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# Electronic Music and Interactivity: Principles, Concepts and Applications

(MA Thesis)

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Translator's Note:

The author uses different terminologies in different contexts. In that regard whenever the term "device" is used in the translation it refers to the German *Gerät* which is device, tool and instrument. Whenever instrument occurs in the translation, instrument was the term used in the original. The term "interface" is always applied when the author uses it in the original or talks about interfacing annotations (e.g. *Schnittstelle*).

# 4. Categories of Interactivity

## 4.1 Overview

This chapter presents an analysis of two schemes of classification of interfaces [Benutzerschnittstellen] for electronic music form existing literature. Deriving form a critique of these approaches I will apply my own attempt for a classification.
The criteria of my classification will be notified and analyzed in respect of their relevance as parameters for electronic music instruments.

## 4.2 Classification

### 4.2.1 According to Joseph Paradiso

In his essay Electronic Music Interfaces [Para98] Joseph A. Paradiso outlines an abrasive categorization of Interfaces for electronic music:

- Keyboards

  All instruments that comprise any sort of keyboard. The definition ranges from the conventional Piano or Organ to the manuals of the *Trauonium*, which consists of finger pads that push onto a touch sensitive resistive strip. The number of keys is not limited to European-classical twelve-tone per octave scheme. The for microtonal music conceptualized *MicroZone* comprises 768 keys in a 8x96 honeycomb matrix and transverses conventional schemes.
- Percussion

  Controllers developed for percussive purposes. These controllers could be single drumpads or entire electronic drumkits such build by the company Simmons. It remains questionable, if instruments such as the *Radiodrum*, which can be also classified under the category of the "baton," or Laurie Anderson's *Drumsuit*, which is also categorizable as "wearable," should remain in the category of percussion.
- Batons

  This category comprises controllers that derive form the idea of the conductors baton. The instrument might consist of one or two "sticks." To me the differentiation from the category of “noncontact gesture” appears problematic.

- Guitar Interfaces

  Instruments which are modeled after the (electric) guitar or implicate MIDI-functions into such an instrument. To me the introduction of this category seems to justify itself only because of the importance of the electric guitar in pop and rock music.
- Other String Instruments

  All other string instruments beside guitars. This category varies form the sensor equipped violin to Miya Masaoka’s *Koto Monster*, a harp-like giant instrument.
- Wind-Controller

  Wind-instrument related controller are in this category. Amongst many others one can name Nye Steiner’s *EWI* and *EVI* (see 3.6.10) as well as the *Lyricon* (see 3.6.10).
- Voice

  Devices and systems which use the human voice as source for the generation of musically meaningful data. Basically these controllers are extended Pitch-Tracker, such as the at MIT developed *Singing Tree*.
- Noncontact Gesture

  This category consists of Instruments that function mostly without physical contact of interface and performer. This category varies form the classical *Theremin* to video-analysis systems such as Tom DeMeyers *BigEye* or the *Very Nervous System* by David Rockeby.
- Wearables

Music-controllers that are directly in contact with the human body like clothing. This category covers data-gloves, e.g. Yamaha’s *Miburi*, as well as experiments such as Maggie Orth’s *Musical Jacket*. Paradiso also mentions bio-electric devices that measure muscle contraction or brainwaves in this category.

Apparently this categorization reveals some insufficiencies because of interferences between the different categories: e.g. one can regard Maggie Orth's Musical Jacket as wearable but at the same time also as keyboard.

On top of the interference of categories, the question arises, why on the one hand the category of string instruments consists of two categories and on the other hand a plethora of keyboard-like instruments gets subsumed under one category.

In addition Paradiso's categorization is incomplete and does not include the important category of fader- and knob-controller, which are the predominant interface for analog modular systems.

### 4.2.2 According to Axel Mulder

Axel Mulder only a certain part of controllers in his Thesis *Design of Virtual Three-Dimensional Instruments for Sound Control*. He divides this group, which he calls *alternate controller that expand the gestural range*, into three sub-groups:

- Touch controller

  The necessity to touch a physical instrument is characteristic for this category. Although one can modify these controllers according to the users needs, larger modifications are only possible with sufficient technical knowledge and are time-demanding.

