MODELING PERCEPTUAL LOUDNESS OF PIANO TONE: THEORY AND APPLICATIONS

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Problem Statement

Imagine I have the MIDI file that is transcribed from Lang Lang's performance at the Carnegie Hall. Am I able to enjoy the same quality of performance by directly playing that MIDI file on my player piano at home?

The answer is NO! Even the same piano may produce different piano tone loudness controlled by the same MIDI note, since the acoustic features of the environment are different.

Is there a way to create a mapping of the MIDI control and its corresponding piano behavior between two different environments?

Key Ideas

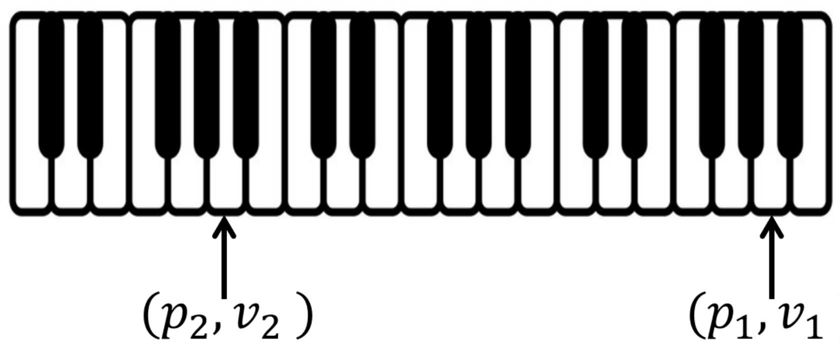
- Measured the first piano-tone equal loudness contour of pitches from two different environments through psychoacoustic experiments
- Proposed a data-driven machine learning model that is capable of inferring piano tone loudness purely from spectral features

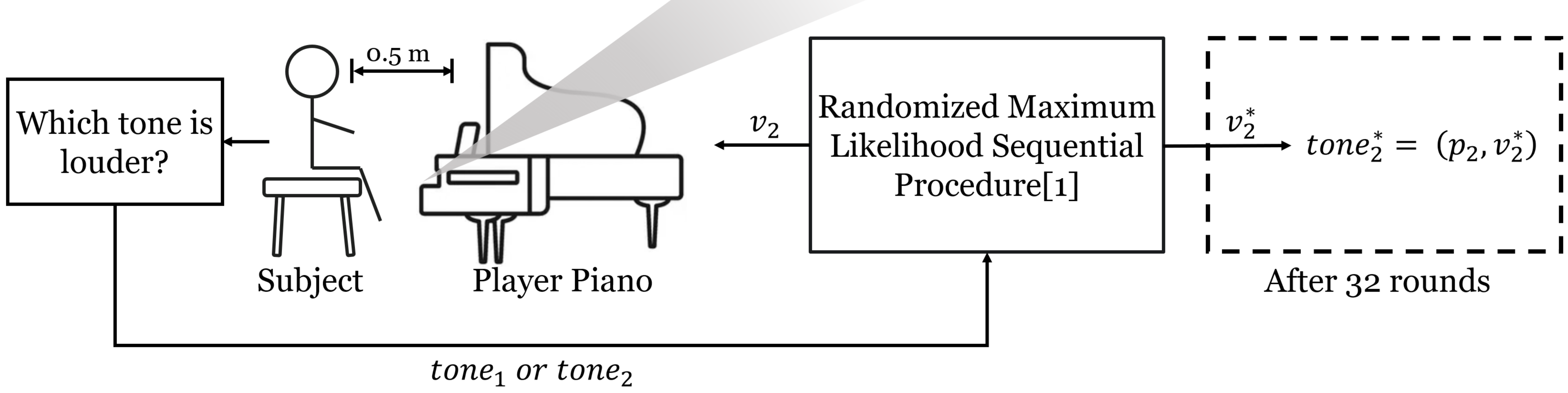
Piano-Tone Equal Loudness Contour

Reference $tone_1$: (pitch, velocity) = (p_1, v_1) (fixed)

