THE COMPUTATIONAL ART OF PETER BEYLS

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9 Evenings: Theatre and Engineering was an epoch-making event that took place in New York in 1969. It brought together ten artists (among them Robert Rauschenberg, John Cage, Robert Whitman, and David Tudor) and thirty engineers, all led by Bill Klüver. The engineers came mostly from Bell Labs in New Jersey, which was at that time the most advanced laboratory for electronics and information technology in the world. This event inspired other groups to explore the same path and led to the formation of E.A.T. (Experiments in Art and Technology), the first steady art/science collective, which would go on to set up many more events and installations, including the extraordinary Pepsi Cola Pavilion at the 1970 Expo in Osaka. This pavilion was dome-shaped and used architecture inspired by Buckminster Fuller. It was enshrouded in an artificial fog and featured a gigantic mirror inside, as well as a floor in which sound and laser-light experiences were integrated. Visitors received a handset with a small speaker and antenna that picked up electromagnetic signals produced by loops in the floor. Different artists and musicians created a program of avant-garde happenings with a strong technological influence.

Why did these artists and technologists come together? Bill Klüver, chief stimulator of E.A.T., stated the motivations as follows: "The artist is a positive force in perceiving how technology can be translated to new environments to serve needs and provide variety and enrichment of life. He may be the only one who can transcend cultural bias and deal with the individuals of a culture on their own terms. The direct, straight-ahead sensibility of the active artist is needed in these difficult problems. Based on this commitment to the artist, one of E.A.T.'s objectives in relation to the Pavilion was to demonstrate physically the variety and multiplicity of experiences that new technology can provide the individual." (Klüver et al. 1972)

The *rapprochement* of artists and technologists in the early seventies was the artistic and technological context in which Peter Beyls started his remarkable career and his work is driven by similar motivations as stated in the E.A.T. manifesto: to create new experiences that technology can provide, but also to transcend cultural bias and ensure that the dialog between technologists and humanists is kept intact. Beyls has a very strong background in both electronics and software, but he has at the same time the sensitivity and training of an artist. He is therefore in an ideal position to bridge the gap between technology and art and to be the "positive force in perceiving how technology can be translated to new environments."

Beyls' early works are magnificent examples of *glitch art*: the physical manipulation of electronic devices (by means of circuit bending, for example), so that errors or unexpected side effects are created and aestheticized into artworks (Reichardt 1968). He used this approach—still actively pursued in the digital domain of today (Krapp 2011)—in the cybernetic modifications of television images—as was the case, for example, with *TV01* (1974), which manipulated broadcast images in real time by interfering directly with the electronics of the TV set—or of sound sources—as was the case in *Sea/Air* (1976), a work that performed real-time audio processing by using a self-built hybrid signal processor. Other early works show links to the Arte Povera movement, exploring the resonances of natural objects, such as in the piece *Sound Sculpture* (1974), which created a continuous soundscape using four metal sheets, electro-acoustic oscillators, and power amplifiers. Many of these works originated when he was working at the IPEM in Ghent, which was at that time one of the major institutions in Europe active in the domain of electronic music, with leading figures such as Lucien Goethals and Karel Goeyvaerts.

However, Beyls very soon began to deviate from the main trends in the early seventies to find his own unique voice. He began to participate in—and help to shape—the movement towards digitality that a small group of pioneering artists had embarked on. In the late nineteen-sixties, computers were only available for numerical calculation. This was the time when programming was done by punching cards and programs were executed once a day using a

batch system. Real-time interactivity was out of the question and very few people had access to computers. In the early seventies, however, the digital revolution was beginning to take off. The first microprocessors in which most of the functions of a computer were integrated in a single circuit were achieved in 1971—with the use of a 4-bit processor! The first microcomputers were becoming available around 1975, and pioneers like Alan Kay at Xerox PARC in Palo Alto began to see the dawn of personal computers very soon after that, and Apple Inc. was founded in 1976. Beyls was right there when it all started and he has to be recognized as one of the few true pioneers of the computational arts in the seventies (Brown et al. 2009).