  One example would be the *aXIO* that is controlled standing and has rotary knobs, fader and keys.

- Expanded Range Controller

  These controller usually require only limited of no physical contact. Hence, the variety of control-gestures is limited. It is possible to exercise gestures without musical meaning and therefore to evade the instrument.

  Michael Waisvisz' *The Hands*, the *Radio Drum* or the *Theremin* fall under this category. With the latter for instance it is possible to step outside the sensing field or to do gestures with the hand that do not evoke any change of the sound.

- Immersive Controller

In this category there are none or almost no restrictions regarding meaningful gestures. One achieves this effect with data-gloves or data-suits. At the height of contemporary technology touch- or force-feedback cannot be guaranteed.

For Mulder the category of immersive controller unfolds into three sub-categories:

- Internal Controller

  Here the human body defines the visualizing parameter of the control-surface. The diffraction angle of joints for instance can be used as control parameter of a system.
- External Controller

  The visualization differs significantly from the human body and therefore one needs a different form of representation. There is no one-to-one relation between body-features and musical parameters.
- Symbolic Controller

  The visualization of the surface appears almost impossible due to the complexity and can only be partially displayed. Formalizations such as sign language or the conductor's gestures function as manipulation of structural aspects of the music.

Mulder approach turns out to be more systematic than Paradiso's, even though he covers only a part of the instruments covered in this thesis. In the following section I will present my own approach.

### 4.3 Attempts of an Introduction

Due to the insufficiency of the two proceeding categorizations I will outline another possible form of classification. Following Müll's idea [Müll95] I will order instruments according to some parameters in an imaginary multi-dimensional space.
The central characteristics of an electronic music instrument are:

- Immersion
- Genericity
- Intelligence of the instrument or the of the mapping[1]
- Feedback
- Expressivity

#### 4.3.1 Immersion

For the evaluation of an instrument it is interesting to look at musically meaningful control gestures. Conventional devices define a clear distinction between environment and interface such as a keyboard of strings. Only the excitement of a mechanism can create a sonorous effect. Since the invention of the *Theremin* this circumstance becomes obsolete. Not the physical manipulation but only the proximity or distance from the antenna alters the sound. Once put into the right position to the *Theremin* it is almost impossible to make meaningless gestures with your hands. The act of playing is more "incorporated" into the instrument itself as of instance with a keyboard where the player just has to lift his hands form the keys to liberate his gestures from having musical effects.
Witmer and Signer [WiSi89] define this "enveloping" or "dipping-in" that is immersion as follows:

> *A psychological state characterized by perceiving oneself to be enveloped by, included in, and interacting with an environment that provides a continuous stream stimuli and experiences.*

The advent of the dataglove enabled a mechanism that turned any kind of hand movement into musically useful data. Through the wireless transmission of data to the sound-generating part of the system, the dataglove liberated the performer from his

[1] For a definition of mapping see 4.3.3.

environment. Different form the *Theremin* the alteration of his location doe not disengage the performer from immersion. Hence, he can still exercise meaningless gestures with other body parts.

Through the extension of the dataglove into a datasuit or through motion capture video-systems or other sensors even the musician's "last" domain of freedom vanishes. Every movement becomes analyzable; the immersion is perfect.

As outlined in chapter 4.2.2 Mulder [Muld98] divides the degree of immersion into three categories: touch-controller, extended-range and immersive-controller.

In general I have applied the same categorization with an bifurcation in the last category:

- Partly Immersive Controller

  This category includes datagloves and other immersive devices, which cover only parts of the human body and allow musically irrelevant gestures.
- Fully Immersive Controller

  The whole body is captured. Irrelevant gestures are almost impossible.

