity to the context of the communication.

This test has the advantage of being able to assess a wide range of non-native speakers' proficiencies by using tasks of varying difficulty levels to allow even low proficiency speakers some degree of success on easier task types.

We select two tasks from this test, one of higher and one of medium to high entropy, and first adapt a non-native English speech recognizer (trained on TOEFL® Practice Online data) to transcribed THT task responses, then compute a set of relevant speech features based on the recognition output, and finally build a scoring model using a subset of these features to predict trained human rater scores. In this paper, we will demonstrate that the machine-human score agreements on these two task types come close to or even exceed the level of inter-human agreement.

This paper is organized as follows: Section 2 discusses related work, Section 3 describes the test and the challenges for automatic scoring involved, Section 4 discusses the speech recognizer and the acoustic and language model adaptations per-

formed, and Section 5 describes the speech features selected for use in the scoring model. In Section 6, we report the construction of the scoring model and its results, Section 7 contains a general discussion and Section 8 concludes the paper with a brief discussion of future research.

2 Related work

There has been previous work to automatically characterize aspects of communicative competence such as fluency, pronunciation, and prosody. Franco et al. (2000) present a system for automatic evaluation of the pronunciation quality of both native and non-native speakers of English on a phone level and a sentence level (EduSpeak). Candidates read English texts and a forced alignment between the speech signal and the ideal path through the Hidden Markov Model (HMM) is computed. Next, the log posterior probabilities for pronouncing a certain phone at a certain position in the signal are computed to achieve a local pronunciation score. These scores are then combined with other automatically derived measures such as the rate of speech (number of words per second) or the duration of phonemes to yield global pronunciation scores.

Cucchiariini et al. (1997a, 1997b) describe a system for Dutch pronunciation scoring along similar lines. Their feature set, however, is more extensive and contains, in addition to log likelihood Hidden Markov Model scores, various duration scores, and information on pauses, word stress, syllable structure, and intonation. In an evaluation, correlations between four human scores and five machine scores range from 0.67 to 0.92.

Bernstein (1999) presents a test for spoken English (SET-10) that uses the following types of tasks: reading, sentence repetition, sentence building, opposites, short questions, and open-ended questions. All types except for the last are scored automatically and a score is reported that can be interpreted as an indicator of how native-like a speaker's speech is. In Bernstein et al. (2000), an experiment is performed to investigate the performance of the SET-10 test in predicting speakers' oral proficiency. It is shown that the SET-10 test scores can predict different levels on the Oral Interaction Scale of the Council of Europe's Framework (North, 2000) for describing oral proficiency of second/foreign language speakers with

reasonable accuracy. This paper further reports on studies done to correlate the SET-10 automated scores with the human scores from two other tests of oral English communication skills. Correlations are found to be between 0.73 and 0.88.

Zechner and Bejar (2006) investigate the automated scoring of unrestricted, spontaneous speech of non-native speakers. They focus on exploring a number of different fluency features for the automated scoring of short (one minute) responses to test questions in a TOEFL-related program. They explore scoring models based on classification and regression trees (CART) as well as support vector machines (SVM). Their findings are that the SVM models are more useful for a quantitative analysis, whereas the CART models allow for a more transparent summary of the patterns underlying the data.

In this paper, we use CART to build the scoring model for one task type. We also adopt multiple regression for another task type which has the advantage of being more easily interpreted than, for example, SVMs. Another major difference between previous work and the work reported in this paper is that we use feature normalization and transformation to obtain statistically more meaningful input variables for the scoring model. In addition, we do not use the whole set of features in an exploratory fashion. Instead, we have carefully selected a subset of features that are both good predictors of human scores and maximize the representation of the concept of communicative competence.

3 The THT test

3.1 Task types and scoring rubrics of the THT Speaking test

There are six task types in the THT Speaking test, ranging from reading-aloud tasks to tasks that require short answers and tasks that require extended responses of one minute. The rubrics differ in both the dimensions of speaking skills measured and the possible score points. (Rubrics are characterizations of candidates' competence at given score levels and are used by human raters to determine the appropriate score for a response.) Below is a brief description of the task types and the rubrics.

