

## Methodologies for Expressiveness Modeling of and for Music Performance

---

by Giovanni De Poli  
Center of Computational Sonology,  
Department of Information Engineering,  
University of Padova, Padova, Italy

## About Giovanni De Poli

---

- Director of the Center of Computational Sonology (CSC) in University of Padova
- Research
  - algorithms for sound synthesis and analysis
  - models for expressiveness in music
  - multimedia systems and human-computer interaction
  - preservation and restoration of audio documents



## Introduction

---

- Three Elements in Music Performance:
    - Composer  
Instill, conveying messages
    - Performer  
Communicate, expressive intentions
    - Listener  
Receive, perceptual experience
- 

## What is Model

---

- To evidence and abstract relations without irrelevant things
  - To predict behaviors under certain constraints
  - To compare observations
-

## Development of Computational Models

- Groove system  
(Mathews&Moore, 1970)
  - First music application of computer
  - Real-time control
  - Editing performer's actions



The GROOVE System at the Bell Telephone Labs , c1970

## KTH Model

- Developed at the Royal Institute of Technology in Stockholm
- Rule-based performance model
- Large number of varying parameters

## Two Kinds of Models

- *Complete Model*
  - Explain all of the observed performance
  - Complex model
  - Poor insight
- *Partial Model*
  - Explain at note level
  - Small and robust rules
  - Suitable for categorical decisions (ex, play fast or slower)

## Information Processing Model

- Mathematical model
  - Described by variables and parameters
  - Variables are divided into input and output variables
- Simulation
  - Given input variables and predict output variables

### Information processing Model

- Models describe the relationship between different kinds of output variables.

### The Layers of Information

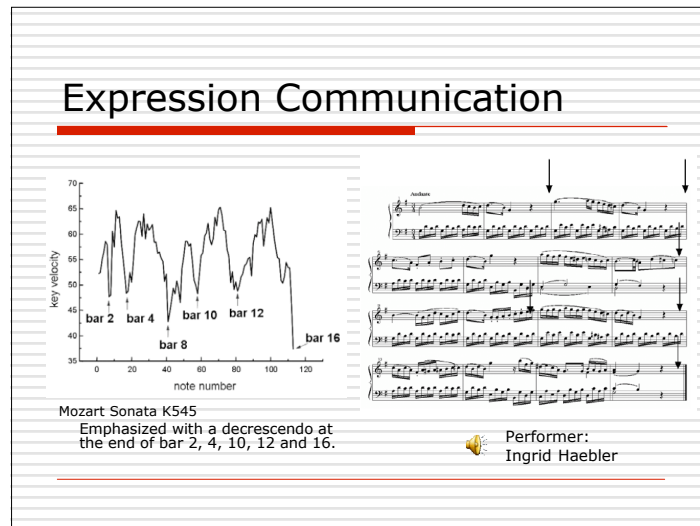
- Physical information
  - Timing and performer's movements
  - Can be measured
- Symbolic information
  - Scores, notes represented by common music notations
- Expressive information
  - Affective and emotional content

### Expressive Contents

- Composer's messages
- Expressive intentions of performer
- Listener's perceptual experience

### Expression Communication

- Finding a correct interpretation of composer's message
- Adding the personal interpretation in the performance
- No mechanical performance, which is without prosodic inflexion



### 3.1 Expression Communication

- Personal interpretation
  - Emotional performance
  - Kansei
  - Expressive intentions
  - Artistic intentions
- Bach, Goldberg Variations – 1 Aria
  - Glenn Gould 1955 (0:50) 🗣️
  - Glenn Gould 1981 (1:30) 🗣️
  - Tatiana Nikolayeva (1:25) 🗣️

### 3.1 Expressive performance parameters

- Information about describing performance and observing the variations of performance
- Physical information level
  - Keyboard – timing of the musical events, tempo, dynamics, articulations, etc.
  - Voice – vibrato, intonation
  - Timbre
  - Basic parameters of MIDI protocol

### 3.1 Expressive performance parameters

- Problem: for some effects that can be rendered in different ways
  - Emphasize a note by increasing loudness, by lengthening duration, by time shift, or by particular articulation or timbre modification
- Solution: Multi-level models
  - First level – what should be emphasize
  - Second level – how to emphasize

### 3.1

#### Expressive performance parameters

- Needing more research:
  - Intermediate parameters, using the multi-level model intuitively
  - Automatic extraction of the musical structure of a score
- Dimensional approach
  - The valence-arousal space (Juslin, 2001)