### 4.3.2 Genericity

For the choice of input technologies Bill Buxton write in [BarGr95]:

> *Choosing the input technologies to be used with a workstation generally involves making a trade-off between two conflicting demands. On the one hand, each task has specialized needs that can be best addressed by a specialized technology. On the other hand, each workstation is generally used for a multitude of tasks. Supplying the optimum device for each task is generally out of the question. A trade-off must be made.*

One can transpose this insight into the realm of electronic music instruments. A wind-controller seems suitable for the control a physical modeling synthesizer. For more general task a fader box might be more appropriate that can in turn operate PM-synthesizer.

Conventional acoustic instruments have a wide spectrum of possible tomes but the the instrument's structure limits principles of sound generation. Many electronic controllers are capable to send data[2] for further processing to any sound generating device without creating sound itself. This genericity can be extended to almost infinite complexity with the help of computers and microprocessors. For instance with the help of the program MAX it is possible to program any imaginable mapping.

Such flexible systems raise the question of where to draw a distinction between Instrument and composition. A complex mapping that with the manipulation of only one knob effects a variety of manipulations or modifications in the sound synthesis could be regarded as part of the composition.

### 4.3.3 Intelligence / Mapping

Donald A. Norman writes in [Norm88]:

> *Mapping is a technical term meaning the relationship between two things, in this case between the controls and their movements and the results in the world. Consider the mapping relationships involved in steering a car. To turn the car to the right, one turns the steering wheel clockwise.*

This definition can be further narrowed in the context of music instruments [HuWa00]:

> *The word 'mapping' refers to the liaison or correspondence between control parameters (derived from performer actions) and sound synthesis parameters. This concept is illustrated in fig. 11 that represents a general computer-based musical instrument; what might be called a 'composite electronic' musical instrument.*

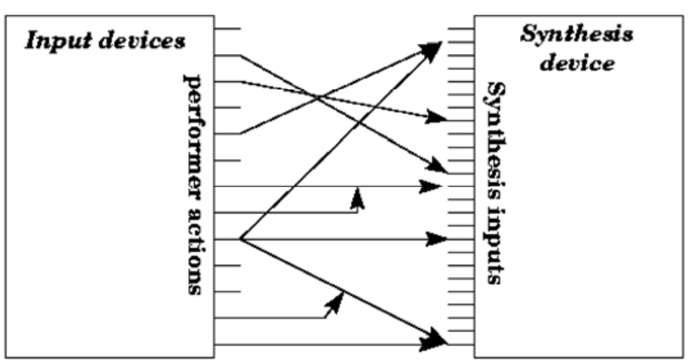


**fig. 36** ***Mapping of performer actions to synthesis parameters*** **[HuWa00]**

[2] in this case foremost MIDI-data

The relation between action and the performer’s gestures occur in different ways. A conventional and simple way would be a one-to-one-mapping. Here every manipulation of a controller alters a synthesis parameter. More complex methods for mapping gesture exist, e.g. neural networks that detect sign language and transform it into musical data.

> *Although intelligent and interface are often used in the same sentence, few user interfaces really manifest much intelligence. [...] Some interfaces, however, may appear to be intelligent, from the perspective of the user, simply by making the right response at the right time. This appearance or illusion of intelligence aids user interaction by fostering a sense of confidence or reasonableness in the interface, and can add a powerful positive quality.*

Intelligence is here similar to [Laur90] note regarded in the sense if Artificial Intelligence but as assistance to solve complexity. The user can predetermine the answer.

### 4.3.4 Feedback

In an HCI-context [Diam01] defines feedback as follows:

> *A reaction to a behavior that has the potential to influence the original behavior. In other words, when a user does something, the computer responds so that the user has some understanding of how the computer interpreted the user's action. When the user moves the mouse, the pointer moves on the screen. When the user types, the keys click. When the user selects an icon, it highlights. When the user selects a menu item, it flashes and some action takes place.*
>
> *Without responsive and relevant feedback, users question whether their actions have been recognized and understood correctly.*

Feedback is a response to the performer’s action through acoustic, visual, haptic and kinesthetic channels. In the realm of musical instruments where the production of sound is the evident aim, acoustic feedback is not possible beyond the actual sound generation. A click-sound by pushing a key seems unthinkable as long as it si not the desired sound during the performance.

