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**Abstract**

*The use of computers for the creative expression, such as in music, interactive digital art and virtual reality, mandates the interpretation of communicative and creative processes in terms of abstract structures and the manipulation of these structures. The former interpretation, namely, the abstraction process, is the central theme of the present paper. The abstraction process is described in a formalized manner. The distinctions between the abstraction process for different disciplines are drawn. Finally, some example projects using implicit abstraction mechanisms are analyzed.*

## 1. INTRODUCTION

The technological breakdown within the last part of the twentieth century, especially in the fields of computer and information technology, initiated radical changes in many layers of society. The creative disciplines, such as art and music, have been also benefited from the new expressive potential of the so-called digital age. With the development of the computer, a formal view of expressive languages supported the application of computers for building interactive abstract and virtual worlds in music, art, and new media, such as virtual reality.

In the cultural history of mankind, however, the abrupt changes without the peripheral nouveau surrounding the new paradigms are rather rare. Emerging new techniques of creativity with computers, in fact, represent a continuity with traditional forms of expression. Experiences within the two last centuries with two new media, namely with photography in the 19th century, and with cinematography in the 20th, give some hints and predictions about future trends of emerging *interactive digital art*.

In its early stages, the first criticism of photography was necessarily based on a comparison with painting or drawing, since no other standards of picture making existed. The critics regretted that, because of the great length of exposure, moving objects were not recorded or were rendered blurry and indistinct. The inability of the first processes to record colors was disappointing. The technique of photography was at once recognized as a shortcut to art. No longer was it necessary to spend years in art school drawing from sculpture and from life, mastering the laws of linear perspective and chiaroscuro. The early films, on the other hand, were perceived by their original audiences not as motion pictures in the modern sense of the term but as ”animated photographs” or ”living pictures,” emphasizing their continuity with more familiar media of the time.

Throughout their evaluation period, both photography and cinematography constructed their own, individual methods and aesthetics to become new forms of creative expression.

Same can be concluded for interactive digital art - it will develop its own methods, narratives and aesthetics, which we may call loosely *digital aesthetics*. The discussion of the continuity with traditional (i.e., pre-digital age) forms of expression has an important purpose: It emphasizes discernible and differentiable distinctions and conventions, and thus portrays the basic milestones of digital aesthetics.

This report aims to review the complete process of creation in computer-generated art and introduce a formal scheme to depict the steps involved in such a process. The formal scheme is constructed after the reports of teams describing their work in a compilation (Sommerer & Mignonneau 1998). Once the scheme is constructed, two important issues emerge:

1. After the definition of the concept of the work, the first step towards the implementation, namely the *abstraction mechanism*, which maps the initial ideas to the computer domain and will be the subject of further discussion in preceding sections, is usually not explicitly documented. A schematic representation, such as the one described here, provides means to put this step under spot-light. Then some details of the abstraction mechanisms are more clear, i.e., they are sometimes not so well-defined and they are often rigidly shaped by the technical implementation details.

2. The concepts of digital aesthetics is still ill-defined, which in turn, forces the artist to combine the art work with more traditional forms. However, this attitude clearly does not help formulize the digital aesthetics, since it will be shaped by the current works, experimenting in non-traditional aesthetic criteria.

The discussion of these two issues is the main concern of this report. For this reason, a general scheme describing the abstraction scheme is drawn in Sec. 2. This scheme is derived from the description of the projects of the artists themselves. It should be noted, that the scheme neither aims to provide a magic receipt for creation, nor premises a system-theoretic approach to under-emphasize the creative effort. It is constructed as a guide for further discussion, and is in no means complete.

The formal scheme is applied to simulation of natural phenomena in Sec. 3, and to creative process in computer art in Sec. 4. Especially, the urging need of the formation of digital aesthetics is discussed in the latter application. Then, in Sec. 6 and Sec. 6, the scheme is used as a guide for analysis of works in conventional and computer-generated art, respectively. Note that the effort is not claiming to be a complete, objective analysis of a particular work, but pinpoints the important concerns summarized above. Finally the conclusions are drawn in Sec. 7.

