Formalized and Non-Formalized Expression In Musical Interfaces

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ABSTRACT

Many musical interfaces are designed to enable a musician for the creation of musical expression. In this process it is the task of the interface to generate data transmitting the expressivity of the players gestures to the synthesis engine. The instrument has to be open or transparent for the players actions. Building interfaces with this kind of openness may be seen as a problem in interface development because the actions of the player have to be translated from a phenomenological level to a formal level. This paper investigates the idea to create openness by leaving essentials non-formalized. Examples of implementations in the fields of musical instruments and computer games using this method are presented. The tasks of openness, transparency and flexibility for the users intentions are discussed.

Categories and Subject Descriptors

J.5 [**Arts and Humanities**]: Performing Arts (music); D.2.1 [**Software Engineering**]: Requirements/Specifications

General Terms

Human factors

Keywords

Musical interface, playing parameters, musical expression, formalization

1. INTRODUCTION

In order to play computer based musical instruments, adequate interfaces are necessary. The construction and use of new controllers has become a wide field of research as shown for example at the NIME conference (New Interfaces for Musical Expression) [10]. A goal is the creation of new interfaces with high potential for musical expression.

This paper investigates two basic approaches found in interface design. One approach tries to model the player and to build interfaces that measure all essential playing parameters in order to provide explicit data of the player's actions. Therefore the input given by the player to the system has to be formalized. The other approach is based on an architecture that makes use of an instruments raw and non-analyzed audio signal, a stream which includes implicit data of the player's actions. This reduces the necessity to formalize all essential playing parameters because they can be perceived in the output signal as long as they are not disrupted in the synthesis algorithm.

Musicians often describe their instruments and playing methods referring to the phenomena they perceive during playing. In order to take those descriptions into account when modeling the player and thus, constructing the interface, phenomenological described player-actions have to be transformed to formalisms. Chapters 3 and 4 focus on that process. The approach to use implicit data and thus to leave essentials non-formalized is described in section 5. An example of an instrument based on a traditional viola is presented. Besides musical performance the question what the player does or might want to do is also important in computer game design. Section 6 provides examples of game architectures that make use of the approach to keep essentials non-formalized. In section 7 possible qualities and the impact presented construction principles of musical interfaces may have, are discussed.

The digital instruments addressed here refer to traditional musicians seeking to expand their repertoire of sounds or timbre. The interfaces of such instruments are planned to make use of existing skills. Ideally one would have to discuss different types of traditional instruments. However, this would be beyond the scope of this paper. While it may be possible to use the proposed methods for different types of instruments, practical examples are mainly given with respect to bowed stringed instruments.

2. BACKGROUND

Research in construction principles of interfaces in order to reach musical goals is one of the main topics in publications on musical interfaces.

2.1 Expression

The question of what can be understood by the term 'expressivity' in this context was addressed by Dobiran and Koppelman [5]. They distinguish between expression in composition and expression in performance. Focusing on performance-interfaces they see the origin of expression in the performer. The interface should transmit the musical information the performer puts to the interface, or better still, increase it. A precondition for the construction of such an interface is mentioned. "It is necessary to consider how the performer will provide musical expression."

2.2 Measure Player's Inputs

It is a commonly found conviction that the measurement process could, in principle, capture all constitutive actions of the player. An example may be seen in the description of the hypercello [11]. "The hypercello sensors measured the player's inputs to the instrument and used them to control a range of sound sources. The goal of the sensing was to unobtrusively and responsively detect the player's actions as he followed notated music."

2.3 Mapping

Fels, Gadd and Mulder focus on questions regarding the transparency of a new instrument [6]. They assume an interface will measure essentials in the playing process. However it is the task of mapping to facilitate a transparency for musical expression that is generated by the player and can be recognized by the audience.
Concerning their idea of transparency they point to the role of the listeners. "The expressivity of an instrument is dependent on the transparency of the mapping for both the player and the audience." The transparency of an instrument can thus be influenced crucially by the perceptual abilities of the listeners.

