Methodologies for Expressiveness Modeling of and for Music Performance
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This paper gives a big picture overview of the basic building blocks and ideas in modeling music performance. It explores what models are, how music information can be modeled, and it presents the main strategies that are used in model development. I found this paper to be unique in its approach. Its style of making lists and categories of information reminds me of psychology and philosophy textbooks. It takes an abstract look at modeling and expression in music. This paper, combined with a review paper, would be a good introduction to the subject of music performance.

A model is said to be "employed to evidence and abstract some relations that can be hypothesized". It has both descriptive and predictive qualities. Recent developments in the areas of computer science and music technology have been beneficial to investigations in music performance and have allowed for the development of models. Models of music performance can be grouped into two categories. The first, a *complete model*, tries to explain all the observed performance deviations on the basis of the given data. The second, a *partial model*, only tries to explain what can be explained at the note level.

The case of music performance is unique in that information can be broken down into three layers. The first layer is the *physical information* that can be measured. At this level, the expressive parameters considered are related to timing of musical events and tempo, dynamics, and articulation. The second layer is *symbolic information*. This layer refers to a cognitive organization of the music. It is referenced by the score and represented as a list of time events. The third and last layer is *expressive information* which refers more specifically to the emotional content of music. There are three points of contact for expressive information. They are the composer, the performer and the listener. Understanding of this layer is rather limited. Currently, the most common range of expression used is the binary 'expressive – inexpressive'. A key issue is how the model represents information. One key factor in music performance is the representation of time. There is *performance time* which refers to the actual time that can be measured during a performance and *score time* which refers to the position in the score. Another aspect of time representation is *tempo* which is the reciprocal of durations as a function of score position. Music performance is complex and any successful model must take the above characteristics into consideration.

There are several model structures that are explored in this paper. The first employs a strategy of assuming that the partial results computed by sub-models can be added to obtain the final result. A more complex approach is the nonlinear combination of the sources in which the interrelations of inputs can be taken into account. Another approach uses the output of one model as the input into another one. In hierarchical models information is process and combined at different levels. The composed models are built by several components.

Using the above model structures, music performance models may be of two kinds. The first kind is models of understanding or analysis. Some strategies for developing the structure of these models are laid out. The first strategy, *analysis-by-measurement*, is based on the analysis of deviations measured in recorded human performances. The method consists of the following stages: selection of performances, measurement of the physical properties of every note, reliability control and classification of performances, selection and analysis of the most relevant variables, and statistical analysis and development of mathematical interpretation models of the data. The second strategy is analysis-by-synthesis. The method consists of the following stages: selection of performances, measurement of the physical properties of every note, reliability control and classification of performances, selection and analysis of the most relevant

variables, statistical analysis and development of mathematical interpretation models of the data, synthesis of performances with systematic variations, judgments of synthesized version, control of the reliability of the judgments followed by classification of the listeners, study of relation between performance and experimental variables, and repetition of the procedure until the results converge. The third strategy, machine learning, tries to extract new and interesting regularities and performance principles from a large data set by using machine learning and data mining. The fourth strategy, case-based reasoning, is based on the idea of solving new problems by using similar previously solved problems. The final strategy, expression recognition, aims at extracting and recognizing expression from performances.

The second kind of music performance models is models that produce music performances. The first type of such models is for performance synthesis. The models discussed above can be also used for synthesis purposes. Such models would be used to automatically generate expression. Another type of model is used for multimedia applications. These interactive performance models convey expression by a joint action of the user and the model.