## 2. ABSTRACTION, A FORMAL DESCRIPTION

An typical attempt to summarize the process about a particular project typically goes like this: [1]:

> Basically we develop the concept for a new work together and then look for technical solutions to its realization. Laurent has great knowledge in electronics and programming which helps us find technical solutions in the search of

[1]This particular description is from Christa Sommerer, summarizing their collaborative effort with Laurent Mignonneau, taken from (Goodman 1998)

> interfaces. When it comes to programming, Laurent writes the main structure of the computer code; whereas I work on the design of the programs and modify the code in terms of shapes, colors, general look. For the interface design, Laurent works on it alone. Once the technical problems are solved, we usually readjust the work and collaborate on the interactive part: we test the system and try to see how people interact with it. After the test period, we generally do some readjustments.

What is meant with the *concept for a new work* is the definition of the problem, the message to deliver to the audience (if any), then transformation of the problem to the computer domain. This step is termed as *abstraction* in this report. There is a danger in such a multidisciplinary effort: Typically, one of the disciplines may reign on the other. Within the context of computer-generated art, the powerful discipline seems to be the technology. Hence, the abstraction mechanisms, which are the main driving forces for creation, are not further questioned.

Generally speaking, the research in science and technology is presented to state that it follows a structural methodology, whereas the arts are supposed to be less-bounded to the methodology for the sake of creative expressiveness. For the scientific end, Feyerabend (1993) claimed that so-called non-scientific factors such as aesthetic criteria, personal whims and social circumstances have a far more decisive role in the history of science, and concluded that there are no useful and exceptionless methodological rules governing the progress of science or the growth of knowledge, and if one insists on a general methodology which will not inhibit progress the only "rule" it will contain will be the useless suggestion: *anything goes*.

On the other extreme, the art in general, and computer-generated art in particular, does not seem to be completely unbounded from the methodology; although it is often stated otherwise. The methods, often inherited from science and technology, have an important role in the abstraction mechanisms. The rest of this section tries to depict the methodology of the digital interactive art disciplines.

The term *abstraction* originates from the Latin word *abstrahere*, which is translated as to draw from or separate. Literally, abstraction means the process of leaving out of consideration one or more properties of a complex object so as to attend to others. Thus, when the mind considers the form of a tree by itself, or the color of the leaves as separate from their size or figure, the act is called abstraction. Similar abstractions are made, when the whiteness, softness, virtue, and existence are considered as separate from any particular objects.

Abstraction mechanisms are of paramount importance in object-oriented programming (c.f. (Stroustrup 1997), Part II), which is a programming paradigm to define the abstract data types and their relationships. Borrowing the key terms from object-oriented paradigm, we can conceptualize the scheme for creative process, as shown in Fig. 1. It is noteworthy to consider the similarities between this scheme and the description quoted above.

The process begins with the *problem definition*. In means of artistic creativity, the problem definition corresponds to clarifying the initial ideas, which in turn, would determine the final outcome of the project. The problem to be defined is necessarily dependent on many factors, such as the ideology and artistic backgrounds of the project.

At this step, typically, one is confronted with a highly-complex *concrete problem*, which is nebulous for a given task and a particular aim. Thus, a canonic description of the problem is needed to separate necessary from unnecessary details: The program-