Task type 1: Reading-aloud (Planning time: 45 seconds; Response time: 45 seconds; zero/very-low entropy)

There are two read-aloud tasks. Each task requires the test-taker to read a short paragraph of 40-60 words aloud. The reading materials include announcements, advertisements, introductions, etc. These two tasks are rated analytically on pronunciation and intonation and stress on a 3-point scale. That is to say, two separate scores are given on each task – one for pronunciation and one for intonation and stress.

Task type 2: Picture description (Planning time: 30 seconds; Response time: 45 seconds; medium-high entropy)

This task requires the test-taker to describe a picture in as much detail as possible.

This task is rated holistically on the combined impact of delivery (fluency, pronunciation etc.), use of structures, vocabulary, content relevance and fullness on a 3-point scale.

Task type 3: Open-ended short-answer questions (Planning time: none; Response time: 15-30 seconds; low/low-medium entropy)

The test-taker responds, without preparation, to three questions about familiar and accessible topics that draw on immediate personal experience. The first two questions each elicit a 15-second response that covers one or two pieces of information related to the specified topic. The third question requires a 30-second response that expresses an opinion or gives an explanation related to the topic. This task is rated holistically on the combined impact of delivery, use of structures, vocabulary, and task appropriateness on a 3-point scale.

Task type 4: Constrained short-answer questions (Planning time: none; Response time: 15-30 seconds; low/low-medium entropy)

The test-taker responds to three questions about a schedule/agenda that is provided in written form. All the information needed to answer the questions should be included on or easily inferred from the schedule. The test-taker has 15 seconds to respond to each of the first two questions. These questions ask for specific information on the schedule or easily inferred information about the schedule. The test-taker has 30 seconds to respond to the last question which requires a summary of multiple

events or multiple pieces of information on the schedule. This task is rated holistically on the combined impact of delivery, use of structures, vocabulary, task appropriateness and content accuracy on a 3-point scale.

Task type 5: Respond to a voice mail (Planning time: 30 seconds; Response time: 60 seconds; high entropy)

In this task, the test-taker listens to a voicemail that describes a problem, question or situation and then assumes a particular role (bank teller, office assistant, etc.) to respond with a proposed solution or answer. This task is rated holistically on the combined impact of fluency, pronunciation, intonation and stress, grammar, vocabulary, register, content relevance, and cohesion and idea progression on a 5-point scale.

Task type 6: Opinion task (Planning time: 15 seconds; Response time: 60 seconds; high entropy)

In this task, the test-taker is expected to state an opinion or position on an issue that is familiar and accessible and to express support for the opinion or position with reasons, examples, arguments, etc. This task is rated holistically on the combined impact of fluency, pronunciation, intonation and stress, grammar, vocabulary, content relevance, and cohesion and idea progression on a 5-point scale.

3.2 Challenges of the THT test design to automatic scoring

1. Some of the tasks require responses that are expected to vary very little in vocabulary and content across examinees (e.g., Reading-aloud and Constrained short-answer questions) whereas others allow much more flexibility and variation in the use of vocabulary and grammatical structure and topical content (e.g. Respond to a voicemail and Opinion task). The predictability of the expected response will dictate what type of language modeling technique is preferable to optimize speech recognition results. Therefore, unlike in other systems focusing either on high or low entropy speech (e.g., Zechner and Bejar, 2006; Bernstein, 1999), in which a single speech recognizer is employed, it is anticipated that different types of speech recognizers are needed to suit different THT task types. This may increase both the amount of development

work and the complexity in integrating different types of recognizers into the real-time automated scoring system.

2. Furthermore, the scoring criteria of these six different task types are somewhat different. This suggests that different scoring models may need to be developed for different task types since the relevant speech features to be included in the scoring model for each task type may differ.