Maura Sile O’Modhrain and Chris Chafe write about feedback in musical applications [OmCh00]:

*Though musicians rely primarily on their sense of hearing to monitor and adjust the sound being produced by their instrument, there exists a second path through which valuable information about the instrument's behavior can be observed - namely the feedback received via the haptic senses, the senses of touch and kinesthesia.*

Classical acoustic instruments besides their acoustic feedback also comprise haptic feedback, which is essential for mastering an instrument. The haptic channel registers both the pushing of a piano key as well as the vibration of a trombone's embouchure. Generally I regard any kind alteration of objects in a space through the performer (except the performer's itself) as haptic feedback. This includes kinesthetic action such as manipulations of the position of potentiometers or the pushing of a key. Instruments with electronic sound generation do not require any kind of this feedback and not really necessary – the mechanical pushing of a piano key could be replaced by a membrane keyboard.

For instance it is almost impossible to imagine a tacticle feedback with a *Theremin* and with datagloves tactile feedback is only possible through the use of complex exoskeleton constructions[3].

Visual feedback, which is almost inexistent with traditional instruments, becomes a replacement for haptic feedback in electronic devices. Thus, the application of datagloves usually always comprises a visual componenet that visualizes the effects of finger gestures. In general the use of software as sound and data processing compartment of the instrument supports the application of visual feedback possibilities. Display of status and data does not require anything else than standard equipment such as the computer that can be inexpensively implemented.

### 4.3.5 Expressivity

*This is for me the ultimate instrument in dealing with expressivity in electronic music -- if you move one finger, everything else moves. It's multiple controls to multiple variables in the sound ...*

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[3] see [LaSm01], [Bouz01] and [Imm01]

says Laetitia Sonami in [Elec00] about her instrument *Lady's Glove*[4] developed together with Bert Bongers. Indeed, the expressivity of an instrument is an important factor for the evaluation of an instrument. The more musical parameters a device can control, the more diverse one can play with it. Non-electroinc instruments possess a wide range of expressive nuances because one can directly mechanically manipulate the physical process of sound generation. For instance by singing through a saxophone embouchure[5] one modifies the sound; or one can play a piano not by hitting keys but by exiting the strings directly. Electronic instruments usually do not comprise this possibility[6]. Here, a distinct interface has to define the possibilities of sound manipulation.

If electronic instruments' possibilities to shape sounds seems to exceed classical instruments they at the same time appear to have less capacities for multiple simultaneously manipulable control parameters. Synthesizers such as the *MiniMoog*, that has a keyboard without aftertouch and several rotary potentiometers, does not allow manipulation for more than two control parameters at the same time, e.g. pitch and speed of an LFO.

Experienced musicians usually request more expressivity. They appreciate an instrument with a wide spectrum for expression. On the contrary a high level of expressivity describes a barrier for laypersons. Due to the fact that there might be no classical electronic music instrument except the *Theremin* almost everyone who deals with electronic instruments is a novice. Adaptive devices, similar to different levels of skillfulness in computer games, could be a feasible answer to this problem that exists for classical instruments as well but gets counter balanced by a plethora of teachers and learning material. The better a player gets the more refined the expressivity of a device becomes. Formerly correction of involuntary parameter shifts can be directly exercised without error correction in a higher level.[7]

[4] see chapter 5.6
[5] This techinque is also known as growling.
[6] If one does not take *Circuit Bending* (see chapter 3.6.9) into account.
[7] See [FeHi95]

