

## Dissertation Outline (Information Science)

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&lt; 博士論文題目（仮） &gt; (Tentative) Title of Doctoral Dissertation

Dimensional Speech Emotion Recognition by Combining Acoustic and Linguistic Information

&lt; 研究の目的と効果 &gt; Research Aim and Impact

Humans process information in multimodal ways. Among many modalities, speech is an important modality in which emotion can be perceived. In the speech, not only acoustic information can be extracted but also linguistic information (via automatic speech recognition, ASR). This research aims to propose methods for combining acoustic and linguistic information for dimensional speech emotion recognition (SER).

Ahead from combining acoustic and linguistic for dimensional SER, acoustic-only dimensional emotion recognition is examined. This study aims to maximize the potency of recognizing dimensional emotion from acoustic information only. In this study, several acoustic features sets have been evaluated on both low-level and high level features. This study contributes to the generalization of high-level statistical functions, i.e., mean and standard deviation which previously observed on a specific feature set. The use these high-level features improves the performance of SER over low-level descriptors. In addition this part of research also contributes to acoustic-only SER by providing and evaluation of the correlation between silent pause features and emotion dimensions and aggregation methods for story-based emotion prediction from chunk-based speech data. One of the drawbacks of acoustic-only SER is the lower score of valence prediction than arousal and dominance prediction, which are also observed in other acoustic-only SER systems.

A method to improve acoustic-based SER, particularly due to low score of valence prediction, is by fusing acoustic and linguistic information. Linguistic information has been reported more predictive than acoustic information in predicting valence. Two fusing methods for acoustic-linguistic information fusion are studied, early-fusion approach and late-fusion approach. First, early-fusion approach are adopted for the fusion of acoustic and linguistic information at the feature level (FL). In this feature-level fusion, two methods to combine acoustic-linguistic information are evaluated, feature concatenation and network concatenation. Beside the contribution of combining acoustic-linguistic information on the used datasets, this study proposes the use of multitask learning to predict valence, arousal, and dominance simultaneously and evaluates bimodal feature concatenation from story-based linguistic information and acoustic feature aggregation done in the previous study.

Motivated by psychological research results, two-stage processing for dimensional SER via deep learning network (DNN) and support vector machine (SVM) are proposed for fusing acoustic-linguistic information at late-fusion approach. In this study, acoustic and linguistic information are trained independently, and the results are fused by SVM to make the final predictions. Although this proposal is more complex than the previous feature-level fusion, the results show improvement over FL fusion and feasible implementation for future speech technology. Currently, ASR produces text from speech accurately. While acoustic features used to train ASR can be used to train SER simultaneously, the transcription from ASR can generate lexical features which result in linguistic-based emotion recognition. This text-based emotion prediction can be fused with acoustic-based emotion prediction to improve SER, as shown in this research.

This research linked the current problem in dimensional SER with its potential solutions. In dimensional SER with valence, arousal, and dominance model, the performance of valence is lower than arousal and dominance due to the lack of valence information in acoustic features. On the other hand, sentiment analysis used linguistic information to predict the polarity of sentiment, which is similar to valence. The combination of acoustic and linguistic information solves this problem. Humans also perceive emotion from multimodal information, which similar to the computer model in several parts, particularly on deciding final emotion recognition via decision-level fusion. The results shown in this study devotes insights for future strategy in implementing SER whether to use acoustic-only features (less complex, less accurate), an early-fusion method (more complex, more accurate), or a late-fusion method (most complex, most accurate).

## < 研究の概要 > Research Outline

The study of speech emotion recognition (SER) needs advancement to move from theoretical side to application side. Twenty years ago SER was only a hypothetical technology. Nowadays, SER is already implemented, from telephone application to automotive safety (Nass, 2005). However, the application of SER still lacks from many issues. This doctoral study aims to propose methods to tackle these issues.

The main issues of this study is whether it suffices to use acoustic features for modeling emotions or if it is necessary to combine them with linguistic (El-Ayadi, 2011). Since linguistic feature can be extracted from speech via ASR, it is reasonable to use this linguistic feature for future real application without a need to use other modalities. SER using acoustic features only itself suffers from several issues. Among others issues, two important issues are being tackled in this study. First is the low score of the valence prediction in dimensional SER. Second is the region of analysis used for acoustic feature extraction, whether frame-based processing (local features) or utterance-based processing (global features). In combining acoustic and linguistic information, how to fuse both information is the among others.