3. THT speaking tasks use two kinds of score scales: 0-3 and 0-5. Classification techniques, such as classification trees or cumulative logit models (Agresti, 2002; Menard, 2001), may be more appropriate for task types that use a 3-point scale. Prediction techniques such as multiple regression may be better suited for task types that are on a 5-point scale. Training different types of scoring models will certainly increase the complexity and the amount of scoring model development and evaluation work.

In summary, the complexity of the design of the THT Speaking test is expected to have a major impact on our efforts to develop an automated scoring system. Given these challenges and the research resources available, we decided on a strategy of starting with high entropy task types and proceeding to low entropy task types. For this paper, we selected the high entropy Opinion task and the medium-high entropy Picture tasks for system development.

4 Adaptation of the speech recognizer

For this work, we are using a state-of-the-art gender-independent Hidden Markov Model speech recognizer whose acoustic model was trained on about 30 hours of non-native speech and whose language model was built on several hundred hours of both native and non-native speech. The non-native data came from the TOEFL® Practice Online system, a web-based practice program for prospective takers of the Test Of English as a Foreign Language (TOEFL) (Zechner et al., 2007). This data is somewhat different from the THT, as there are only high-entropy tasks in TOEFL Speaking and as the speakers are generally more proficient. Due to this difference, the baseline word accuracy was fairly low (see Table 1).

Therefore, as a first step, we needed to adapt the automatic speech recognition engine to the THT speech data.

We had approximately 1,000 responses each from the Picture and Opinion tasks transcribed. As mentioned above, while the Opinion task responses are generally more spontaneous, the Picture task requires the candidate to accurately describe a picture and thus restricts the possible answer space considerably. Still, there is more room for individual choice and variation in the vocabulary, grammar and content produced than there is in the more restricted low-medium and low entropy task types in the THT Speaking test.

When using our baseline automatic speech recognition (ASR) engine without any adaptation to the THT speech data, we only obtained word accuracies between 25% and 33%, which was clearly inadequate, and far below a word accuracy where, at least for some speakers, meaningful information can be drawn from the ASR hypothesis.

Therefore, we undertook a series of adaptation and optimization steps with the goal of maximizing the word accuracy on the two task types for the THT Speaking test. We first adapted the acoustic model in batch mode with supervised maximum a posteriori (MAP) adaptation using the combined data from both tasks, then the language model, optimized the filler cost parameter and finally conducted unsupervised maximum likelihood linear regression (MLLR) acoustic model adaptation based on individual speakers.

4.1 Acoustic model batch adaptation

We randomly selected about 90% of Picture and Opinion task response data for acoustic model (AM) adaptation, which contained 1,800 response files (over 25 hours of speech, adult speakers with typically low to intermediate English proficiency). Results are always reported on the held-out evaluation data containing 100 files for the Picture task and 80 files for the Opinion task.

We performed supervised maximum a posteriori (MAP) adaptation which is the method of choice for larger amounts of data and is typically performed in batch mode (Tomokiyo and Waibel, 2001; Wang et al., 2003). After one cycle of adaptation, word accuracy improved by about 8%, as is shown in Table 1. We also performed unsupervised maximum likelihood linear regression (MLLR) adaptation, which is discussed in Section 4.4 below.

Method	Picture task word accuracy		Opinion task word accuracy	
	Absolute	Increase from previous step	Absolute	Increase from previous step
Baseline recognizer	25.8%	NA	32.2%	NA
AM MAP adaptation	33.6%	7.8%	40.0%	7.8%
LM adaptation	50.4%	16.8%	51.0%	11.0%
Filler optimization	57.0%	6.6%	56.3%	5.3%
Ignoring fillers	60.5%	3.5%	59.2%	2.9%
MLLR Speaker adaptation	62.4%	1.9%	61.2%	2.0%

Table 1. Word accuracies after each incremental step of adaptation or optimization and performance improvement within each step for Picture and Opinion task types.

4.2 Language model adaptation

The second step was language model (LM) adaptation. The Picture and Opinion tasks were adapted separately using the same training sets as above. We built interpolated models between the task-specific LM and the baseline LM (from the original recognizer).