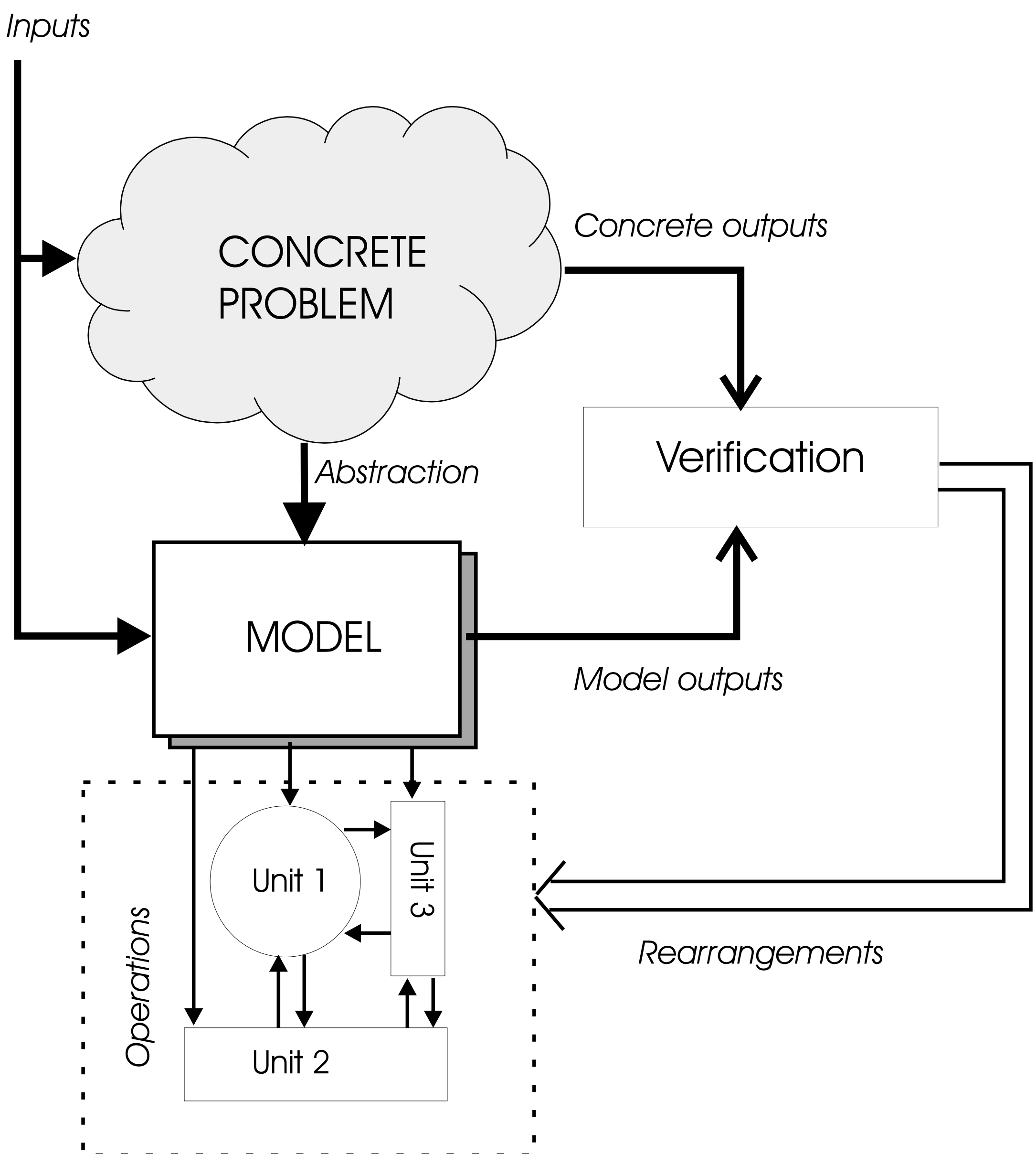


Figure 1: Schematic presentation of creative process.

mer (or artist, in this context) tries to obtain his/her own abstract view, or model, of the problem. This process of modeling is called *abstraction*. The abstraction mechanisms contain tremendous amount of information regarding the reading of the work: It reflects the programmer-creator's choices and preferences about what to include and what to dissect from the concrete problem. This choices are, like in the problem definition step, determined by various factors, but this time technical capabilities appear to be a strong constraint.

The *model* defines an abstract view to the problem, hence becomes its representation. This implies that the model applies the *Occam's razor* to the unnecessary attributes of the concrete problem. It is expected that the concrete object and its representative model would respond similarly to the given inputs, this issue is an important factor for the verification & validation step, which will be discussed shortly afterwards.

The elements of the model are the *units* which provide the basic data to be operated on, and the *operations* to organize and manipulate the units in a hierarchical fashion. The number of basic units and the complexity of the operations determine the overall model complexity. The implementation issues govern in this step.

