ratio of depression-related words over the total number of words over the duration was calculated.

In addition, we introduced a new set of **text sentiment** features, obtained using the tool of AFINN sentiment analysis (**?**), that would represent the valence of the current text by comparing it to an exiting word list with known sentiment labels. The outcome of AFINN is an integer between minus five (negative) and plus five (positive), where negative and positive number number shows negative and positive positive sentiment subsequently. The mean, median, min, max, and standard deviation of the sentiment analysis outcomes (as a time series) were used. A total of 8 features were extracted. The new set of sentiment features was found to be highly helpful in experiments.

Multi-Modal Fusion Framework

We adopted an input-specific classifier for each modality, followed by a decision-level fusion module to predict the final result. In detail, for each modality biomarker we used a random forest to translate features into predictive scores, while these scores were further combined in a confidence based fusion method to make final prediction on the PHQ8. To fuse the modalities, we implemented a decision-level fusion method. Rather than simple averaging, we recognized that each modality itself might be noisy. Therefore, for each modality we calculated the standard deviation for the outcomes of all trees, defined as the modality-wise **confidence score**. After trying several different strategies, the *winner-take-all* strategy, i.e., picking the single-modality prediction with the highest confidence score as the final result seems to be the most effective and reliable in our setting. In most cases, we observed that audio modality tends to dominate during the prediction. We conjectured that it implies the imbalanced (or say, complementary) informativeness of three modalities, and one modality often tends to dominate in each time of prediction. An overview of the confidence based decision-level fusion method is shown in Figure 1.

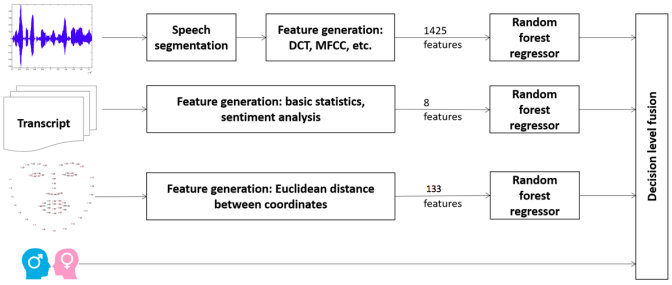

Figure 1: Overview of the confidence based decision-level fusion method

Preliminary Result and Future Work

Baseline scripts provided by AVEC have been made available in the data repositories where depression severity was computed using random forest regressor. Table 1 reports the performance of the baseline and our model for development and training sets. For both models, we reported the performance of single modality and multi-modal fusion methods. Comparing to the baseline, confidence based fusion could achieve comparable or even marginally better performance than the baseline in terms of both RMSE and MAE.

Table 1: Performance comparison among single modality and confidence based fusion model

Feature used	'development'		'train'	
	RMSE	MAE	RMSE	MAE
The baseline provided by AVEC organizer				
Visual only	7.13	5.88	5.42	5.29
Audio only	6.74	5.36	5.89	4.78
Audio & Video	6.62	5.52	6.01	5.09
Our model that doesn't include gender variable				
Visual only	6.67	5.64	6.13	5.08
Audio only	5.45	4.52	5.21	4.26
Text only	5.59	4.78	5.29	4.47
Fusion model	5.17	4.47	4.68	4.31
Our model that includes the gender variable				
Visual only	5.65	4.87	4.99	4.46
Audio only	5.11	4.69	4.84	4.23
Text only	5.51	4.87	5.13	4.28
Fusion model	4.81	4.06	4.23	3.89

We plan to enhance our methodology in the following directions. First, to improve decision rules, we will use Rule ensemble models to exhaustively search interactions among features and scale up the high-dimensional feature space. In addition, we are interested to perform vowel formants analysis to allow a straightforward detection of high arousal emotions. Second, we found that with more relevant features refined, the overall performance could be improved (e.g., silence detection). Finally, we plan to implement our model to a more general clinical environment (e.g., routine patient-provider communication) to characterize social interactions to support clinicians in predicting depression severity.

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