2.4 Select Measurements

In the Digital Stradivarius Project Schoner [20] uses the synthesis method of Cluster Weighted Modeling to simulate the sound of a Stradivari violin as well as the sound of other instruments or singing voices. Similar to physical modeling, this synthesis method is constructed to be driven directly by the measurement output. While this approach does not need to focus on questions of mapping, it still has to ask how the performer will create a musical input to the system and thus, which physical measurements of the musical input are necessary. "Defining and carefully executing these measurements was assumed crucial for the success of the model." Criteria to identify these measurements according to Schoner are: hierarchy of input parameters, the physical and technical possibility of measuring these parameters, and signal to noise ratio of the measurement process. It is the task of the developer to investigate and determine the hierarchy of input parameters and to develop fitting measurement methods.

2.5 Formalize Measurements

Prem [15] analyses the process of measurement in control systems for robots. Regarding the question how the measurement process can be formalized Prem expresses the following conviction: "It was already John von Neumann who pointed out that results of measurements, choices of observables, the construction of measurement devices and the measurement process itself cannot in principle be formalized [24], [25]. The reason lies in the fact that the process of measurement is not of a purely formal nature." Due to the fact that two dynamical systems interact the measurement process provides an "inherently dynamic nature". It may be asked whether the described problem can play a role in musical interfaces and under which conditions this might happen.

2.6 Levels in Expression to Convey

Developing the conductors Jacket, a device to analyze the process of conducting and to control a virtual orchestra, Marrin asks for important factors in expressive music [8]. Expression is seen here as the creation of emotion.
In the section "Interpretative variation as the key to emotion in music" Marrin distinguishes between variations on a macrostructural level (such as the tempo) and variations on a microstructural level. Such slight variations may be done in for example phrasing, timbre or articulation, however they have a significant effect on a specific expression. It is sometimes more significant than those on the macrostructural level. Beyond these two levels Marrin mentions the dimension of "the magical, deeply felt, emotional (some might call it spiritual) aspect that touches the core of our humanity." She reports that "many dedicated musicians believe that this aspect is not quantifiable".
While Marrin writes that technology we have so far is not "for the most part, able to convey this aspect" she is also convinced that future will offer solutions. Looking at the instruments built from wood and metal she mentions "there is no reason that we cant do the same with silicon and electrons". However, it is a task of the future to figure out how to do that.

3. THE PLAYER'S ACTIONS

If the instrument has the need to be open or transparent to the players actions, the questions comes up what the players actions are and what is meant with the terms 'open' and 'transparent'.

3.1 Open and Transparent

The openness that is strived for here is understood as the principal possibility to influence the sound result with all actions that might be meaningful for the player in the instrument interaction. It would for example not be open if the player plays different dynamics and the interface had no ability to transmit these changes. Transparency in this paper is understood as the possibility for the player to generate a result that is similar to what the player expects according to the knowledge and skills the player already has (as long as the instrument is referring to these already existing skills). The results can differ slightly from what is expected, however they have to lie in an expected area. In the case of a piano-like interface, transparency would not be achieved if the keystroke the player does to form the sound would not result in a similar ability to form the sound the player is used from the piano. That means that openness and transparency are dependent on the interface as well as on the player with the actions that are thought to be meaningful and with the area of similarity that is defined by the player.

3.2 Fields of Analysis

What are the player's actions? There are five fields that may be seen as important resources to answer this question:
- Individual players and their actions: One can simply ask them: "What are you doing when you play?"
- Instrumental pedagogy: This is important, because the

questions of how to play the instrument or what to do when playing the instrument are addressed.
- Musicians rehearsing together: One can study what musicians achieve and how musicians explain each other what to do.
- The luthier's workshop: Musicians talk about instrumental requirements when their instrument has to be adjusted or when they seek to buy a new instrument.
- Physical analysis: Measurement of playing parameters for individual players.

