A privacy-preserving technique to identify the useful content of documents owned by multiple institutes: Supplemental File

Rina Kagawa[0000−0002−0482−5179], Akira Imakura[0000−0003−4994−2499], and Masaki Matsubara[0000−0003−1950−683X]

University of Tsukuba, Tsukuba, Japan
kagawa-r@md.tsukuba.ac.jp

1 Empirical Experiments

The proposed method was demonstrated with textual feedback documents of musical performances for amateur players written by professional teachers in multiple music schools. Using the proposed method, features (content) that significantly increased the usefulness of the feedback documents were selected. The experiments assume a situation in which the original documents and corresponding research data owned by each school cannot be shared.

1.1 Preprocessing of the Feedback Documents

Feedback Documents Our empirical experiments used the published feedback documents[1] of musical performance written in many schools. This dataset consists of feedback documents written in Japanese on three types of musical instruments: 144 documents for piano in 24 schools (6 documents per school), 252 documents for guitar in 13 schools (19 or 20 documents per school), and 239 documents for oboe in 12 schools (19 or 20 documents per school).

Annotation Each document was annotated for both explanatory and objective variables, which will be used in the experiments. Participants were recruited via a crowdsourcing platform[2] and different participants were recruited for each questionnaire and each musical instrument.

Explanatory variables. To identify features (content) that significantly increased the usefulness of the feedback documents, what kind of content and how much of it is described in the feedback documents were annotated. This research referred to Music Teacher's Ontology [1] and the following 18 types of features were the subjects of our empirical experiments: *tempo*, *rhythm*, *metre*, *dynamics*, *note value*, *playing method*, *timbre*, *tone*, *articulation*, *music theory*, *musical*

[1] **piano:** https://zenodo.org/record/7753365, **guitar:** https://zenodo.org/record/7778923, and **oboe:** https://zenodo.org/record/4964997

[2] https://www.lancers.jp/

cohesion, *fingering*, *posture*, *pedal* (for piano)/*reed* (for oboe)/*nail* (for guitar), *difficulties*, *expression*, *breathing*, and *others*.

For each document, the number of sentences meaning each of these 18 types of features was annotated. We recruited 230 (60 for piano, 80 for oboe, and 90 for guitar) participants who had music lessons in club activities. For each sentence in each document, participants selected several features that they thought the sentence meant, from the 18 types of features. Sentence breaks were periods or exclamation marks. Each participant responded to all sentences of 25 (for piano), 30 (for oboe), and 30 (for guitar) randomly selected document. The average number of sentences meaning for each feature in each document was used as an explanatory variable for each document.

Objective variables. The usefulness of each document was rated. Since there is no widely accepted measure of the usefulness of a document, the aggregated opinions of amateur players were used as the usefulness of the documents.

We recruited 100 (for piano), 200 (for oboe), and 100 (for guitar) participants who were amateur music players[3] and asked them to answer the question "Do you think that this document is useful for your future performances?" with an 11-point Likert scale (10: useful–0: useless), and the average value for each feedback document was used as the usefulness (i.e., objective variable) for the document. Each participant responded to 46 (for piano), 50 (for oboe), and 100 (for guitar) randomly selected documents.

1.2 Methods

Using the number of sentences meaning each of the 18 types of features (explanatory variables) and the usefulness (objective variables) of the documents, we identified features (content) that significantly increased the usefulness of the documents, from 18 types of features based on multiple regression. The analyses were conducted using the following three different methods and the results were compared.

Centralized analysis. All original research data (explanatory and objective variables) distributed to each school were centralized. Multiple regression was conducted on the centralized data.

Local analysis. Multiple regression was performed using only the local dataset. That is, the analysis was performed in each local party without centralizing original research data distributed to each school.

Proposed method. Our proposed method was used for the task. That is, the original research data were transformed to the intermediate representations by dimensionality reduction, the intermediate representations were centralized, our proposed method was applied to the centralized intermediate representations, and each school obtained the model parameters and corresponding statistics of multiple regression.

[3] Participants had taken lessons outside of school classes.

