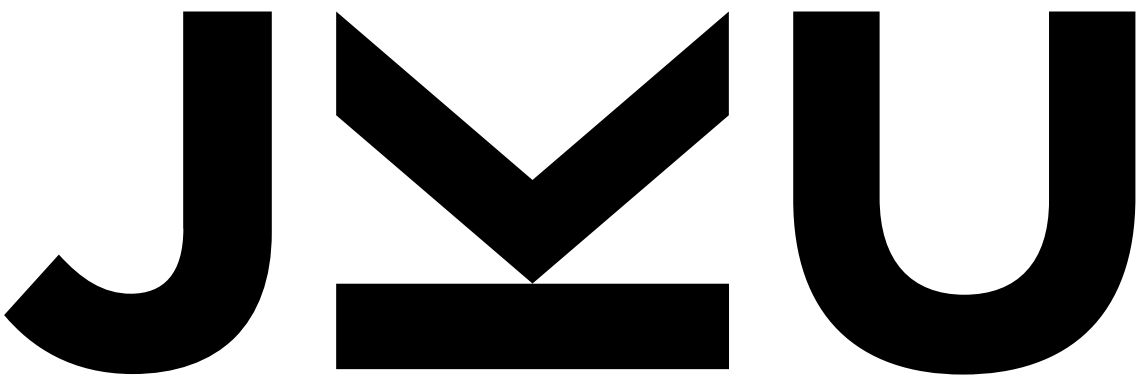

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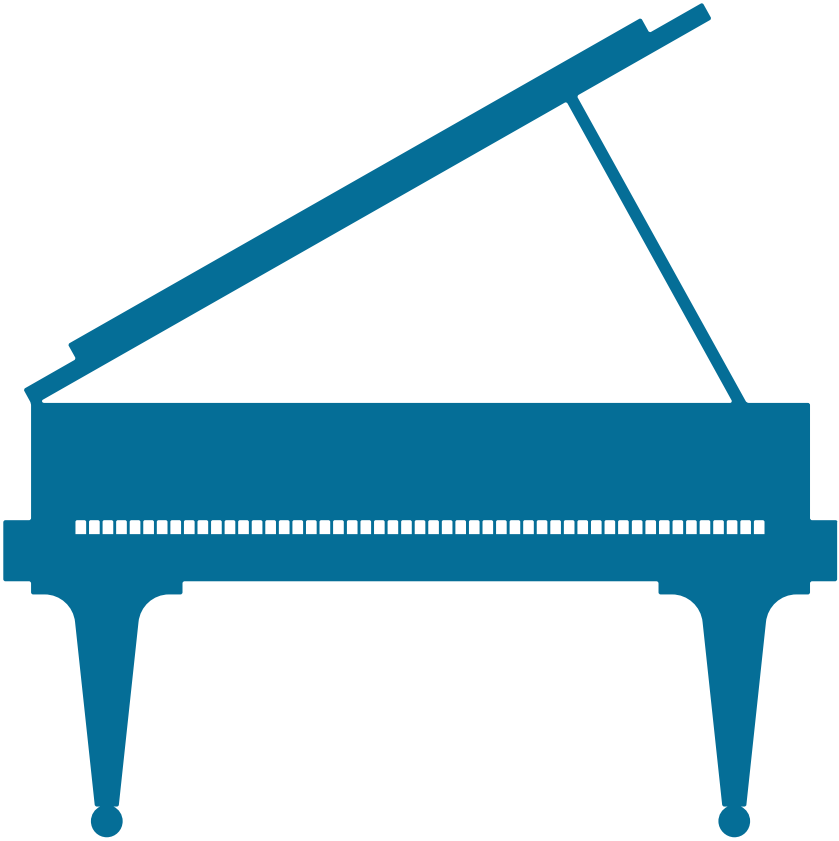


How do Performance Features relate to Expressive Dimensions?