We obtained the best results using only the task-specific LM trained on the THT data set (given in Table 1). This indicates that the domain of each of the tasks is narrow enough that it can be sufficiently described with a set of about 900 transcribed examples each and it does not benefit from a larger LM such as our baseline LM.

4.3 Filler cost optimization

“Filler cost” is a recognizer-internal parameter that determines the likelihood of filler and noise words to be inserted into the hypothesis before or after “real” words. The higher the parameter’s value, the less likely fillers will be inserted.

The experiments with the filler cost parameter grew out of an observation that the baseline recognizer has a tendency to hypothesize too many words when faced with different kinds of “uncertain” audio, such as mumbled words, noises or fillers. Therefore we conjectured that having the recognizer hypothesize more filler and noise words

in these cases and be more restrictive with actual word hypotheses might increase the word accuracy overall.

We varied the filler cost parameter from its default, 3, down to its lowest meaningful value, 0. Our experiments show that for $\text{fillercost}=0$, a maximum word accuracy was achieved (given in Table 1), albeit at the cost of more than doubling the length of the recognizer’s hypothesis by introducing a large amount of fillers (such as “um” or “uh”, noises, mumbles etc.). We observe that using such a low filler cost parameter setting can negatively affect some speech features which are candidates for being used in a scoring model, such as “language model score”. Therefore we have to carefully assess whether achieving a higher word accuracy is more beneficial to the overall performance of the feature set or whether it has too many negative effects on some important speech features. In future work we will attempt to tune the recognizer in such a way that it is not only optimized for a high word accuracy, but also for high accuracy in filler (and noise) prediction.

Word accuracy was computed with the fillers included or excluded. Since fillers are not real words, and in this round of scoring model development we did not use any features based on fillers, it was reasonable to compute the overall word accuracy with the fillers removed from the human and recognizer transcriptions, resulting in a moderate performance gain (see Table 1).

4.4 Unsupervised speaker adaptation

We used unsupervised maximum likelihood linear regression (MLLR) AM adaptation on top of the previous adaptation and optimization steps (Tomokiyo and Waibel, 2001; Wang et al., 2003). In this step, all words whose confidence score was higher than a pre-set threshold were collected and their acoustic information was used to adapt the acoustic model. All adaptations were done based on the utterances of a single speaker and pertained to that speaker only, i.e., it was not incremental or cumulative. Since a second decoding run is needed after the actual MLLR adaptations, the recognizer’s response time more than doubles when this method is employed. The unsupervised speaker adaptation led to an additional increase of

Feature Number	Feature Name	Feature Class	Description	Used in
1	hmmscore	Pronunciation	Acoustic Model score: sum of the log probabilities of every frame, normalized for length	Opinion & Picture
2	typesper-second	Fluency & Vocabulary diversity	Number of unique words in response (“types”) divided by length of response	Opinion & Picture
3	silences-persecond	Fluency	Number of silences per second	Opinion & Picture
4	repetitions	Fluency	Number of repetitions divided by number of words	Opinion
5	relevance-cos5	Vocabulary & Content	Cosine word vector product between a response and all responses in the training set that have the highest score (5 for the Opinion task)	Opinion
6	relevance-cos3	Vocabulary & Content	Cosine word vector product between a response and all responses in the training set that have the highest score (3 for the Picture task)	Picture

Table 2. Final features used for the scoring models for the Opinion and Picture tasks

approximately 2% for the Picture and Opinion tasks (see Table 1). There were large differences between different speakers in terms of the performance gain of MLLR adaptation on our data set, however. There was also a large variation of word accuracies between speakers (13-100%). The variation in accuracy across speakers can be due to many different factors, including the degree of accent, the grammaticality of the response, the voice quality and the recording quality.

5 Speech features

Based on the output of the ASR engine, a feature computation module computes a set of about 40 features for each response, mostly in the fluency domain (e.g. “average silence duration”), but also some features related to pronunciation, vocabulary diversity and content.

Instead of using all of these features in a scoring model, we used a process of iterative refinement and selection to narrow down the feature set, based on both the coverage of the concept of communicative competence and empirical performance (correlations with human scores) of the features. Following this process, five features were selected to be included in developing the scoring models for the Opinion task type and four for the Picture task type (see Table 2).