Excluding the literature review, this research is divided into three parts: (1) SER using acoustic features only, (2) combining acoustic and linguistic information at feature level, and (3) combining acoustic and linguistic information at decision level. A brief description of each part is given below.

Prior to discussing the main issues is a literature study of the research theme. This part summarize current trends in speech-based emotion recognition, particularly on research that used both acoustic and linguistic features as information to recognize emotion within the speech. Although a literature study, deep review is being conducted; hence this part of study contributes to the speech emotion recognition community by presenting a summary of some approaches, results, and the remaining problems in the SER area. Emotion from a psychological perspective will also be reviewed, including several models of emotion theories. Datasets commonly used in speech emotion research are summarized, including the datasets used in this research. Finally, the most challenging problems in SER are addressed at the end of this part of study, including its potential solution and direction. This literature study opens insights for the next research parts in this doctoral study.

The second part is the first contribution of this research. This research part evaluates and proposes several methods to maximize acoustic-only dimensional speech emotion recognition. Since the target application of this study is speech-based technology, the natural way to investigate the need of such improvement is to study the basic workflow proposed by other researchers. Speech, particularly acoustic and prosody, is known to be related with human emotion. Several acoustic features are examined to evaluate its effectiveness on predicting dimensional emotion within speech. Next, the region of analysis used for feature extraction is evaluated, short region and fixed longer region (statistical functions). This part of research includes the generalization of the effectiveness of two high-level statistical functions, i.e., mean and standard deviation from GeMAPS feature sets (Schmitt, 2018) to several acoustic feature sets. Another important issue tackled by this part of study the effect of post-filtering on speech signal, i.e., the effect of removing silence vs. using silence as an acoustic features. Other evaluation include aggregation methods for chunk-based features to represents story-based features and development of frame-based mel-filterbank features for dimensional SER, which is being developed.

The third part of this research attempts to provide detail of fusing acoustic and linguistic information at the feature level. There is three motivation of conducting this part of study: the low performance of valence in most DSER, human multimodal perception, and simplicity of early fusion methods. While the first of two motivations are clear, the third motivation, i.e., the proposed methods, is briefly explained here. Two information fusions of acoustic and linguistic at decision level are evaluated, feature concatenation, and network concatenation. At feature concatenation, both acoustic and linguistic features are concatenated and fed into the same classifiers (e.g., SVM, DNN) while at network concatenation, both features are fed into different networks (e.g., LSTM, CNN, MLP). Different datasets are used for these approaches, as well as features sets and classifiers. This part of research also introduces multitask learning (MTL) to concurrently predict valence, arousal, and dominance along with its variants: MTL without parameters, MTL with two parameters, and MTL with three parameters. The differences among these approaches are explained along with their results. Finally, this part will end with some conclusions, contribution, and remaining problems.

The fourth part of this study is the second evaluated method to fuse acoustic and linguistic information, i.e., decision-level fusion. The motivation of the work is the drawbacks of the previous early-fusion method and how humans perceive multimodal information. Given the results from the previous method and motivated by the psychological result on speech emotion perception by acoustic and semantic information, a method was proposed to evaluated dimensional speech emotion recognition by using late fusion or decision-level approach. Psychological and physiological research showed the relation between speech and emotion and how they are processed in our brain. In psychology, research on speech emotion is less developed than in speech processing technology. However, the evidence from psychophysical experiments is strong enough to model human speech emotion speech perception. For instance, it is believed that semantic and vocal are processed independently via a verbal channel and a vocal channel. This knowledge from psychological research is used to build a computer model to recognize human emotion, particularly for predicting valence, arousal, and dominance.

< 研究の概要（つづき） > (continued from previous page)

Motivated by this psychological evidence, a late-fusion dimensional SER from acoustic and linguistic information is proposed. The proposed late-fusion approach is two-stage processing. First, each feature set is trained independently to predict valence, arousal, and dominance by using a long-short term memory network (LSTM). This model represents vocal and verbal channels in the psychological approach. Second, a support vector machine (SVM) is utilized to decide the final prediction of valence, arousal, and dominance from the previous results using LSTM, from both acoustic and linguistic/text networks. The difference in this approach from the previous early-fusion approach will be discussed in the dissertation, as well as its results. In a brief, an improvement of using two-stage late fusion approach is observed over early-fusion approach.