- **Multiple Linear Regression** to test the position of the pieces (their centroid) in the expressive character dimensions using the following **Performance Features**:

Performance Parameters

tempo, loudness

Mid-level Features

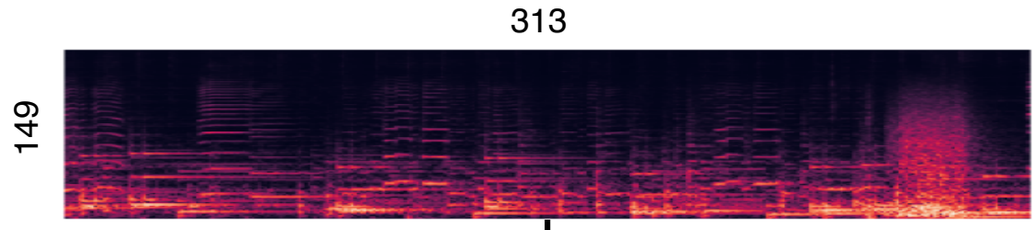
- From [Aljanaki and Soleymani, 2018]: *melodiousness, articulation, rhythmic complexity, rhythmic stability, dissonance, tonal stability, minorness*

- extracted from spectrograms using a CNN from [Chowdhury et al., 2019]

High-level Features

- 2D emotion space: *arousal and valence*

- Predicted using a CNN + GRU



Conv (5, stride-2, pad-2) -- 64 -- BN -- ReLU

Conv (3, stride-1, pad-1) -- 64 -- BN -- ReLU

MaxPool (2) + Dropout (0.3)

Conv (3, stride-1, pad-1) -- 128 -- BN -- ReLU

Conv (3, stride-1, pad-1) -- 128 -- BN -- ReLU

MaxPool (2) + Dropout (0.3)

Conv (3, stride-1, pad-1) -- 256 -- BN -- ReLU

Conv (3, stride-1, pad-1) -- 256 -- BN -- ReLU

Conv (3, stride-1, pad-1) -- 384 -- BN -- ReLU

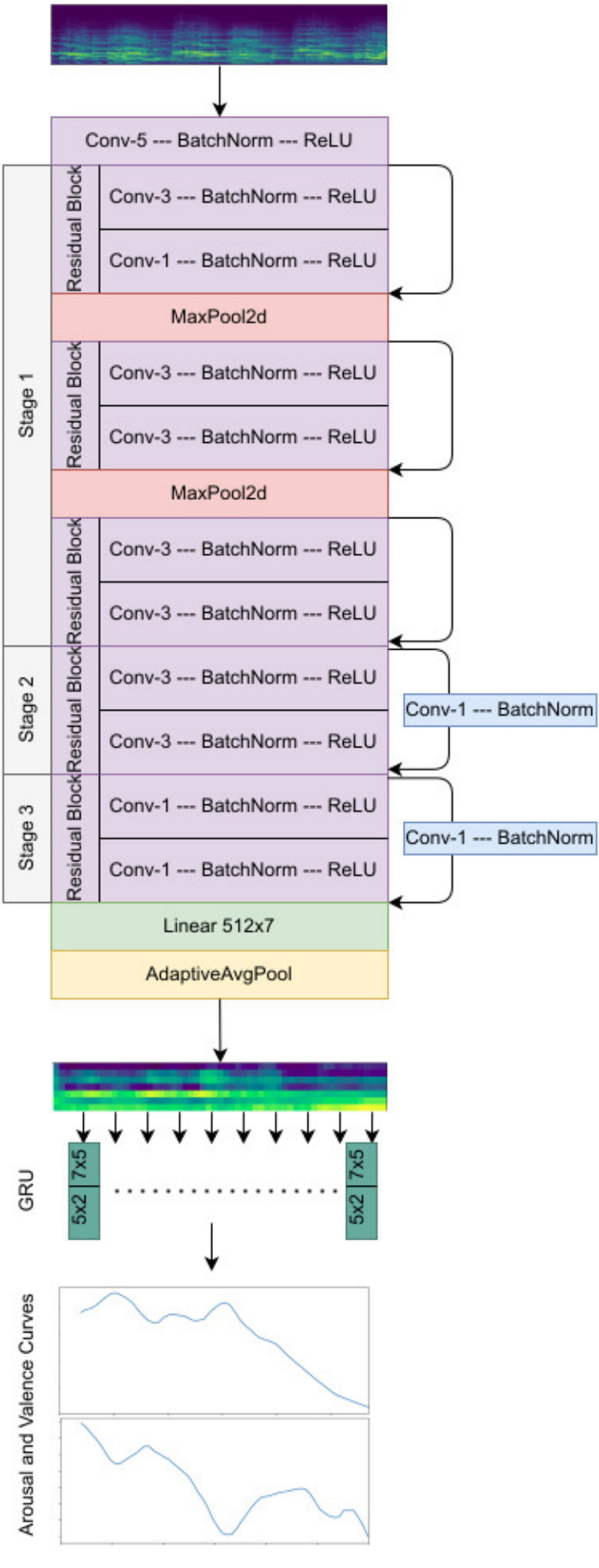
Conv (3, stride-1, pad-1) -- 512 -- BN -- ReLU