There are of course many ways in which computers can play a role in art. For visual artists, the computer has now become a standard tool for recording, storing, manipulating, reproducing, and distributing graphical works. The artist in this case uses existing programs that empower his or her methods of work. The same is true for musicians who use software for composing or rendering their musical scores, and for distributing music over the Internet. In contemporary installation art, the use of computers goes one step further, because the computer controls the movement of physical objects, possibly after sensing aspects of the environment or the actions of spectators. However, the artists here almost invariably rely on programmers to execute their ideas, in the way that architects bring in builders and technicians to realize a building.

For Beyls, however, the use of computers is quite different, simply because he is able to program computers himself. He is like a painter who makes his own painting, or the sculptor who physically works with materials like marble, steel, or wood. An interaction then appears between the medium and materiality on the one hand, and the activity of creation on the other. This interaction gradually shapes the artwork. The only difference with the painter or sculptor is that for Beyls, the medium is computer programming. This makes the art of Peter Beyls truly computational.

Beyls talks about this creative process as *conceptual navigation*. He writes programs defining a process for creating a visual or musical work, and then interacts with this process, constructing materializations, which are subsequently used in a self-reflexive loop to change the programs again and explore other areas of the landscape of computer programs. The programs are therefore similar to the genotypes of living systems. Genotypes co-determine through a complex process of development and environmental influence what the organism (the phenotype) looks like, and the organism tests the viability of the genotype through its interaction with the environment. The programs of Peter Beyls are genotypes and the materializations are the phenotypes that confront the viewer.

Generative devices

In the earliest examples, such as the *RPX* series (1974–1975), the programs focused on drawing structures on a piece of paper using a plotter and blue ink [006, 191]. Beyls is here using a programming paradigm later formalized by Seymour Papert as "Turtle Geometry" and used as the basis of the Logo programming language. We can imagine a turtle that is moving around on a surface, possibly turning according to given angles. There is a pen under the turtle that can move up and down. You can draw a triangle, for example, by having the turtle go 50 steps forward with the pen down, then make a right angle of 120 degrees and move again 50 steps forward, before making another 120 degree turn and moving another 50 steps. As a side effect, the turtle will have drawn an equilateral triangle. More generally, using these very simple primitive building blocks, you can make any kind of drawing (Abelson & diSessa 1981). Things get even more interesting and open-ended when the movement rules incorporate an element of randomness. For example, rather than simply going 50 steps forward, the turtle might first generate a random number "r"—that might be between 10 and 50, for example—and then move r steps further. Or instead of drawing just 3 lines, the turtle may move forward a random number of times and each time turn at a random angle. You will of course only rarely end up with a regular shape like a triangle, but a never-ending menagerie of geometric objects will result.

Randomness was a *hot topic* in art and science in the seventies (Haks 1972), as seen for example in the work of Xenakis, but Beyls used it as a vehicle for realizing his idea of *conceptual navigation*. By defining a set of basic geometric building blocks and a set of choice points

[192] Peter Beyls, *EWA (v1)*, 1984, dot-matrix printer transfer and watercolors, 230 mm x 253 mm

determining the size, orientation or other parameters of geometric figures, a particular drawing is on the one hand very constrained by its predefined building blocks, but also very open, due to the random choices that the program itself can make. Each drawing thus presents one point in the infinite space of possible drawings that the artist has defined using a single computer program.

The earliest plotter drawings of Peter Beyls remind us aesthetically of the work of American minimalist artists and artists participating in the NUL-movement in the Netherlands (like Jan Schoonhoven), or the ZERO movement in Germany [191] and they resonate with the earliest digital works by Dutch artists such as Peter Struycken or Remko Scha (Fritz 2011). In later experiments, the drawings became less rigid and the objects were hand-colored. This results in works that are more playful. They evoke joy and the artificial structures seem to move around on the paper. Indeed in more recent work, such as *Petri* (2010), the same techniques are used to produce moving images and control is no longer uniquely due to random number generators, but to human participant interaction. This evolution reflects a general tendency in the work of Peter Beyls to escape rigid mathematical structures in order to achieve life-like forms and movements by appropriating generative techniques gleaned from biology.