At the next step, the modeler takes the role of the target audience, and he or she experiences the first interaction with the abstract model under development. If the model outputs bears a resemblance to the real experience with the given number of units and given complexity of operations, the model is *validated*. If the resemblance is unclear, then the units and operations are realigned, and the *verification* step is executed again. Repeating this process may converge a useful representation of the model in terms of units and operations. If the convergence fails, then it is necessary to reconsider the abstraction to obtain a model that may have better convergence characteristics.

Given the definition of an abstraction mechanism, the next step to answer the following important question: *What is a good model, and how can we verify it?* Prusinkiewicz (1998) addresses this question in the context of modeling natural phenomena. The next subsection summarizes his formalization about abstraction mechanisms for natural scientific visualization and artificial life, whereas Sec. 4 discusses the fundamental difficulties projecting this formalism onto interactive digital art.

## 3. ABSTRACTION MECHANISMS FOR SIMULATION OF NATURE

Prusinkiewicz (1998) favors the *faithfulness*, or the degree which it approximates reality, and *simplicity* as criteria of a model's quality. The ideal model, in his formulation, represents a favorable trade-off between complexity and accuracy. Being influenced by cybernetics and system theory he states the ultimate goal of modeling nature as to construct simple yet faithful models of reality. For measuring the model complexity, he proposes the Kolmogorov complexity measure, which is the length of the shortest description of a model. The modeling process, as he describes it, is as follows:

- Observation of the facts.
- Construction (induction) of a mathematical model using the observations.
- Deduction of predictions concerning the reality using the mathematical model.
- Optimization of the agreement between model predictions and new observations.

The agreement between this formalism and the scheme in Fig. 1 is noticeable. However, the last item requires further examination. The difficulty here is the lack of an objective measure to state the agreement between model predictions and new observations. Being aware of this fact, Prusinkiewicz relies only on the visual comparisons and agrees that this comparison may seem highly subjective, qualitative, and unscientific. However, he rationalizes the visual comparison as only available option today, given the state-of-the-art in characterizing arbitrary forms (for example, developed within the field of computer vision).

As a conclusion, validation step in natural simulations is based on ad-hoc comparisons, which may be governed by factors not contained in the simulation process itself. Still, the suggested comparison is more clear compared to the validation step, when the abstraction scheme is applied to digital interactive art. This issue is discussed further in the following section.

## 4. ABSTRACTION SCHEME IN COMPUTER ART

The description of the scheme shown in Fig. 1, when applied to summarize the abstraction mechanisms in computer art, can be stated as follows:

- Statement of an abstracted, idealized creation (e.g. outcome) space of the model maker, according to his/her own aesthetic needs.
- Construction (induction) of a mathematical model to *operate* on the abstract *units*.
- Deduction of outcomes using the model, i. e., the execution of the model to create some outputs, which are to be considered as original creative interactive digital art works of the modeler.
- Optimization of the agreement between the model outcomes and the initial aesthetic concerns.

The fundamental difficulty lies again in the last step, validation. Since there are no predefined criteria about the match of model outputs and the initial expectations, the artist is forced to consider the pre-digital aesthetics for verification.

This problem is implicit essentially in most of the attempts that use computers for creation. In web, most of the people still use paper-like background textures to resemble the more traditional printed media. Computer music walks trough the safe territories of a conceptually unlimited timbral space, transforming the traditional instruments to the digital domain. These examples all show what is missing: Digital aesthetics. But the formation of the digital aesthetic is clearly dependent to the courage and enthusiasm of the digital artists to explore new, untouched territories.

## 5. A CASE STUDY OF AN ABSTRACTION MECHANISMS IN PRE-DIGITAL ERA

Long before the computers were used for creative purposes, Kandinsky defined a grammar for a language of visual harmonies and dissonances (Kandinsky 1979). For Kandinsky, the concrete problem was the redefinition of the visual composition by establishing a complete and coherent system of visual elements in dynamic relationships, with no element treated in isolation. His abstraction mechanism is heavily influenced by the music and spirituality (Kandinsky 1977). Kandinsky recognized the abstract nature of the music and consciously sought to develop a similar foundation for the visual arts. Just as music can be seen as an abstract system relating elements realized in sound, Kandinsky saw the visual arts as an abstract system relating elements realized in visual form. This was his model.