### 4.3.6 Graphs

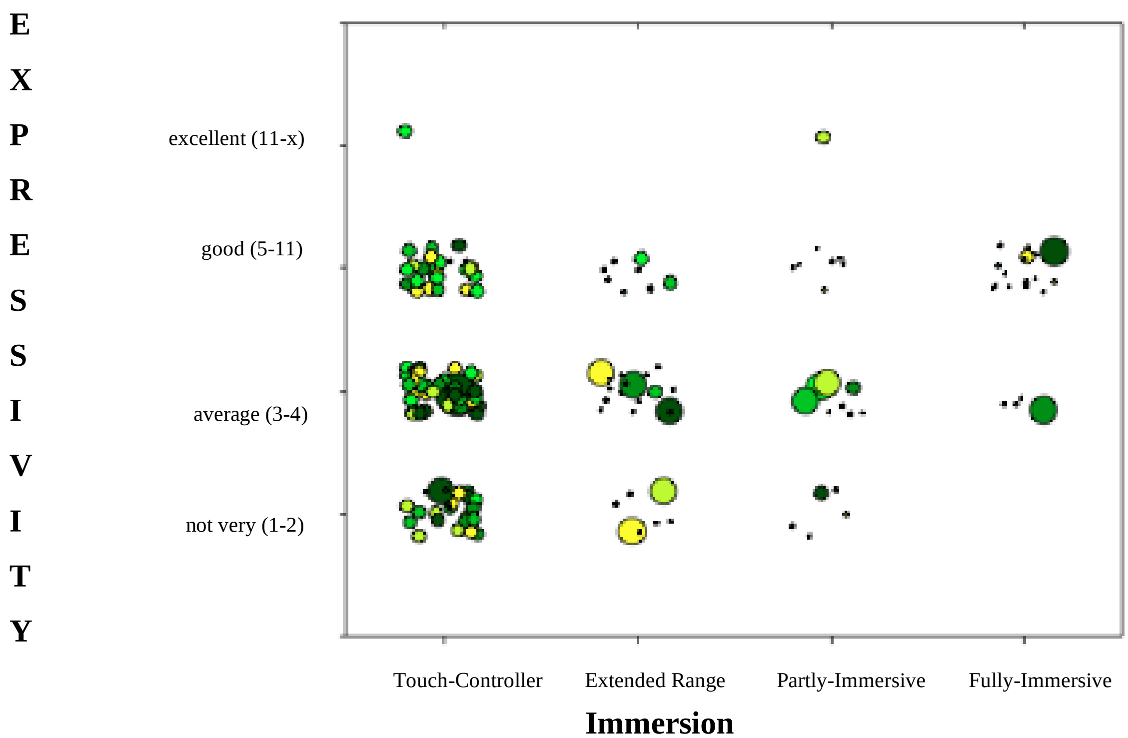


**fig. 37 This graph shows the dispersion of the in chapter 7 analyzed instruments according to their characteristics Immersion and Expressivity on the x- and y-axis, as well as the capacity for feedback according to the radius of the dots.**

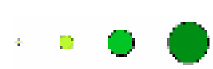

**fig. 38 The size of the dots indicates the kind of possible feedback. In the order form left to right the dots indicate: only acoustic feedback; acoustic and haptic feedback; acoustic and visual feedback; and acoustic, haptic and visual feedback**