In sum, several issues in dimensional speech emotion recognition is being studied. Several methods has been developed and the improved version of these methods are being crafted. The current results shows that the concept used in this research, by fusing acoustic and linguistic information for dimensional emotion prediction, works well. This research not only contributes to acoustic-linguistic dimensional emotion prediction but also in acoustic-only emotion recognition. In acoustic-only SER, a generalization of high level features is presented, as well as the contribution of silence and aggregation of acoustic features. In combining acoustic and linguistic information, two different methods are proposed and evaluated. The results shows potential advantage of the proposed methods to advance speech-based emotion recognition technology, particularly on dimensional SER.

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  5. Summary
5. Conclusions
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  - 2) Future work

# <研究業績> Publication List

## Domestic Conferences (unreviewed):

1. Reda Elbarougy, B.T. Atmaja, Masato Akagi, "Continuous Tracking of Emotional State from Speech Based on Emotion Unit", ASJ Autumn Meeting, Oita, 2018.
2. Atmaja, B.T., Arifianto, D., Akhmad, F., Akagi, M., 2019. "Speech recognition on Indonesian language by using time delay neural network." ASJ Spring Meeting, Tokyo, pp 1291-1294.
3. Atmaja, B.T., Elbarougy, R., Akagi, M., 2019. "RNN-based Dimensional Speech Emotion Recognition," in: ASJ Autumn Meeting, Shiga, pp. 743-744.
4. Bagus Tris Atmaja and Masato Akagi, "Dimensional Speech Emotion Recognition from Speech and Text Features using MTL," in: ASJ Spring Meeting 2020, Saitama, pp. 1003-1004.

## International Conferences (reviewed):

1. Atmaja, Bagus Tris, Kiyooki Shirai, and Masato Akagi, "Deep Learning-based Categorical and Dimensional Emotion Recognition for Written and Spoken Text", In *2019 International Seminar on Science and Technology (ISST)*, Surabaya, 2019.
2. Atmaja, Bagus Tris, and Masato Akagi. "Speech Emotion Recognition Based on Speech Segment Using LSTM with Attention Model." In *2019 IEEE International Conference on Signals and Systems (ICSigSys)*, pp. 40-44. IEEE, 2019.
3. Atmaja, Bagus Tris, Kiyooki Shirai, and Masato Akagi. "Speech Emotion Recognition Using Speech Feature and Word Embedding." In *2019 Asia-Pacific Signal and Information Processing Association Annual Summit and Conference (APSIPA ASC)*, pp. 519-523. IEEE, 2019.
4. Atmaja, Bagus Tris, and Masato Akagi. "Multitask Learning and Multistage Fusion for Dimensional Audiovisual Emotion Recognition." In *ICASSP 2020-2020 IEEE International Conference on Acoustics, Speech and Signal Processing (ICASSP)*, pp. 4482-4486. IEEE, 2020.
5. Atmaja, B.T., Akagi, M. "The Effect of Silence Feature in Dimensional Speech Emotion Recognition." Proc. 10th International Conference on Speech Prosody 2020, 26-30, DOI: 10.21437/SpeechProsody.2020-6.

## Journals (reviewed):

1. Atmaja, B.T., Akagi, M. (2020). Dimensional speech emotion recognition from speech features and word embeddings by using multitask learning. *APSIPA Transaction on Signal and Information Processing*, vol. 9, e17. DOI: <https://doi.org/10.1017/ATSIP.2020.14>
2. Reda Elbarougy, Bagus Tris Atmaja, Masato Akagi (2020). "Continuous Audiovisual Emotion Recognition Using Feature Selection and LSTM", *Journal of Signal Processing* (accepted/to appear).

## <現在の単位修得状況> Courses I have obtained credits

	発展科目 Intermediate	先端科目 Advanced	その他 Others	合計 Total	必修 B 科目(S50x) Required Courses
科目数 Number of courses	6	3	3	12	S503 <input type="checkbox"/> S501 / S502
単位数 Number of credits	11	6	6	23	