SIMILARITY EVALUATION OF VIOLIN DIRECTIVITY PATTERNS FOR MUSICAL INSTRUMENT RETRIEVAL

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Abstract

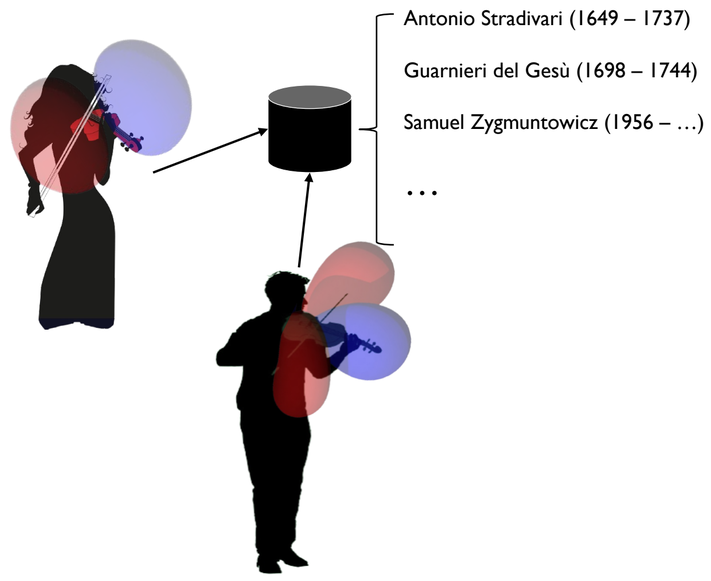
The directivity of a musical instrument is a function that describes the spatial characteristics of its sound radiation. The majority of the available literature focuses on measuring directivity patterns, with analysis mainly limited to visual inspections. Recently, some similarity metrics for directivity patterns have been introduced, yet their application has not been fully addressed. In this work, we introduce the problem of musical instrument retrieval based on the directivity pattern features. We aim to exploit the available similarity metrics for directivity patterns in order to determine distances between instruments. We apply the methodology to a data set of violin directivities, including historical and modern high-quality instruments. Results show that the methodology facilitates the comparison of musical instruments and the navigation of databases of directivity patterns.

1. Problem Formulation

Increasing interest in modeling source directivity
- Spatial audio
- Dataset availability
- Musical instruments studies

Directivity comparison is an open problem:
- Visual inspection
- Simple metrics

Directivity of sound source:
Function describing the directional dependent sound propagation of a source



How can we compare different different directivities?

2. Proposed Similarity Distances

JACCARD SIMILARITY DISTANCE (JSD) [1]

$$\mathrm{JSD}_{j,k}(\omega) = 1 - \frac{\left|\overline{\mathcal{D}}_j(\omega) \cap \overline{\mathcal{D}}_k(\omega)\right|}{\left|\overline{\mathcal{D}}_j(\omega) \cup \overline{\mathcal{D}}_k(\omega)\right|}$$

CENTER OF MASS DISTANCE (CMD) [1]