Music seen as an abstract language, however, had a tradition that went back centuries. In music, the essential elements, notes, were clear. There was extensive theory that considered musical structures in terms of the relationships between sounds in temporal sequences. The visual arts had not been thought of in such atomistic terms. Kandinsky had to define the basic elements (or units) for visual languages, which he defined as colors, points, lines, and planes. And he had to define ways of thinking (operations) about the structures built out of these elements.

Most importantly, his abstraction shaped an aesthetic criterion to evaluate the prior works of various styles, and his own works in the abstract terms he proposed. As a summary, he defined each and every sub-block of Fig. 1 in his own terms, including the verification block.

## 6. CASE STUDIES OF ABSTRACTION MECHANISMS IN DIGITAL ERA

### 6.1. Case Study 1: Digital Kandinsky

Sixty years later than their original proposal, Lauzzana & Pocock-Williams (1988) interpreted Kandinsky's visual language by a computer. They used two set of rules to describe Kandinsky's language; the *physical* and the *spiritual* rules. The physical rules define the form and the composition. They adopted Kandinsky's basic units, and defined a new set of sub-units, e.g, straight lines, jagged lines, curved lines, and complex lines for line units. The operations are also revised.

The spiritual rules are also based on Kandinsky's writings. Being concerned with the meaning of a painting, these rules characterized the emotional attributes of the units, e.g, a vertical line is attributed to be warm, horizontal as cold, and diagonal as neutral.

Using this rule system, Lauzzana and Pocock-Williams then developed a set of rules that characterize Kandinsky's *Dream Motion* (See Fig. 2). Starting with a blank canvas, they described a set of rules that creates two intersecting lines (steps 1 and 2). The point of intersection then becomes the center of the circle. The intersecting lines are also used as the sides for two triangles (step 3). Other units, such as rectangles and circles are added as part of the central figure (steps 4 and 5). Similar rules generate additional clusters. Different rules described different types of clusters: arrangements of circles, stray lines, and triangles.

Using the rules thus defined, the computer can generate a number of images. Six such images are shown in Fig. 3.

Although being a very useful tool for analysis, and a good candidate for passing the *Turing test*, the outcomes of this and similar studies are not considered as original computer-generated art works (actually they were not intended to be). Two important factors may explain this:

1. The abstraction mechanism is not originally created, but it is derived.

2. The outcomes are to be judged with the aesthetic criteria of the pre-digital era. Thus, this study fails to broaden the digital aesthetics.