Conv (3, stride-1, pad-0) -- 256 -- BN -- ReLU

Adaptive Average Pooling 2D (1,1)

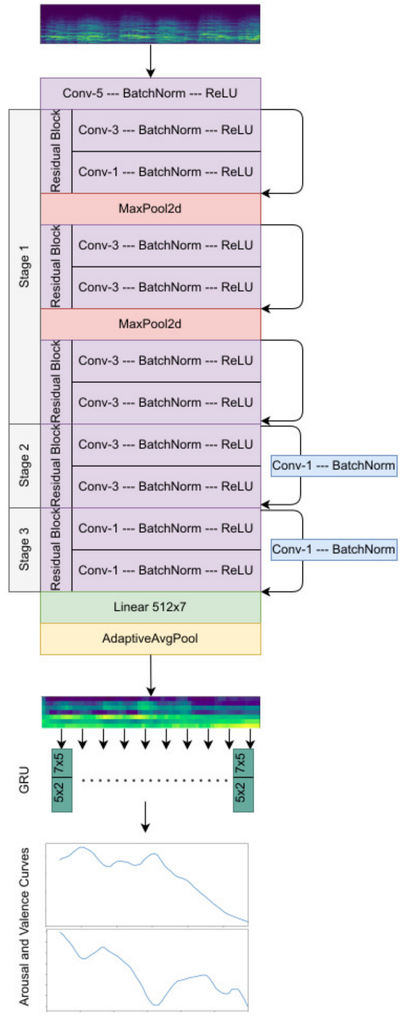
Linear (256x7)

Mid-level features


Conv-5 --- BatchNorm --- ReLU
Stage 1
Residual Block
Conv-3 --- BatchNorm --- ReLU
Conv-1 --- BatchNorm --- ReLU
MaxPool2d
Residual Block
Conv-3 --- BatchNorm --- ReLU
Conv-3 --- BatchNorm --- ReLU
MaxPool2d
Residual Block
Conv-3 --- BatchNorm --- ReLU
Conv-3 --- BatchNorm --- ReLU
Stage 2
Residual Block
Conv-3 --- BatchNorm --- ReLU
Conv-3 --- BatchNorm --- ReLU
Conv-1 --- BatchNorm
Stage 3
Residual Block
Conv-1 --- BatchNorm --- ReLU
Conv-1 --- BatchNorm --- ReLU
Conv-1 --- BatchNorm
Linear 512x7
AdaptiveAvgPool
GRU
7x5
5x2
7x5
5x2
Arousal and Valence Curves

How do Performance Features relate to Expressive Dimensions?

- **Multiple Linear Regression** to test the position of the pieces (their centroid) in the expressive character dimensions using the following **Performance Features:**
  - **Performance Parameters**
    - *tempo, loudness*
  - **Mid-level Features**
    - From [Aljanaki and Soleymani, 2018]: *melodiousness, articulation, rhythmic complexity, rhythmic stability, dissonance, tonal stability, minorness*
    - extracted from spectrograms using a CNN from [Chowdhury et al., 2019]
  - **High-level Features**
    - 2D emotion space: *arousal and valence*
    - Predicted using a CNN + GRU



Sorting Musical Expression: Characterization of Descriptions of Expressive Piano Performances

Carlos Cancino-Chacón[1,4], Silvan Peter[1], Shreyan Chowdhury[1], Anna Aljanaki[2] and Gerhard Widmer[1,3]

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[2]Institute of Computer Science, University of Tartu, Estonia
[2]LIT AI Lab, Linz Institute of Technology, Linz, Austria
[4]RITMO Centre for Interdisciplinary Studies in Rhythm, Time and Motion, University of Oslo, Norway