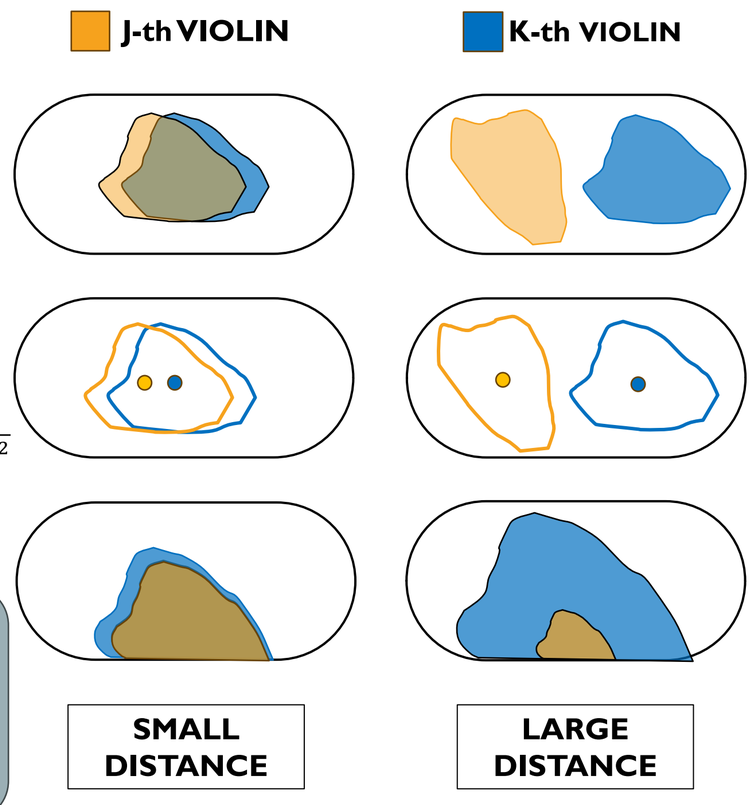
$$\mathrm{CMD}_{j,k}(\omega) = \tan^{-1}\left(\frac{\boldsymbol{r}_j(\omega) \times \boldsymbol{r}_k(\omega)}{\boldsymbol{r}_j(\omega) \cdot \boldsymbol{r}_k(\omega)}\right)$$

DIRECTIVITY INDEX DISTANCE (DID)

$$\mathrm{DID}_{j,k}(\omega) = \sqrt{\left(\frac{1}{\iint \mathcal{D}_j(\phi,\theta,\omega)\,d\phi d\theta} - \frac{1}{\iint \mathcal{D}_k(\phi,\theta,\omega)\,d\phi d\theta}\right)^2}$$

DIRECTIVITY PATTERN DISTANCE (DPD)

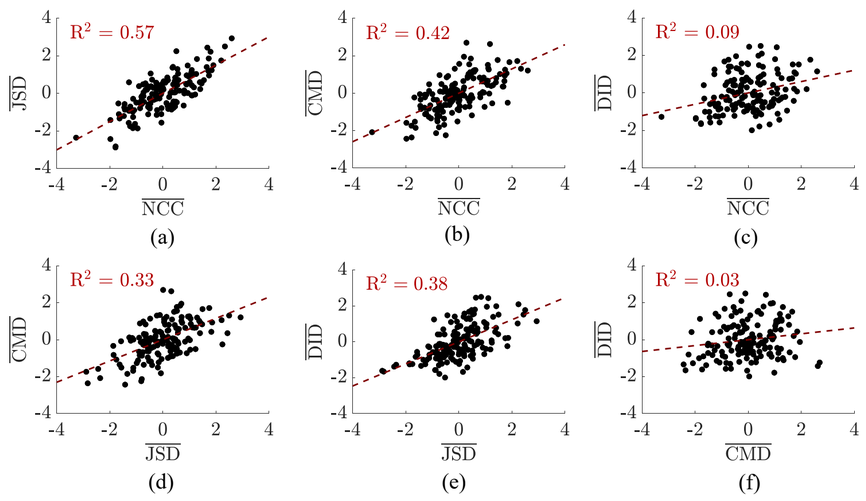
$$\mathrm{DPD}_{j,k} = \langle \mathrm{JSD}_{j,k} \rangle + \frac{\langle \mathrm{CMD}_{j,k} \rangle}{\max\langle \mathrm{CMD} \rangle} + \frac{\langle \mathrm{DID}_{j,k} \rangle}{\max\langle \mathrm{DID} \rangle}$$