Figure [191] and figure [192] display an evolution in the generative plotter drawings from the early works in the seventies to more lifelike forms in the eighties.

In later decades, Beyls would continue this line of artistic research using other programming paradigms. In particular, he pioneered the use of cellular automata, originally invented

by Stanislaw Ulam in the 1940s, for creating artistic work in auditory media. A cellular automaton consists of a regular grid of cells. For example, consider a matrix of 10 by 10. Each of these cells can be in a particular state, typically on or off, but there can also be more variation, for example, with cells having differently hued color values, or different musical tones. Each cell also has a rule on how it is going to change based on the state of the neighboring cells. There is a global clock, and all cells update each other to the next state with every tick of the clock. It turns out that with this simple device you can generate amazingly versatile forms, and even create a cellular automaton that makes copies of itself.

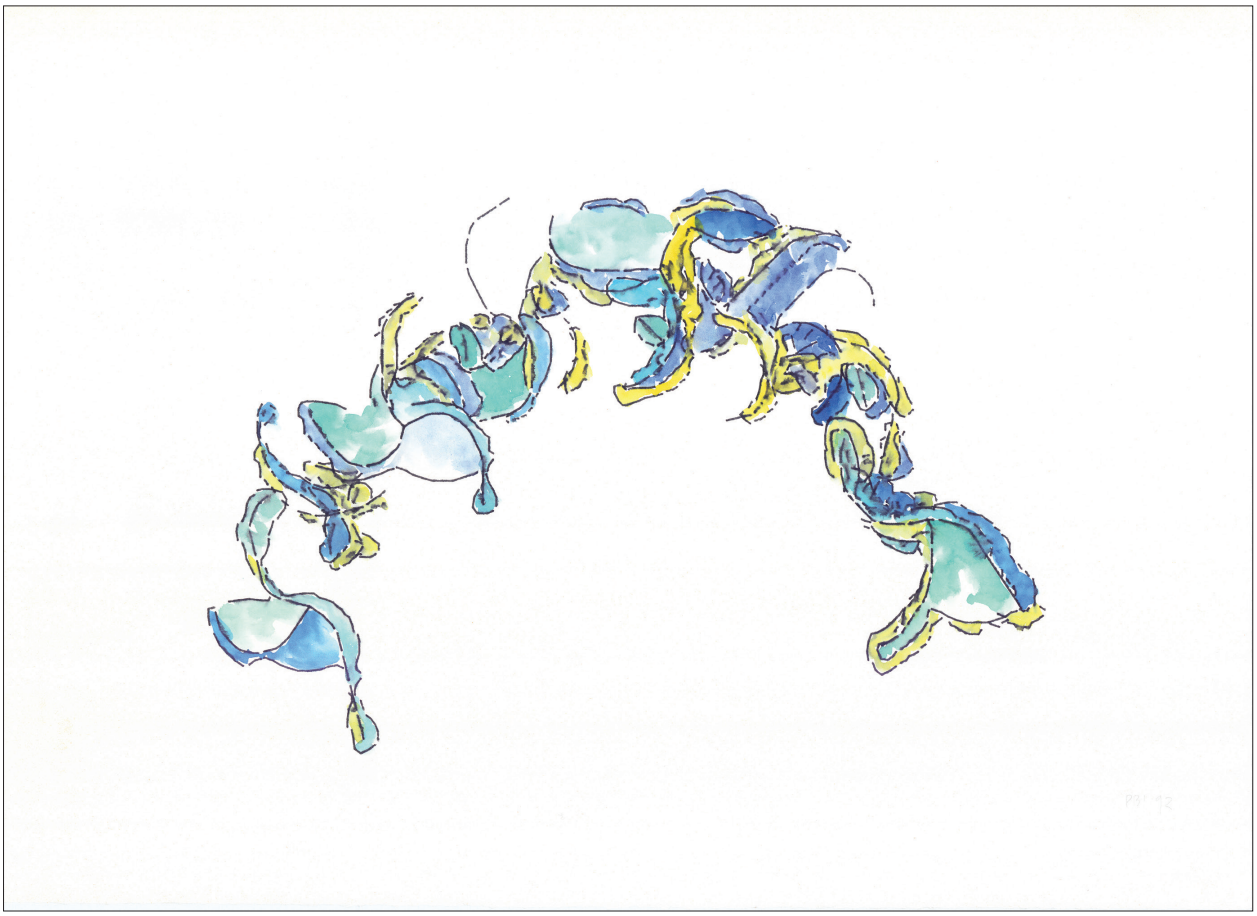
Figure [195] depicts the interface of a computational workbench developed by Beyls for using cellular automata for musical composition. The idea here was to think of the implied automaton rule as a genotype and make it available for genetic optimization through a procedure known as *aesthetic selection*.