3.3 Levels of Reality

Measurement of playing parameters and understanding the player-instrument interaction will provide results on a physical level of description.
Looking at literature of instrumental pedagogy or asking individual players will provide descriptions that may be classified on a phenomenological level. Players as well as teachers will describe the player-instrument-interaction usually on the base of perceived phenomena and not on physical measurement results. It may be seen as an open question whether "the reality" about instrumental playing or what "in fact" happens when a player performs is better described on the phenomenological level or on the physical level.
Interfaces address to and will be examined by the players and their perception. Therefore descriptions of the phenomenological level are estimated as what the player "in fact" does. Descriptions on the physical level are seen as abstractions of the player's actions.

3.4 Examples of Player's Actions

Here are some examples of what a string player's actions might include:
- Playing with different pitches, dynamics, bowings (for example martelé, detaché, spiccatto), finger pressure, bow speed, bow pressure, bow position, bow angle, vibratos, articulations, timbre, muscle tensions.
- Playing vocal and consonant notes, more or less open or sated notes, more or less lively, dying, aggressive, delightful.
- Leaning into the sound, pulling the note, squeezing the note, making the note more or less big, bearing, penetrating.
This list is of course not complete. It would have to include relevant actions that could be gathered in the fields mentioned in section 3.2.

4. PHENOMENOLOGICAL AND FORMALIZED LEVEL

4.1 Requirements

In answering the question of what the interface and resulting instrument has to be open and transparent to, one will get a list of requirements. It is common in software engineering to define a requirements document for a system that has to be developed [21].
According to our list of string player's actions, one might find in a requirements document of a string synthesizer:
- The instrument should react adequately to different pitches, dynamics, bowings, finger pressure, bow speed, bow pressure, bow position, bow angle, vibratos, articulations, timbre, muscle tensions.
- It should be possible to play vocal and consonant notes, more or less open or sated notes, more or less lively, dying, aggressive, delightful.
- It should provide the possibility to lean into the sound, pull the note, squeeze the note, make the note more or less big, bearing and penetrating.

4.2 Formal Specification

Similar to our requirements such documents contain user needs and user descriptions in natural language and will have to be translated into a more detailed software requirements specification. The process of arriving at a formal specification that can be fully translated into code in a programming language, must somewhere include the transformation from a non-formal to a formal specification. This process is called formalization and is understood here as the transfer of a procedure or an object into a form where it can be described completely and definitely (i.e. it will be non-interpretable) by a finite algorithm. Formalization may be seen as a problem, because answers to the question of what the player does when playing
- are described in natural language and thus may be interpreted in different ways,
- may include descriptions that cannot be expressed in non-interpretable terms because players may wish to play in a undefined grey zone in specific moments,
- may be different from person to person (playing style) and thus be incomplete from a general point of view,
- may not offer a known physical relation in order to be (yet) measurable,
- may include needs - and thus necessary tracking methods - of an unlimited ability to create slightly different but new playing methods (and micro playing parameters) according to situations that come up in a new playing context.
An example concerning the mentioned requirements:
It is possible to track playing parameters like pitch, bow speed or muscle tensions due to the obvious physical relations. But it is not yet possible to track how much a player leans into the tone due to the missing physical relation. According to the physicist and violinmaker Schleske [19] there is no physical description of 'leaning into the tone' available.

4.3 Abstraction

It is a common conviction in software engineering that formalization of descriptions on a requirements document can be done by making them more detailed and more precise until the formal level is reached. This is an operation that involves the process of abstraction.
Abstraction will free objects or processes from inessentials and reduce their descriptions to essentials. Winograd and Flores [27] describe a problem that comes with such a deliverance. Citing Heideggers concept of situations that are "ready-at-hand" when they are new and get "present-at-hand" when we start to treat those by "analyzing it in terms of objects and their properties", they conclude that abstraction, in general, generates a blindness due to the limited view "to what can be expressed in the terms we have adopted". In our case one might say that the system specification was not complete. However, is it in fact possible to get a 100% complete software specification? According to [21] one would have to say that it is not possible. An important question would then be if, the blindness of the interface bothers the player and if yes, how much.
A general problem occurs if a need on the requirement doc-

ument contains an open ended explorability of the instrument.