When we look at the correlations of these features to the human scores, we find that hmmscore, after being transformed to improve normality, was the strongest predictor of human scores for both the Opinion and Picture tasks with typespersecond as the second strongest ($0.5 \leq \text{Pearson } r \leq 0.7$).

6 Scoring models

All the responses were double scored by a randomly selected pair of raters who were trained for scoring this test. The agreements between the two ratings (both kappa and Pearson r correlation) were around 0.50 for the Picture and 0.72 for the Opinion task. (Note that the fewer points a scale has, the lower correlation we can expect due to less score variability, everything else being equal.)

While we use the same training sets for the scoring model experiments as for the above ASR experiments (sm-train), we add about 600 responses each to the evaluation sets (these responses were untranscribed) to yield a scoring model evaluation set size of about 700 responses each (sm-eval).

Scoring models were developed and evaluated for the Opinion and Picture task types separately. The Opinion tasks are on a 0-5 point scale whereas the Picture tasks are on a 0-3 point scale. There were only a handful of 0s on each task and they were excluded in building the scoring models.

For the Opinion tasks, multiple regression models employing different weights for the features were developed, namely an Equal Weights model, an Expert Weights model and an Optimal Weights model. In the Equal Weights model, each feature was assigned the same weight, indicating that all features are equally important in the prediction. In the Expert Weights model, different weights were assigned to different features that reflected our understanding of the different roles features play in indicating the overall speech quality. In the Optimal Weights model, weights were determined by

the least squares optimization procedure using the sm-train data. All features were normalized to have a mean of 0 and a standard deviation of 1, such that their respective baseline influence on the model is comparable across features.

For the Picture task type, CART was used to predict the score class each response should be assigned to. CART 5.0 (Steinberg & Colla, 1997) was used to build the classification trees.

In addition, generic and task-specific models were developed for both task types. The task-specific models made use of task-specific vocabulary features (Features 5 and 6 in Table 2) which required using previous response data to each of the tasks within a particular task type. (Both task types had 4 different tasks each). The generic models, in contrast, used features that were the same across all tasks for a particular task type and did not use any task-specific vocabulary features. As it would be much more time-consuming and costly to build task-specific models, it is worthwhile to investigate how much more predictive power the task-specific vocabulary features could add over and beyond the features in the generic models.

6.1 Opinion task type

For the Opinion tasks, four features were used in building the generic models and five in developing the task-specific models. The following features were used: hmmscore, typespersecond, silencespersecond, repetitions and relevancescos5 (the latter only in the task-specific model).

Table 3 shows the results on the sm-eval set. The Expert Weights model and the Optimal Weights models yielded very similar results (weighted kappa and correlation = 0.61-0.63) if we look at predicted scores that were rounded to the nearest integer. The agreements between regression model predicted scores and scores of human rater 1 were just a little below the agreements between two human raters (weighted kappa and correlation = 0.72). However, the results for the Equal Weights model were inferior.

The results for the task-specific models showed no improvement over the generic models, suggesting that the task-specific vocabulary feature did not contribute more predictive power beyond the four features already in the generic models.

Model	Multiple Regression (Equal Weights)	Multiple Regression (Expert Weights)	Multiple Regression (Optimal Weights)
Weighted κ	0.53	0.62	0.61
Pearson r Correlation (unrounded)	0.62	0.68	0.69
Pearson r Correlation (rounded)	0.56	0.63	0.63

Table 3. Performance of different weighting schemes on THT scoring model evaluation set for Opinion tasks (generic model)

6.2 Picture task type

As mentioned earlier, the Picture tasks are on a 0-3 point scale and we removed a small number of 0-scores from the analyses, making it a 3-point scale. Given this particular score scale, multiple regression may not be appropriate for this data as it requires a continuous or a quasi-continuous dependent variable (i.e. a variable that has at least 5 or more data points). Some classification techniques such as CART (Brieman et al., 1984) or logistic regression, which can take ordered score categories as the outcome variable, are better suited for this data. In this study, we analyzed the data with CART models.