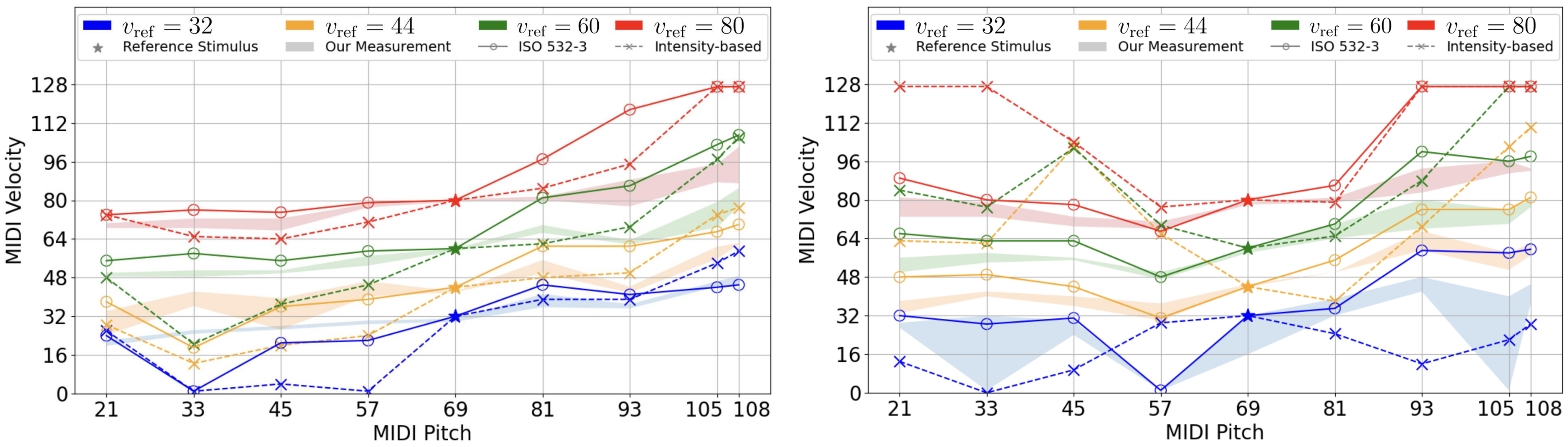
Variable $tone_2$: (pitch, velocity) = (p_2, v_2)

Goal: find $v_2^* = \underset{v_2}{\operatorname{argmin}} |loudness(tone_1) - loudness(tone_2)|$





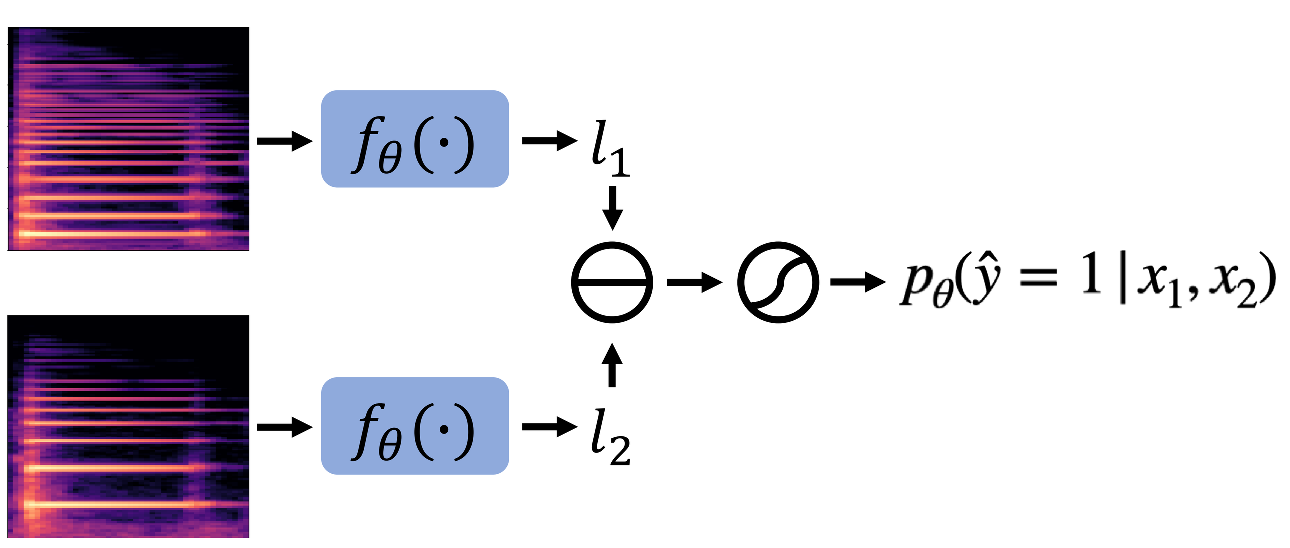
Schematic diagram of the experiment setting