### 3.2 Information Representation

- How model represents the information
  - Time
    - Performance-time, actual time that measured in performance
    - Score-time, a phrase or a measure
    - Models aim – describe the relation between two things above
  - Tempo
    - Reciprocal duration as a function of score-time
    - Units: beats per minute (bpm)

### 3.2 Information Representation

- Mean tempo, average tempo over whole piece
- Main tempo, prevailing tempo
- Local tempo, a short-time measure, inverse of IOI  
(Repp, 1994; Gabrielsson. 1999)

### 3.2 Information Representation

- Discrete time representation
  - Articulation of timing of individual notes
  - Micropauses between melodic units
  - Related to symbolic level
- Continuous time representation
  - Vibrato of a note
  - A crescendo curve
  - Related to physical level

## 3.2 Information Representation

- Granularity
  - Numerical values, time interval or IOI
  - Categorical description, staccto vs. legato, shortening vs. lengthening
  
- Conclusion
  - Models should have different time scales, such as
    - note scale - attack time or vibrato,
    - local scale - articulation of a melodic gesture,
    - global scale - phrase crescendo

## 3.3 Expressive Deviations

- Communication between musician and listener
- Models of deviations explain where, how , and why a performer modified what is indicated by the notation in the score
- Not directly accessible but easily measurable

## 3.3 Expressive Deviations

- Reference
  - Score – theoretical and practical, but affects listener's judgment
  - Intrinsic definitions of expression - defined in terms of performance itself (Gabriellsson, 1974; Desain&Horing, 1991)
  - Non-structural approaches relating expression to motion, emotion, etc.

## 3.3 Expressive Deviations - Example

- Expressive variations of the duration of beats
  - Using bar duration as reference from the score
  - Using this intrinsic definition to describe expression from the performance data itself
  - Then taking global measurements as reference for local ones

### 3.3 Expressive Deviations - Example

- A performer plays a piece according to different expressive intentions
  - Using neutral performance, the performance without any specific expressive intention, as a reference
  - Using mean performance, the mathematical mean across different performances, as a reference

### 4.1 Model Structures

- Additivity Hypothesis
  - Measuring deviations by principal component analysis (PCA) (Repp, 1992)
  - PCA is a mathematical procedure that transform correlated variables into a smaller number of uncorrelated variables called principal components
  - 1st principal component accounts for as much of the variability as possible, and succeeding component accounts for as much of the remaining variability as possible.

### 4.1 Model Structures

- The original data are a linear combination of few significant and independent variations around their mean values.
- Pros: easily interpretable
- Cons: over-simplifying and the interrelation of different aspects of performance is hidden

### 4.1 Model Structures

- Multiplying
  - Nonlinear combination  $y=f(x_1, x_2, \dots, x_n)$  (Bresin, 1998)
  - Functional composition  $y=f[g(x)]$  (Honing, 1991)
  - Hierarchical models – the information is processed and combined at the proper level (KTH system, Bresin&Friberg, 2000)
  - Local models – acts at note level and try to explain the observed facts in a local context (Friberg, 1991; Widmer, 2002)

## 4.1 Model Structures

---

- Phrasing models – take into account higher levels of the musical structure or more abstract expression pattern
  - Composed models – built by several components (models), each one for different sources of expression
- 

## 4.2 Comparing Performances

---

- Measure of distance the mean of the absolute differences
  - Euclidean distance, square root of difference squares
  - Maximum distance
  - Conclusion: It is hard to achieve comparison. We don't have clear strategy of how to weight variables
- 

## 4.3 Models for understanding

---

- [Analysis-by-measurement](#)
  - [Analysis-by-synthesis](#)
  - [Machine learning](#)
  - Case-based reasoning
- 

### 4.3.1 Analysis by measurements

---

- Analysis of deviations measured in recorded human performances
  - Finding the regularities in the deviation patterns and describing them by means of a mathematical model
  - (Gabrielsson, 1999)
-

### 4.3.1 Analysis by measurements

#### □ Steps

- 1 - Selection of performances
- 2 - Measurement of the physical properties of every note
- 3 - Reliability control and classification of performances
- 4 - Selection and analysis of the most relevant variables
- 5 - Statistical analysis and development of mathematical interpretation models of the data

### 4.3.1 Analysis by measurements

#### □ Approaches

- Statistical models
- Mathematical models
- Multidimensional analysis, e.g., Principal Component Analysis (PCA) (Repp, 1992)