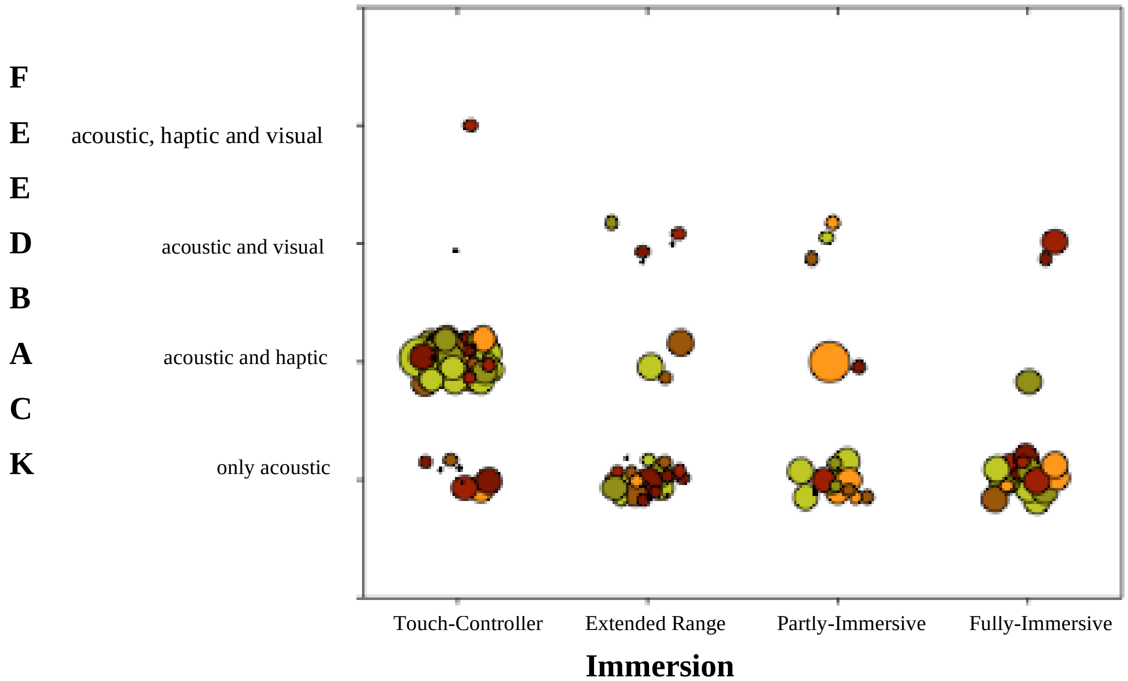


**Fig. 39 This graph shows the distribution of the in chapter 7 analyzed instruments according to their characteristics of immersion and feedback along the x- and y-axis, as well as expressivity according to the radius.**

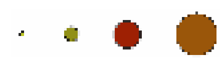

**fig. 40 The size of the dots indicate the degree of expressivity. The dots form left to right signify (in parenthesis the number of simultaneously manipulable parameters): not very expressive (1-2), average (3-4), good (5-11), excellent (11-?)**

### 4.3.7 Annotation and Interpretation of the Graphs

The two compiled graphs demonstrate the distribution of the analyzed instruments according to the characteristic couplings expressivity/immersion and feedback/immersion. One dot represents one instrument, whereas the radius always indicates the missing characteristic. According to the first graph the smallest radius signifies that the instrument has only acoustic feedback; the largest radius defines an instrument with acoustic, haptic and visual feedback; similar rules apply for the second graph, the radius here indicates expressivity.

The distribution of dots regarding the inflection of the two characteristics contains a minute arbitrary deviation to avoid augmented overlapping. The accumulation into groups occurs due to the classification. The minimal deviations are meaningless and allow better visualization. The colors also don't have any meaning, they enable better determination between the dots.

The categories of feedback and immersion become evident through earlier sections. The degree of expressivity is divided into four steps whereas the number in parentheses indicates the number of simultaneously manipulable parameters. A Controller with rotary potentiometers allows control of just two parameters whereas one can control a huge number of parameters with *The Matrix*.

At first glance one can see an accumulation with the touch controller. Here are all the devices mentioned that require physical contact, like key instruments and fader boxes. At the same time most of them comprise haptic feedback, some only acoustic feedback like the *Crackle-Box*. The metallic bright resistors of this sensor do not facilitate any sensible feedback. Regarding expressivity touch-controllers are distributed among the first three steps, the fourth is barely represented.

Form the extended-range controller onwards there is a shift towards good to average. The more immersive an instrument is, the more parameters can be measured and transformed into musically relevant data. Conversely other forms of feedback except acoustic feedback decrease. Haptic feedback becomes in most cases impossible and visual feedback is used seldmoly and if it is used then mostly with datagloves.

### 4.4 Summary

The classifications of Paradiso and Mulder point into different directions. Paradiso groups instruments according to traditional instrument categories such as key instruments, string instruments etc. Mulder categorizes according to characteristics. My classification presents a set of parameters that a relevant for the evaluation of instruments. By means of immersion, genericity, mapping, feedback and expressivity I have captured the devices and categorized them in a diagram that elucidates their distribution.

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