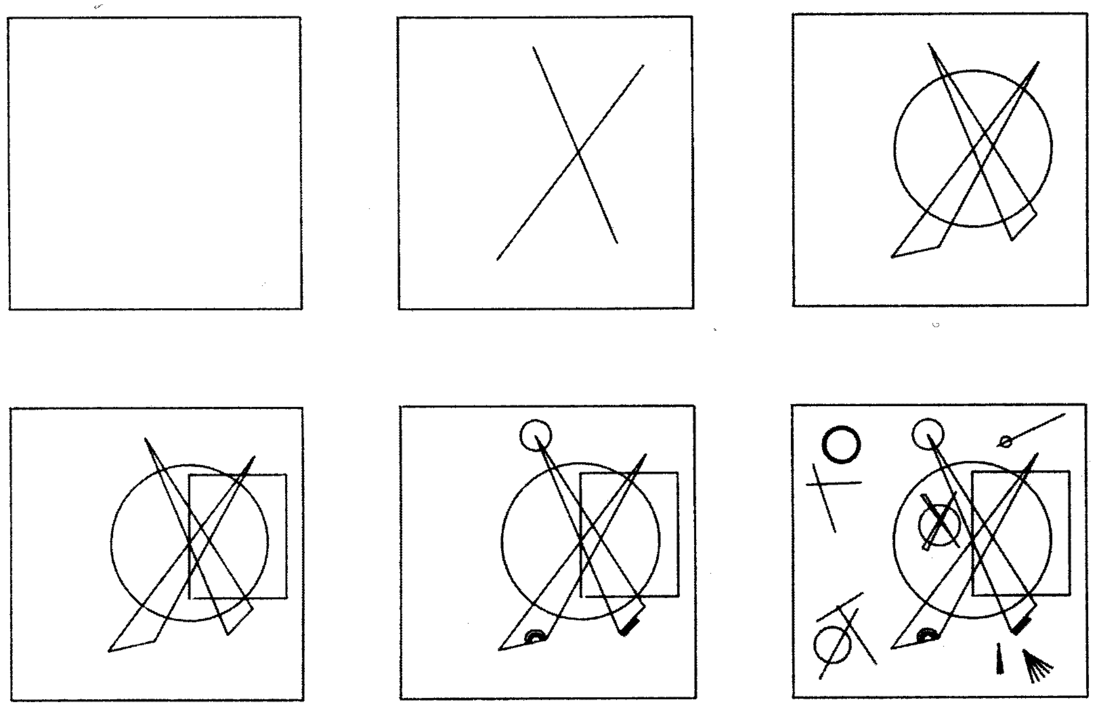

Figure 2: Six steps of development using rules describing Kandinsky's *Dream Motion*. From Lauzzana and Pocock-Williams (1988).

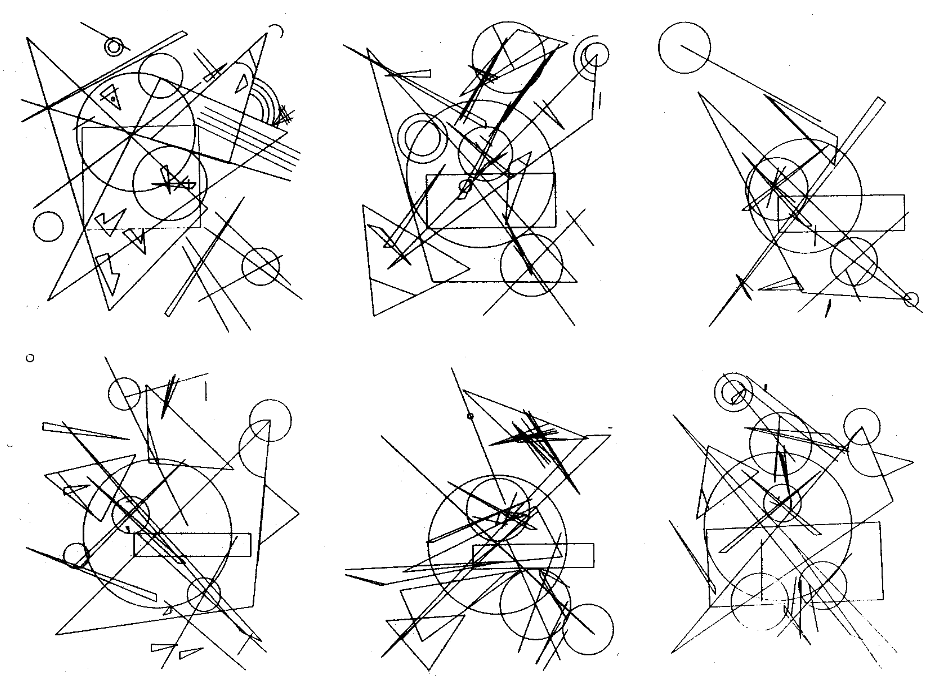

Figure 3: Six images created by Lauzzana and Pocock-Williams (1988) using rules describing Kandinsky's *Dream Motion*.

This case study is important to give some hints about the evaluation of digital art. For an original digital art work, the originality needs to be absorbed both in the abstraction and the implementation steps. Furthermore, like in conventional art, the outcomes should provide a balance with expectancy and surprise, or according to mathematical analogy, between *bias* and *variance*.

## 6.2. Case Study 2: Head

The second case study analyzes a contemporary work, *Head* by Ken Feingold[2]. It should be noted that the analysis could be highly subjective and far away from the original intentions of the artists. Nevertheless, it provides a good basis for a discussion of the proposed formal scheme, and all the details about the work seem to be explained by the scheme.