Often musicians say that they have to newly adapt or re-learn again their instrument every day, and that it is in fact interesting to explore it and adapt to it again and again and again. An example may be found in the cellist Pablo Casals [4]. If the requirements document would contain the requirement to have a part of the interface and instrument that keeps being "ready-to-hand" it would be impossible to find a fitting abstraction. This process would it already make "present-at-hand".

4.4 Player's Focus Move

As pointed out in the introduction, formalization of the measuring process may be a problem because two dynamic systems interact. Measuring the playing parameters in order to get data on the player's actions would disturb those if the measuring process causes the player to do other actions than intended.

According to the author's experience one may find a focus move when playing systems that mainly use measurement values to control the sound [12]. In a bowed stringed instrument the focus moves from the response of string to the response of the tracking system because the tracking systems can cause values that were not intended. A participant in a study [13] mentioned: "With this instrument one has to play extremely correct. Otherwise I get bubbling sounds I don't want to have. I feel musically restricted." This problem was caused by pitch tracking values that started to tackle around when the audio signal of the string had a specific amount of noise. However, using some kind of noisy and knocking sounds is necessary for a string player in order to generate consonant sounds [7] necessary for articulation.

In this case one might say that the formalization of the measuring process is done, however it is not done correctly because the measurement disturbingly influences the object that has to be measured.

5. LEAVING ESSENTIALS NON-FORMALIZED

5.1 Parameter Based Approach

Focusing on practical aspects in the design of new computer based instruments, the problems researchers are dealing with lie often in two fields.

1. Physical measurement one would want to do is not possible because of missing or not available methods of measuring.

2. The translation from the phenomenological level to the level of physical descriptions is not possible due to a lack in knowledge of physical relations forming the basis of the addressed phenomena.

Therefore a lot of research is done by developing required methods of measurement and by the search for physical descriptions that form the base of selected phenomena. For example the physical rules of traditional instruments are studied [28], the player-instrument-interaction is studied [17] [1] or the gestures in playing and their relation to the produced sound are studied[26].

A general idea behind this research may be found in the aim to gain knowledge of where the expressive potential of traditional instruments comes from and to arrive at an adequate abstraction of tasks in the requirements document in order to have computer based instruments that are open, transparent, and expressive. With this knowledge essential coherences could be described physically and essential playing parameters could be defined. With these abstractions the formal specification becomes possible because essentials could be formalized. It is of great importance to go on with this approach.

5.2 Audio Signal Based Approach

Besides that, an approach from a different direction may also be of use. This approach tries to create openness by leaving essentials non-formalized [22].

An implementation for a synthesizer-viola that makes use of this approach has been described [12]. Additions for a synthesizer-trumpet were presented [14]. The basic system architecture that is common in musical interface research uses playing parameters as the base to control the synthesized sound. In contrast, the approach focused here uses the raw and unanalyzed audio signal as the base to drive the synthesis algorithm. Therefore it is called "Audio Signal Driven Sound Synthesis".

Where necessary - it depends on the synthesis method used - the synthesized sound is modified indirectly by parameters extracted from the audio signal or by any other kind of parameters that might modify the sound in an appropriate way. The basic principle is presented in figure 1.

