THE *CON ESPRESSIONE!* EXHIBIT: EXPLORING HUMAN-MACHINE COLLABORATION IN EXPRESSIVE PERFORMANCE

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EXTENDED ABSTRACT

Human performances of written music are not exact mechanical renderings of a score as a computer would produce: a performer does not play all the notes of a chord at the same time, nor do they keep a strict tempo; some notes start a few milliseconds earlier, or are released a bit later, some are played louder than others, etc. Each performer has their own experience, understanding of a piece, and expressive intentions. Communicating these in a performance requires control over musical parameters at many levels: from precise note-level details like articulation or micro-timing to high-level, long-term tempo and dynamics shaping.

The *Con Espressione!* Exhibit (developed as part of a research project by the same name[1]) is an interactive system designed for popular science exhibitions. It demonstrates and enables joint human–computer control of expressive performance. The exhibit allows visitors to explore the difference between a mechanical reproduction of a piece and a more "expressive" interpretation, in a collaborative setting. In a joint performance of a classical piano piece, the human user controls overall tempo and loudness via hand movements (tracked by a LeapMotion sensor[2]), while the computer provides local deviations in dynamics, timing, and articulation for each note in the score. The vertical position of the user's hand determines the trend in MIDI velocity at the current score position; left-right movements control the tempo (local beat period in beats per second) of the music. The position of the hand is displayed visually in a manner inspired by the *Performance worm* [3] (see Figure 1). The overall idea of this collaboration is that the user should control those aspects of a performance that are hard for a machine to grasp (because they require an understanding of the high-level structure of the piece), while the computer takes care of those local details that are difficult or impossible to control with simple hand movements (and would require full pianistic skills).

The computer's contribution is computed in real time by the *Basis Mixer (BM)*, a computational model of expressive piano performance [2]. It adds subtle modifications to the performance. The BM model receives symbolic score information (encoded in a numerical way via so-called basis functions) as input and uses neural networks to predict five expressive parameters, which represent the contribution of the machine to the performance [1]:

Dynamics Trend Ratio (DTR): Ratio of the maximal MIDI velocity at each score position to the trend MIDI velocity controlled by the user. A value of DTR > 1 means that the maximal MIDI velocity will be higher than the trend MIDI velocity specified by the user.

Dynamics Spread (DS): Difference in MIDI velocity for each simultaneously played note (e.g., in a chord) from the maximal MIDI velocity specified by the DTR and the trend MIDI velocity controlled by the user.

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[1] https://www.jku.at/en/institute-of-computational-perception/research/projects/con-espressione/
[2] https://www.leapmotion.com

ISMIR Late-Breaking/Demo [Unrefereed]

Figure 1. *Con Expressione!* Exhibit at the "La La Lab – The Mathematics of Music" exhibition. The hand movements are tracked with a LeapMotion sensor, enabling the user to shape overall tempo and loudness of the performance. The Basis Mixer (BM) adds more subtle performance characteristics, such as micro timing. The contribution of the BM can be controlled and experimented via a slider. The higher the value, the more freedom does the BM have in adding deviations from the prescribed parameters.

Beat Period Ratio (BPR): Ratio of the local beat period to the beat period controlled by the user. A value of BPR > 1 means that the music will be played slower than the current tempo specified by the user, while a BRP < 1 indicates a speeding up of the music.

Micro-timing (TIM): Difference (in seconds) in onset time of individual chord with respect to the chord's theoretical onset time (implied by the local beat period controlled by the user and the BPR). This permits asynchronies within a chord and effects like *melody lead*.

Articulation Ratio (ART): Ratio of the performed duration of a note to its notated duration according to the current local tempo. A value of ART > 1 means that a note will be played a bit longer than notated, while ART < 1 means it will be shortened. In musical terms, this relates to notions such as legato and staccato.

The *Con Espressione!* Exhibit was initially shown at "La La Lab – The Mathematics of Music", a science exhibition organized by IMAGINARY gGmbH and presented in the context of the Heidelberg Laureate Forum in Heidelberg, Germany.[3] The source code is publicly available on our GitHub repository.[4] The audio rendering can be created using any software synthesizer. However, since the output of our system is plain MIDI, the system can also be connected to any MIDI instrument. In particular, we have recorded a video of the system in combination with a Bösendorfer CEUS grand piano, which can be found online.[5]

ACKNOWLEDGMENTS

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[3] https://imaginary.org/exhibition/la-la-lab-the-mathematics-of-music
[4] https://github.com/IMAGINARY/con-espressione
[5] https://www.youtube.com/playlist?list=PLLHH876JYrarNFSZ3CW1eSEt-zspNX_9k