### *6.2.1. Concrete Problem*

The concrete problem of the work is computer intelligence. The verbal communication ability of mankind is often stated as a sign of the intelligence. In the discipline of artificial intelligence, systems such as psycho-analysis program Eliza try to mimic this ability, but the results are not considered to be satisfactory. The artists transforms this problem in the creative domain, constructing very realistic animatronic human head and letting the observer communicate with the head. The concern of the artist is not creating a system to give the impression that it is real, but rather, he wants to emphasize the unpredictability of his system.

### *6.2.2. Abstraction*

The human communication is a very complicated process. In the physical layer, there are words, gestures, gazes and non-verbal responses. In higher layers, there are factors such as meaning associated with the words, denotations, connotations, and context analysis. The artist abstracts the communication process by including the words, some of the facial gestures, and a limited context analysis ability. This limitation is directly implied by the current state of available speech recognition systems. Being aware of this, the artist gives the head a very distinct and complex personality: He warns the audience that the head is crazy!

### *6.2.3. Model*

The model is a constructed head, placed on a small table. The choice of a head as a model is not trivial, since it contains the primary organs for communication (brain, ears and mouth). The eyes add to the non-verbal communication by blinking, and the facial expression adds to the impression that this represented person may have some mental problems. The tone of the voice and the intonation are also consistent with the same presumption. The table covers the hardware of the system. The project is depicted in Fig. 4.

[2]Head and 15 other works can be seen under *Alien Intelligence* exhibition between 12.02.2000 and 28.05.2000 in *Kiasma*

Figure 4: Head by Ken Feingold.

### *6.2.4. Units and Operations*

The units of the system are the bust, servo-motor mechanisms to control the mouth and the eyes of the head, and a personal computer for speech processing. The computer runs several software applications with Linux operating system. The operations of the application software is defined as follows:

- The first software is a speech recognizer, translating the speech of the observer to text.
- The second tries to evaluate the meaning of the processed speech and formulates a reply. Although the precise algorithm of this application is unavailable, it may capture some isolated words stored in a database, and if there is a match, it may select a pre-formulated reply from an answer database.
- When there is an un-match, i.e., none of the words of the observers sentence is close enough to database entries (the un-match can be caused by the limited performance of the speech recognizer as well), then the application software may choose a random entry from the answer database.
- A third application software translates the answer to the synthesized speech. Like many other text-to-speech synthesizers, it uses a linear prediction-based algorithm.
- Some subroutines synchronizes the mouth movements with the speech, and controls the eye movements.

#### 6.2.5. *Verification and Validation*

Although not stated explicitly, the project must have been a subject of many rearrangement steps. If the speech recognizer operates on a neural algorithm, then it must have been trained by several people, male and female, for the sake of generalization. Then, the comparison database, random selection routines, and the answer database must have been reshaped according to the experimentation with the model. At the validation step, primary concern would be to test if the model would respond to the words of the recognition database as intended. If this is true, then additional tuning may be required to keep the conversation in track, and to give the intended impression about the imaginary personality about the head.

#### 6.2.6. *Evaluation of the work*

The abstraction mechanism of the project is original. It is build upon the idea of interaction, and it is stimulates the observer to keep on with the ”conversation”. The technical implementation is robust and well-defined and the technical limitations are creatively bound to the representation of the project. Validation cues on the observer side are carefully transformed to a common experience of dealing with a complex personality.

## 7. CONCLUSIONS

The interaction between the art and science provides new ways to express the creative process. One possible pitfall in such an experimentation may be that the technological innovations of the implementation may shadow the initial artistic motivations. The optimum balance between these factors can be best understood by a formal description of the process.

The structural analysis of the excogitative digital art necessitate the originality in the abstraction mechanisms, and the careful statements in the validation steps. The formation of digital aesthetics, which may radically change the way we interpret the works in the era, is far from the maturity. Every single project is indirectly contributing to reshape a yet amorphous concept of digital aesthetics.

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