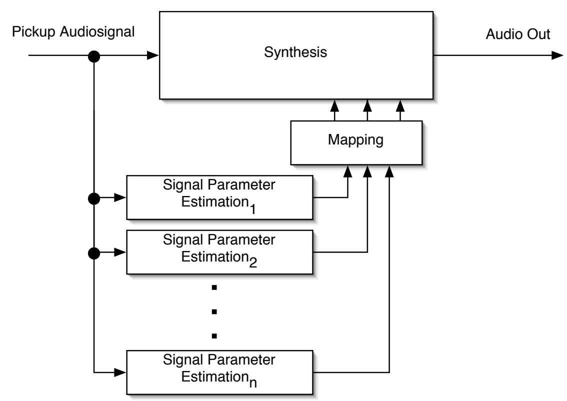

Figure 1: Basic principle of Audio Signal Driven Sound Synthesis

One might say that this method lies between Sound Synthesis and Sound Processing. Modified Versions of simple FM Synthesis and Subtractive Synthesis that have been modified in the sense of Audio Signal Driven Sound Synthesis, were presented in [12]. Dannenberg developed a method based on this principle that he called "Self-Modulation" [14].

5.3 Advantages and Drawbacks

How do the resulting instruments relate to mentioned tasks on requirement documents? Assuming the possibility to bring the personal expression of a player to the audio signal of the string of a bodiless violin, the openness will be given because all the actions a string player does affect the sound of the string. It is not necessary to transform natural language descriptions from a non-formal to a formal level because the players essential actions are implicit in the resulting audio signal. Since the audio signal mainly drives

the synthesized sound an explicit representation of all essential player actions is not necessary. However, transparency is still an issue. In this approach it is the task of the algorithm to be transparent.
An example where transparency is disrupted may be found in modified Subtractive Synthesis (see figure 2). The timbre of the sound will change crucial as long as the filter frequency is not modified by measurement values of a pitch tracker. In this case the algorithm has to be made transparent by influencing it with measurement data of the input signal. If the transparency is re-established, the player can still make use of playing parameters or methods from the requirements list, which are not formalized and coupled with a measurement.

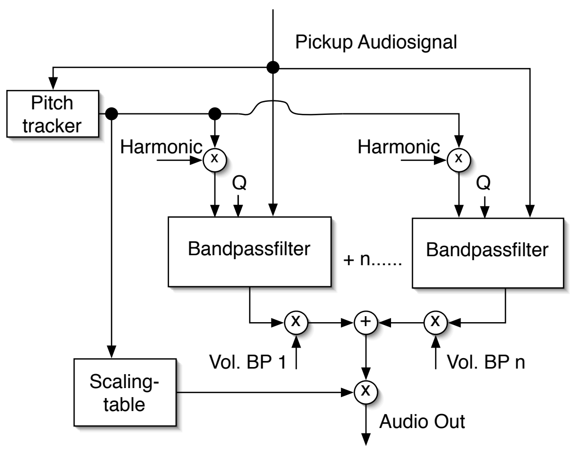

Figure 2: Modified Subtractive Synthesis

However, one has to say clearly that this method has a big drawback. The common requirement of an interface to drive any kind of parameter driven sound synthesis is not met. Known methods of sound synthesis have to be modified in order to be driven with the audio signal. It is an open question which methods of sound synthesis can be transformed to work with this approach. The principle that was used so far in the modification was to replace digital oscillators with the audio signal [14].

6. OPENNESS IN COMPUTER GAMES

Similar to the requirements document for computer based musical instruments computer games are usually built with the help of a game design document. This document tries to describe the complete game in order to give the developers information necessary to implement the game. It includes descriptions about the general idea and goals of the game as well as detailed ideas about e.g. game characters, user interfaces, weapons, sounds, world layout etc. In order to provide a satisfying interaction, the designers will consider the question of how a player might want to interact inside of the game.

6.1 The Problem of Anticipation

Trogemann [22] mentions a problem that comes with anticipation in designing computer games. As games increased in complexity, a point was passed beyond which developers were unable to anticipate all the possible actions of a player. According to Trogemann the solution game developers are using recently is to develop systems where this detailed anticipative process is no longer necessary. These systems build a framework where all states occur as implicit natural states within the system and not as explicit implemented features about what exactly the player is doing at present. One might say that in this approach the essentials of what the player does in detail are not formalized. The code does not "know" or analyze what the player does in a specific moment. However, the framework in which all the actions happen are of course formalized.