Measurement results in ***two environments*** compared with baseline methods

Loudness Model

Parametric Method



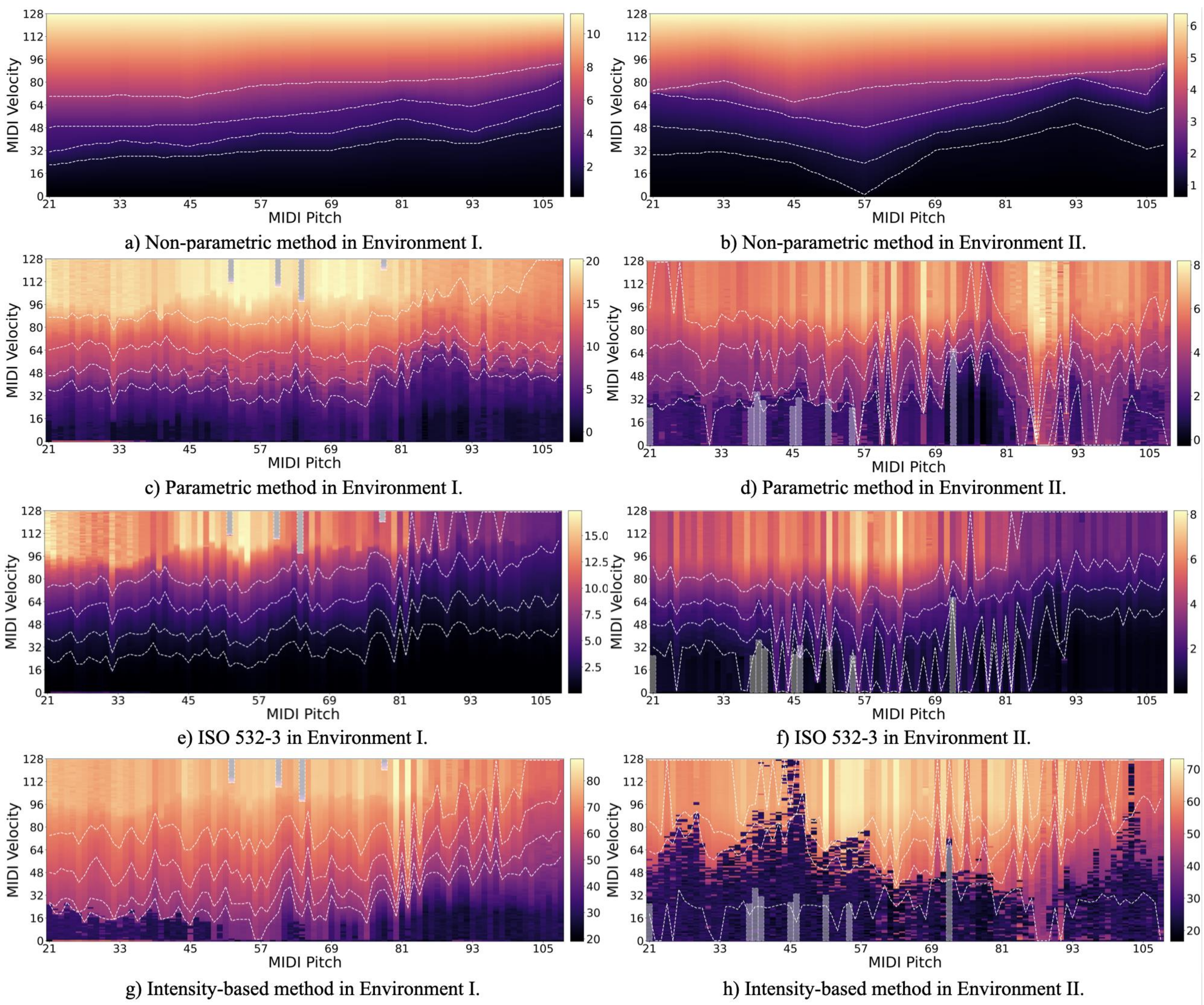
Models in Comparison

- **ISO 532-3** [2]: SOTA loudness model based on the modeling of human auditory systems.
- **Intensity-based** [3]: computing the average intensity of the first 10 ms after the peak.
- **PM**: Our proposed parametric method
- **Hybrid PM**: Our proposed parametric method trained in both environments

Objective Evaluation

Methods	Acc. in Env. I		Acc. in Env. II	
	C.1	C.2	C.1	C.2
ISO 532-3	**0.9689**	0.9631	0.9037	0.9455
Intensity-based	0.9658	0.9290	0.8377	0.8555
PM - Env. I	**0.9689**	**0.9893**	<u>0.8976</u>	<u>0.9614</u>
PM - Env. II	<u>0.9528</u>	<u>0.9607</u>	0.9121	0.9793
Hybrid PM	0.9401	0.9785	**0.9370**	**0.9881**