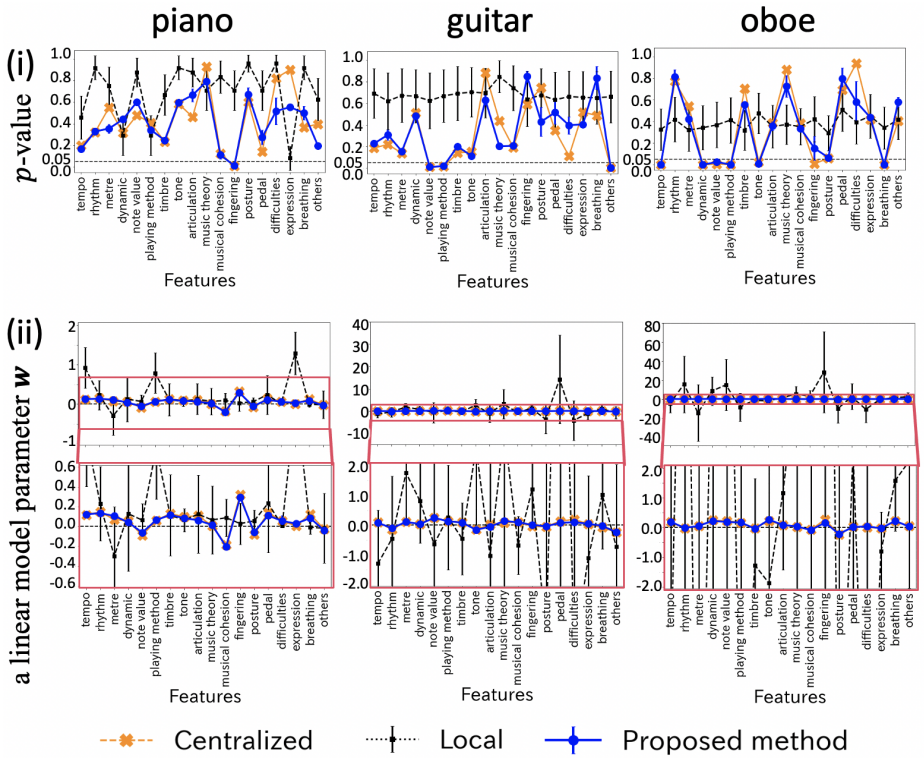

Fig. 1. Results of (i) p-value and (ii) $\boldsymbol{w}$. **Remark:** *The proposed method (blue) estimated almost the same p-values and* $\boldsymbol{w}$ *values for almost all features as the Centralized analysis (orange), while the Local analysis (black) did not.* **Note:** The lower figures in (ii) are the expanded views of the area squared by the red lines in the corresponding upper figures in (ii) to make the results more visible to the readers.

To discuss the differences in results between musical instruments from a musical perspective, the three types of analyses were performed for each of the three instruments. All the experiments were performed on Windows 10 Pro, 11th Gen Intel(R) Core(TM) i7-1185G7 @ 3.00GHz, 32GB RAM using MATLAB2022b[4].

1.3 Results

Performance of the proposed method. Fig. 1 shows (i) p-value and (ii) $\boldsymbol{w}$ of each of the 18 features estimated for each musical instrument by each of the three methods.

The following 10 features with small p-values (≤ 0.05) were obtained using the proposed method (Fig. 1(i)).

Piano: *fingering*

[4] Program codes are available from the corresponding author upon reasonable request.

Guitar: *note value*, *playing method*, and *others*
Oboe: *tempo*, *dynamics*, *note value*, *playing method*, *tone*, and *breathing*

As shown in Fig. 1(i), all of these 10 features had small p-values (≤ 0.05) calculated by the Centralized analysis. On the other hand, the Local analysis failed to estimate small p-values (≤ 0.05) for these 10 features. Moreover, the proposed method estimated correctly yielded small p-values (≤ 0.05) for all essential features with small p-values (≤ 0.05) calculated by the Centralized analysis except *fingering* of oboe. These results indicated that the proposed method successfully found essential features with small p-values calculated by the Centralized analysis, while the Local analysis did not find any of the essential features.

As shown in Fig. 1(ii), the proposed method estimated almost the same $\boldsymbol{w}$ values for all features as the Centralized analysis, while the Local analysis did not. For the practical purpose of feature selection, it is important to determine whether $\boldsymbol{w}$ is positive or negative for each feature. The proposed method yielded the same positive and negative values as the Centralized analysis for all features, while the Local analysis did not.

From these results, we confirmed that the proposed method successfully works on the privacy-preserving feature selection of distributed data without iterative cross-institutional communications.

From a musical performance perspective. The proposed method found that *note value* and *playing method* were significantly useful for amateur players in common for guitar and oboe. Of the features with a p-value less than 0.05, only *others* for guitar had a negative $\boldsymbol{w}$ value; this result suggested that the more the feedback document contains sentences that imply content not specified in Music Teacher's Ontology [1], the less useful the feedback document is.

References

1. Yee-King, M.J., Wilmering, T., Rodriguez, M.T.L., Krivenski, M., d'Inverno, M.: Technology enhanced learning: The role of ontologies for feedback in music performance. Frontiers in Digital Humanities **5**, 29 (2019)