6.2 Examples

Examples may be found in many recent computer games. 'Half Life 2' [23], one of the most sold games in 2004, offers features where the physical behavior of elements is modeled while the states the player has to reach and the possible ways in which this might be done (anticipation) are not explicit formalized [18].

An example from Half Live 2: the player has to get onto a wall in order to proceed. In front of the wall a seesaw as well as some bricks are found. If the side of the seesaw that is pointing to the wall would be up one might be able to jump from this side onto the wall. Placing the bricks on the other side of the seesaw enables the player to run over it and to jump upon the wall. However, it is also possible to put some bricks closer to the middle of the seesaw and to jump on it. The seesaw starts to swing. Running and jumping in the right moment the player will be able to jump onto the wall. Perhaps one could build stairs with the bricks in front of the wall and walk over it. Perhaps one could fetch objects from other places to build a way in order to get onto the wall. Different solutions are possible and can be found in several game related websites.
The user can recognize the mentioned states, however, using a physical engine it is not longer necessary to formalize these explicitly. The openness is achieved by leaving such essentials non-formalized. It is not necessary for the developer to explicitly implement the state 'whipping seesaw' or 'stairs in front of wall' or any other possibility that would allow the player to jump onto the wall. These options are implemented implicitly by using the physical engine. Using this basic principle in computer games up to a certain extend, the user might find methods to solve problems, that were not even thought of by the developers.

A precedent of such physical engines, and thus the approach not to anticipate every action a player might want to do, may be found in earlier games like 'Lemmings' [16]. There it is possible to place workers with specific tasks, the so called lemmings, on different places influencing the movement of the lemming community. It is obvious that situations might arrive that the developers did not anticipate when designing the game. This openness might be an important reason for the success of this game.
However, since the physical engine and the presentation in Half Life 2 tries to be realistic the user does not need to adapt to the game as much as an adaptation in Lemmings is necessary. In other words, the goal to use existing knowledge in order to deal with game problems may be reached more

easily when using a highly developed physical engine.

More sophisticated gaming concepts, which we find for example in the game 'Oblivion' [3] even leave the player in an open concept concerning the general goal or history of the game. While there is a main story, it can always be left and it is possible to define personal goals that have nothing to do with the presupposed goals of the game. It depends on the fun-parameters of the player to define what actions to do when playing this game.

6.3 Restricted Openness

A problem in this kind of open systems may occur due to the fact that any game will have to have somehow an anticipative approach in order to answer the question: Why should this game be interesting for a player? One might conclude that the anticipation will never be complete. Oblivions precedent the game 'Morrowind' [2] for example enables a player by several tricky combinations to mix a drink that makes the player so strong that she or he can beat all enemies with no more problems at all [18]. If such possibilities are found often this may be estimated as a killer-criteria for a game. In order to minimize such problems the principal openness which a game could have, is often restricted. While it is important to give the player the feeling that in this game a lot of existing knowledge can be used to master challenges, the number of possibilities in a concrete situation is often kept much smaller than the basic principle of software construction would allow.

7. DISCUSSION

As pointed out earlier, interfaces that use a fixed set of defined parameters are limited in their openness. Concerning flexibility the user will be restricted. It is not possible to focus playing methods and thus parameters that were estimated to be not important and have therefore not been implemented. The flexibility that a player might have, is therefore fixed into a set of actions predefined by the construction principle of the interface.
One might say that a cello, a drum, or a piano is not flexible due to the fact that a cello always sounds like a cello and cannot switch or morph to other sounds. This is of course a true limitation. With respect to the flexibility and potential for expression the player has within a specific sound, one may say that new interfaces based on the idea of traditional instruments have not yet been - except the keyboard - tremendously successful. Due to this reason research on traditional instruments and the comparison is still found very often in musical interface publications [6].