Visualization



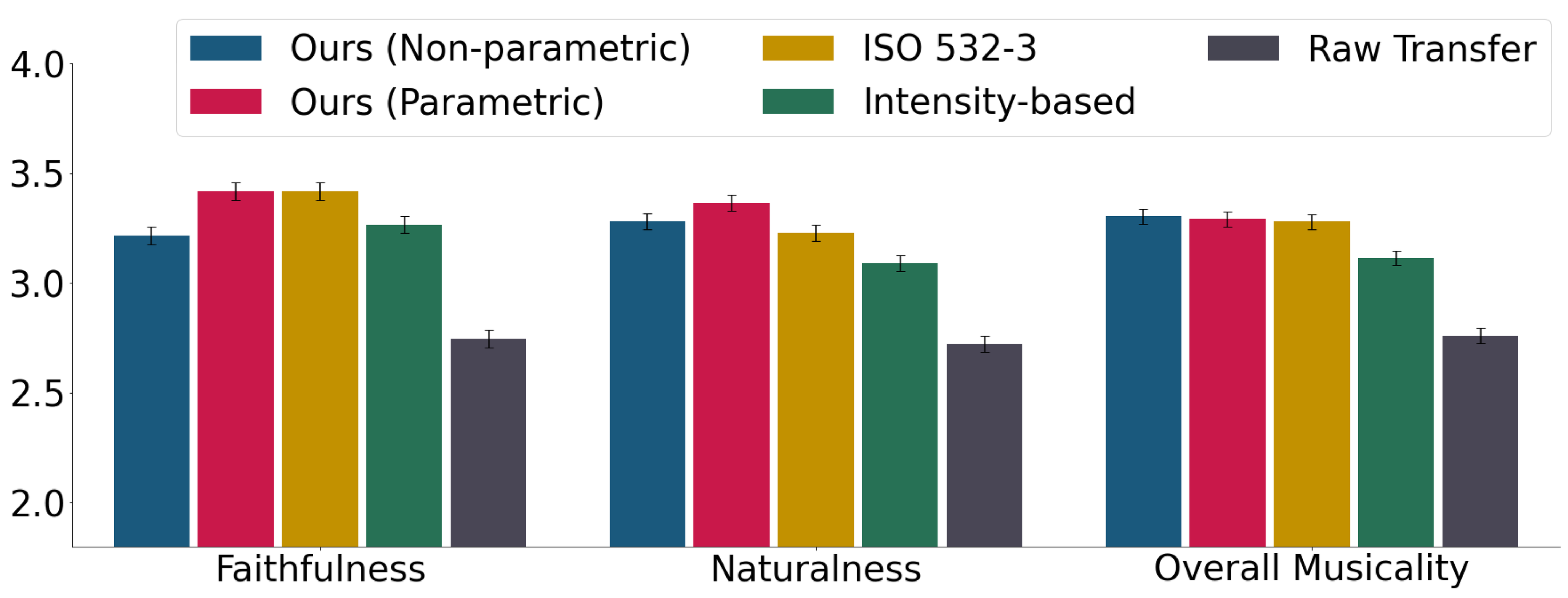
a) Non-parametric method in Environment I. b) Non-parametric method in Environment II.

c) Parametric method in Environment I. d) Parametric method in Environment II.

e) ISO 532-3 in Environment I. f) ISO 532-3 in Environment II.

g) Intensity-based method in Environment I. h) Intensity-based method in Environment II.

Performance Control Transfer



Environment Setting

ID	Environment	
	Instrument	Acoustic environment
Env. I	Grand Disklavier	Anechoic chamber
Env. II	Upright Disklavier	Non-anechoic chamber

Resources

Code · Paper · Recordings

Selected References

[1] Takeshima H, Suzuki Y, Fujii H, Kumagai M, Ashihara K, Fujimori T, Sone T. Equal-loudness contours measured by the randomized maximum likelihood sequential procedure. Acta Acustica united with Acustica. 2001 May 1;87(3):389-99.

[2] “Acoustics — Methods for calculating loudness — Part 3: Moore-Glasberg-Schlittenlacher method,” International Organization for Standardization, Geneva, CH, Standard, 2017.

[3] M. Xu, Z. Wang, and G. G. Xia, “Transferring piano performance control across environments,” in ICASSP 2019-2019 IEEE International Conference on Acoustics, Speech and Signal Processing (ICASSP). IEEE, 2019, pp. 221–225.