The *Con Espressione* Game

Research Aims: Find the dimensions of musical expression that can be attributed to a performance, as perceived and described in natural language by listeners

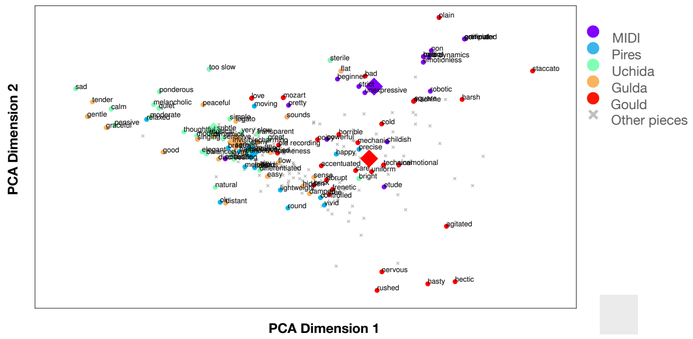
- Web based questionnaire: verbal descriptors of expressive performance.
- Different performances of 9 classical piano pieces (45 performances)
- Dataset enriched with score-to-performance alignments

Composer	Piece	#	Pianists
Bach	Prelude No.1 in C, BWV 846 (WTC I)	7	Gieseking, Gould, Grimaud, Kempff, Richter, Stadtfeld, MIDI
Mozart	Piano Sonata K.545 C major, 2nd mvt.	5	Gould, Gulda, Pires, Uchida, MIDI deadpan
Beethoven	Piano Sonata Op.27 No.2 C# minor, 1st mvt.	6	Casadesus, Lazić, Lim, Gulda, Schiff, Schirmer
Schumann	Arabeske Op.18 C major (excerpt 1)	4	Rubinstein, Schiff, Vorraber, Horowitz
Schumann	Arabeske Op.18 C major (excerpt 2)	4	Rubinstein, Schiff, Vorraber, Horowitz
Schumann	Kreisleriana Op.16; 3. Sehr aufgeregt (ex 1)	5	Argerich, Brendel, Horowitz, Vogt, Vorraber
Schumann	Kreisleriana Op.16; 3. Sehr aufgeregt (ex 2)	5	Argerich, Brendel, Horowitz, Vogt, Vorraber
Liszt	Bagatelle sans tonalité, S.216a	4	Bavouzet, Brendel, Katsaris, Gardon
Brahms	4 Klavierstücke Op.119, 2. Intermezzo E minor	5	Angelich, Ax, Serkin, Kempff, Vogt

What are the main dimensions for expressive character?

Principal component analysis (PCA) on the occurrence matrix of the terms and find 4 principal dimensions

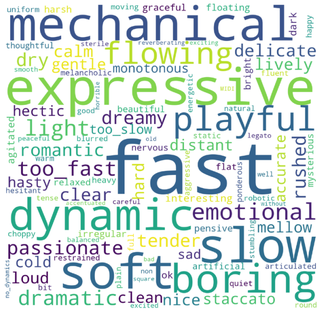
Dimension 1				Dimension 2			
positive correlation		negative correlation		positive correlation		negative correlation	
hectic	0.17	sad	-0.20	rushed	0.22	hard	-0.19
staccato	0.15	gentle	-0.18	nervous	0.20	stumbling	-0.18
hasty	0.15	tender	-0.18	too fast	0.17	staccato	-0.17
agitated	0.14	calm	-0.16	bit	0.16	ponderous	-0.14
irregular	0.14	graceful	-0.16	hasty	0.15	monotonous	-0.13
Dimension 3				**Dimension 4**			
positive correlation		negative correlation		positive correlation		negative correlation	
monotonous	0.22	heavy	-0.14	ok	0.24	cold	-0.15
bad	0.17	graceful	-0.13	happy	0.21	warm	-0.14
warm	0.16	smooth	-0.12	joyful	0.19	floating	-0.14
peaceful	0.16	ponderous	-0.12	free	0.15	blurred	-0.14
beautiful	0.15	soaring	-0.10	breathy	0.14	mysterious	-0.13

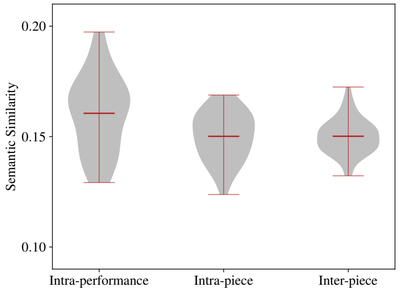


How similarly do listeners describe the performance of a piece?