### 4.3.1 Analysis by measurements

#### □ Approximation of human performance

- Neural network techniques (Bresin, 1998)
- Fuzzy logic approach (Bresin et al., 1995a,b)
- Using multiple regression analysis algorithm (Ishikawa et al., 2000)
- Linear vector space theory (Zanon&De Poli, 2003a,b)
- Controlled experiment, manipulating one parameter in a performance (Desain et al., 2001)

[back](#)

### 4.3.2 Analysis by synthesis

#### □ Steps

- Steps 1-5 are the same as previous topic
- 6 - Synthesis of performance with systematic variations
- 7 - Judgment of synthesized versions, paying particular attention to the different experimental aspects selected
- 8 - Study of relation between performance and experimental variables
- 9 - Repetition of the procedure (steps 3-9) until the results converge

### 4.3.2 Analysis by synthesis

- Key point: only one variable is modified while imposing constant values to the others
- Example:
  - KTH rule system
  - The rule developed by De Poli et al., 1990
  - Dannenberg&Derenyi, 1998

### 4.3.2 Analysis by synthesis

- Every rule tries to predict some deviations of a human performance
  - First, the rules are obtained based on professional musicians
  - The performance produced by applying the rules are evaluated by listeners
  - Then tuning and developing the rules
- Rules can be grouped into:
  - Differential rules
  - Grouping rules, e.g., Duration Contrast rule [back](#)

### 4.3.3 Machine learning

- Searching for and discovering complex dependencies in very large data sets, without any preliminary hypothesis  
(Widmer, 1995a,b, 1996, 2000, 2003, 2004)

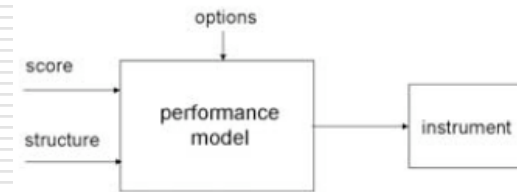
### 4.3.4 Case-based reasoning (CBR)

- Using the knowledge of previously solved problem, and adaptations of solution to the actual problem
- The system learns from experience
- Example:
  - SaxEx system (Arcos, 1998, 2001)
  - Suzuki system (1999)

#### 4.3.5 Expression recognition models

- To extract and recognize expression from a performance
- Example:
  - Dannenberg (1997) - to classify improvisational performance style among different alternatives
  - Friberg et al. (2002) recognized basic emotions in music performance
  - Zanon & Widmer (2003, 2004) try to identify famous pianists based on their style of playing

#### 4.4.1 Performance Synthesis Models



Typical structure of a performance synthesis model

#### 4.4.2 Discussion on Synthesis Models

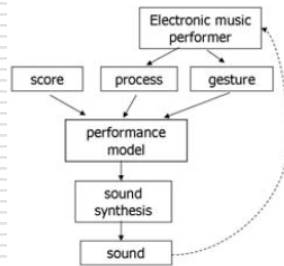
- A recording of a classical music performance is just a reproduction of an event, not an experience of the music conceived at that time
- A real artistic value is necessary, no automatic performance can be acceptable except for the entertainment purpose
- Performance models has the application for teaching, helps student to know the performance strategies

#### 4.4.3 Models for Multimedia Application

- Multimodal
  - User interacts freely through movements and non-verbal communication with machine
  - Most multimodal system is bimodal
  - Human senses are not well represented in multimodal interfaces

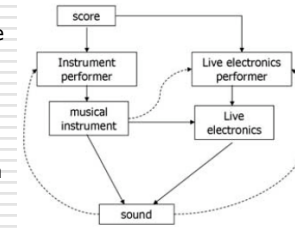
## 4.5 Models for Artistic Creation

- Scheme of music performance with digital instruments
  - Electronic instrument performer controls the sound synthesis with gestures and suitable processes
  - A performance model lies between the symbolic and the audio control level
  - The performer receives an audio feedback from the instrument as with transitional instruments



## 4.5 Models for Artistic Creation

- Scheme of live electronic music performance
  - The live electronics performer processes the sound produced by the instrument performer
  - The live electronic box, merging score processes and gestures, controls the sound processing devices via a performance model
  - The performer receives audio feedback from both the instrument and the sound processing



## Conclusion

- The knowledge gained in classical music performance studies and formalized in performance models
- The practical knowledge of new music creators in order to extract possible new performance models
- Music performance research is a joint development of art, science and technology