CART 5.0 (Steinberg and Colla, 1997) was used to build the classification trees. We built two sets of CART models, one set with the task-specific vocabulary feature (relevancescos3) and one set without it. We explored different model configurations, i.e., different combinations of priors and splitting rules. For each combination, a 10-fold cross-validation was conducted. Subsequently, the optimal sub tree that was a relatively small tree with the highest or near-highest agreement with the human scores (weighted kappa) on the cross-validation sample was identified. Then the cases in the sm-eval data set were dropped down the optimal tree to obtain the evaluation results on the held-out data.

The results for the generic model vs. task-specific models are compared in Table 4. For both

models, CART trees built using the Twoing¹ splitting rule combined with mixed priors (average of equal priors for different score classes and sm-train sample priors) yielded the best kappa values on the cross-validation data and were selected as the optimal trees. The agreements between the CART model predicted scores and first rater scores slightly exceeded that between two human raters on the sm-eval data set. Another observation from Table 4 was that for this task type, the task-specific CART model did not demonstrate an advantage over the generic model; actually, its performance was slightly worse than that of the generic model, a finding in line with the Opinion task.

	Generic	Task-specific	Inter-human agreement
Weighted κ	0.51	0.50	0.49
Pearson r Correlation	0.52	0.50	0.50

Table 4. Performance of CART models on THT scoring model evaluation set for Picture tasks (generic model vs. task-specific model)

7 Discussion

This paper investigates the feasibility of developing an automatic scoring system for the THT Speaking test, focusing on the particular challenges posed by the design of the test. The main challenge posed by the test design is the high variability in task types -- ranging from low-entropy Reading-aloud tasks to high-entropy Opinion tasks. While previous tests of spoken language have focused mainly on either high or low entropy tasks (Bernstein, 1999; Zechner and Bejar, 2006), we have made an attempt at starting to address the whole scale of entropy within a single test.

In this paper, we selected one high entropy task (Opinion) and one medium-high entropy task (Picture) to start our explorations. While we found that we could, for the most part, use a similar set of features for both tasks, we had to address the difference in score scales between these two task types. While we could use multiple regression for scoring the 5-point-scale Opinion task, we had to

¹ The Twoing rule divides the cases into two groups, gathers similar classes together, and attempts to separate the two groups in descendant nodes.

employ CART trees for the 3-point-scale Picture task, demonstrating that one can not necessarily use one type of scoring model for all tasks.

When moving to low and low-medium entropy tasks, we expect further adaptations, both in terms of the feature set (e.g., the higher importance of pronunciation features in Reading-aloud tasks), and in speech recognition, where more restrictive language models will be needed.

We have reported findings associated with the performance of the scoring models for the Opinion and Picture task types. Overall, the preliminary findings are quite promising: with a few key speech features, we were able to achieve prediction accuracies that could almost emulate or slightly exceed the agreements between two human raters at task level. Once we have developed scoring models for all task types, it is conceivable to aggregate the task level scores to produce a total summary score at the test level and it is very likely we would see a much stronger association between human scores and automated scores for the whole test.

The findings also suggest that task-specific modeling efforts did not seem to be necessary for the two task types investigated. This does not preclude the possibility, though, that task-specific scoring models are superior for other task types in which the expected content is much more restricted (such as the Constrained short-answer questions).

8 Conclusions and future work

We have demonstrated that by using a three-stage architecture of automatic speech recognition, feature computation, and scoring models, we are able to achieve some degree of success in generating automated scores for two task types of a spoken language test with a wide variation in entropy in its tasks. The agreement between machine scores and human scores comes close to or reaches the inter-human agreement levels for these two tasks.

In future work, we will switch our focus to task types that elicit more constrained speech (such as the Reading-aloud tasks and Constrained short-answer questions). In the meantime, we will continue to refine and evaluate the preliminary scoring models developed in this paper. In particular, we will explore cumulative logit models for tasks that are on a 0-3 point scale and compare the results to those of CART models.

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