Distribution of Terms

- 94 participants (on average listened to 4.5 out of 9 pieces)
- 88% had some musical training
- 1,515 individual descriptions, 3,166 terms (45% unique)





Semantic Similarity

- Semantic similarity for short sentences by [Li et al., 2007]
- **Intra-performance**: same piece, same pianist
- **Intra-piece**: same piece, other pianists
- **inter-piece**: other pieces

Pile Sorting Experiment

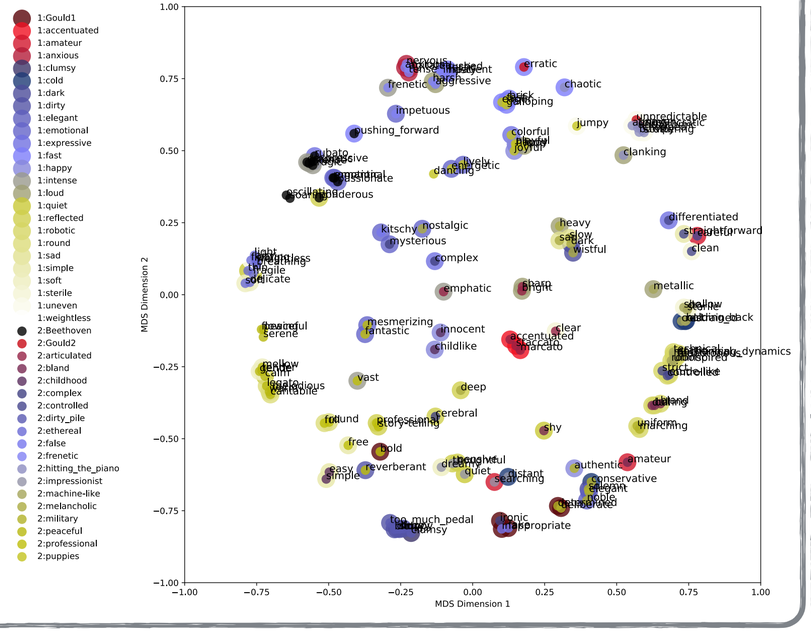
Participants

- Two groups of expert musicians (G1 and G2)
- Each group sorted (independently) 150 of the most frequently used terms that had been collected through the CEG.
- The number of piles as well as the types of similarity within the piles were left open.

Explore the interactive visualization!

Results

- G1 (25 piles), G2 (19 piles)
- Average maximal overlap (Szymkiewicz-Simpson coefficient):
  - 62 % piles G1 with piles G2
  - 65% piles G2 with piles G1
- Multidimensional Scaling (MDS) to explore the structure of the terms



Get the Dataset!

Acknowledgements

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How do Performance Features relate to Expressive Dimensions?

Dimension 1		Dimension 2		Dimension 3		Dimension 4	
PP ($R^2 = 0.24$)		PP ($R^2 = 0.18$)		PP ($R^2 = 0.26$)		PP ($R^2 = 0.24$)	
loudness avg	0.51^{***}	loudness sk	0.45^{**}	loudness std	-0.53^{**}	beat period k	-0.34^{*}
						loudness std	-0.44^{*}
MF ($R^2 = 0.39$)		MF ($R^2 = 0.00$)		MF ($R^2 = 0.00$)		MF ($R^2 = 0.29$)	
rhythmic complexity	-0.74^{*}	minorness	0.15	articulation	-0.15	rhythmic complexity	0.52^{*}
tonal stability	-0.94^{**}					tonal stability	0.84^{***}
articulation	0.46^{*}						
HF ($R^2 = 0.22$)		HF ($R^2 = 0.00$)		HF ($R^2 = 0.36$)		HF ($R^2 = 0.09$)	
valence sk	0.48^{**}	valence avg	0.14	valence k	0.42^{**}	valence k	-0.33^{*}
				arousal avg	-1.24^{***}		
				valence std	0.27^{*}		
				valence avg	-0.82^{*}