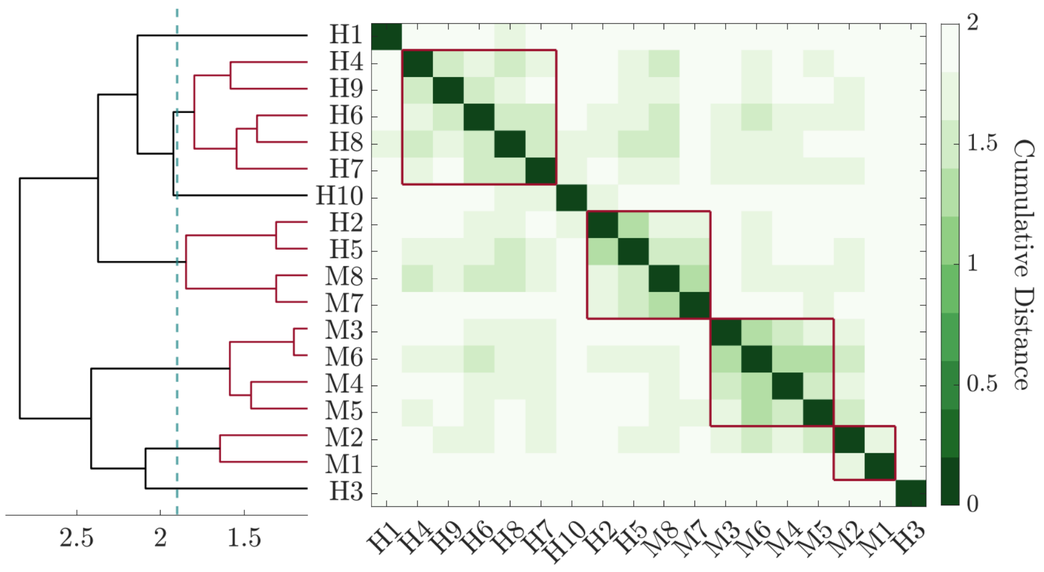
3. Metrics analysis

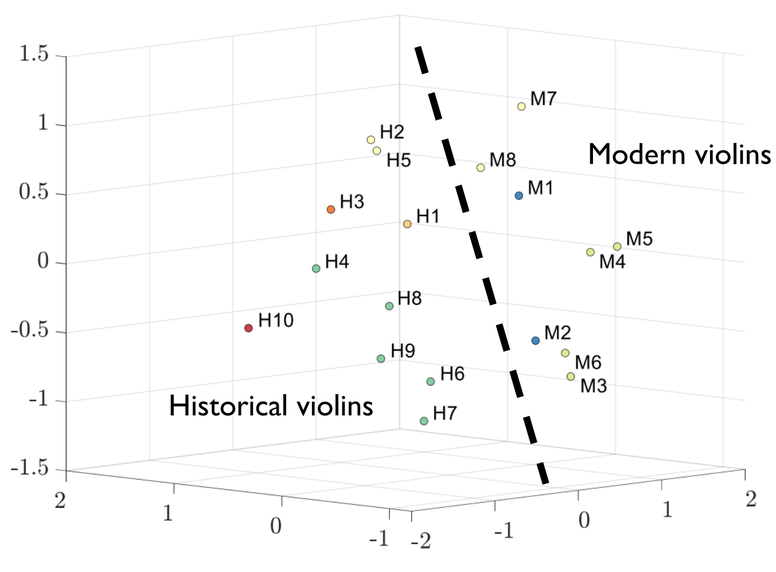
TEST DATA SET

Eighteen violin directivities experimentally collected as in [2]
- Ten historical violins (H1 – H10)
- Six contemporary high-quality violins (M1 – M6)
- Two identical violins made by the same maker (M7 – M8)



4. Results





- ✓ JSD, CMD and DID provide mutually uncorrelated information about directivity similarity
- ✓ Clustering based on DPD enables distinction between historical and modern violins
- ✓ MultiDimensional Scaling based on DPD allows the navigation of datasets

References

[1] M. Pezzoli, A. Canclini, F. Antonacci and A. Sarti. "A comparative analysis of the directional sound radiation of historical violins". The Journal of the Acoustical Society of America, vol. 152, no. 1, pp. 354–367, 2022.

[2] A. Canclini, F. Antonacci, S. Tubaro and A. Sarti. "A methodology for the robust estimation of the radiation pattern of acoustic sources". IEEE/ACM Transactions on Audio Speech and Language Processing, 28, art. no. 8889429, pp. 211-224, 2020.

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