7.1 Player's Estimations

According to the author's experience, derived from discussions and an empirical study [13] involving digital bowed stringed instruments and traditional instrumentalists, the loss of openness, transparency and flexibility compared with the possible advantages in sound variations often leads to a rejection of new instruments. Marrin [8] shows similar experiences when she writes "There are good reasons why most musicians have not yet traded in their guitars, violins, or conducting batons for new technologies". She is convinced "that these technologies do not yet convey the most deeply meaningful aspects of human expression".
On the other hand one may say, that the world of traditional musicians is a slowly decreasing one, while lots of wonderful and fascinating art work has been done in the area of digital arts. This is an increasing field with innumerable and highly skilled artists. After discussions with students in the field of media arts, the author came to the conclusion that media musicians may have absolutely no problem with interfaces using a limited fixed set of parameters.
As Moog pointed out [9] also the theremin with only two parameter inputs (frequency and amplitude) has a high potential for expression. So, why should it be important to distinguish between formalized and non-formalized aspects in musical interfaces and to focus this field?

7.2 Different Qualities

An answer may be found in the conviction of the author, that the difference between formalized and non-formalized approaches may be of use because it offers different possibilities how qualities can be produced. The success of digital arts provides evidence, that formal methods may produce a lot of new qualities. The remaining question, why and how traditional instruments can offer the assumed potential for musical expression, provides evidence, that non-formal methods may produce a lot of qualities. It is an open question whether such non-formal qualities are not yet formalized or cannot, in principle, be completely formalized.
However, one will only produce music with the present possibilities. Therefore qualities produced by non-formalized (or not yet formalized) expression may be of use. In addition, as long as the potential for expression is combined with a necessity to keep elements that are ready-to-hand and thus are not formalizable, it seems to be important not to lose the knowledge of its potential.

7.3 Impact of Formalisms

Assuming that a lot of input parameters that might have been estimated to be important in the requirements document cannot be implemented due to missing measuring methods or because they are not yet physically understood, one may ask what impact it will have on musicians who grow up in the digital domain of music. Do we have to expect that the blindness of computer based applications and thus instruments Winograd and Flores are referring to [27], will create a similar reflection in their users?
Given the condition that performed and perceived music lies in the digital domain and given the condition that musical experience will form the sensitivities of musicians, it may be likely that an experience-specific sensitivity and unreceivability might occur. In this case a digital artist might lose an area of quality if music is understood mainly from a physical descriptive point of view that allows to formalize all essentials in music.
According to the experience of the author, digital artists often start by doing personal research on what can be done with the one or the other application, device, programming language, interface, sensor technology or Microcontroller. The artistic question, the artistic problem and resulting the requirements evolve out of this process including the personal interests of the artist. One may estimate that descriptions of reality found on a formal level will influence the artists idea on what is possible and what is crucially of interest.

The composer Hans Zender writes: "Strictly speaking, it is not possible to translate musical thinking into language." [30]. While Iannis Xenakis did a big step ahead with his book 'Formalized Music' [29], it might be interesting to have a book focusing on occurrence and on meaning of non-fornmalized aspects in music.

8. CONCLUSIONS

In summary the opposite poles of formalized versus non-formalized, explicit versus implicit, parameter based versus audio signal based and physical descriptions versus phenomenological descriptions have been addressed. It has been discussed what implications their use in the construction of computer based musical instruments might have. Important differences between the two poles were found in the question on what kind of openness, transparency and flexibility can be generated if using construction principles that tend to one or the opposite pole.
An interesting question concerning digital arts might be, whether the old opposite terms, digital versus analog, might be supplemented by the poles formalized versus non-formalized. Computer based arts show formalisms everywhere. However, formalisms do not necessarily fall into the digital domain because analog computers use also formal programming languages. If formalisms are estimated to have an important impact in contemporary art, it might be interesting to do research on how this impact takes place and what consequences it has.

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