On the left side we see a pane with the different steps in the operation of the cellular automaton (from top to bottom). We see on the right (in the middle) the *rule inspector*; it shows how the current state of the cells is about to change for the next time instant. The right top pane shows a *piano roll* representation of the score that will be synthesized. The composer is able to select and manipulate the mapping programs that will transform states of the automaton into music.

Beyls already started to use cellular automata in the nineteen seventies when working at the Slade School in London. He developed a versatile framework for exploring cellular automata, typically using regular lattices and 5 x 5 matrices for the update rules [144]. The cells are initially filled with random values and then the automaton goes through a sequence of time steps creating a pattern. The main breakthrough introduced by Beyls is to use first a cellular automaton to create a complex self-organized pattern, but then to add a sophisticated additional mapping program that analyses the patterns in order to extract structured objects that can then be turned into visual or auditory shapes (Beyls 2004). For example, some aspects of the state of the cells are used to define a melodic contour, and others are used to determine the harmony or the rhythm. The mapping programs that Beyls developed integrate elements of traditional harmony using techniques from expert systems and knowledge representation. As a result, his cellular automata create a rich tapestry of sounds and images with a definite coherence, but also endless unpredictable variation.

The construction of complex objects almost invariably involves a search process, and this is no different for artistic objects (Steels 1986). That is why constraint

[193] Peter Beyls, *EWA (v3)*, 1987, color pencil on laser print, 120 mm x 155 mm



[194] Peter Beyls, *Untitled*, 1990, drawing, ink and watercolor on paper, 571 mm x 770 mm

optimization is a significant part of the research into computational creativity (Pachet & Roy 2011). For example, the harmonization of a melody can be viewed as a complex constraint optimization problem, where the constraints are given by the rules of harmony, such as: avoid parallel fifths. When working with cellular automata, Beyls had to address these issues, but he moved the search process up to a higher level. Not only is there search in the process of mapping the automata to audio or visual output, but there is also search in the space of possible constraints, similar to the artist who is developing a new style and introduces or retracts some of its defining characteristics.

Beyls has explored many other programming paradigms, including genetic algorithms, neural networks, molecular collision simulations, Lindenmayer systems, constraint optimization algorithms, and most recently, machine learning techniques. He has constantly searched for new ways in which computation can be expressed and in which complex adaptive systems can be exploited for creating rich interactive artworks.

Can computers be creative?

In his now classical paper, "Creativity and Computation" (Beyls 1993), Beyls asks the question: "Can we build machines that merely simulate human creative activity or is there potential to emulate true creative thinking in computer programs?" This question does indeed go beyond the works

described earlier, where a computer program generates a work based on the design of its creator, but the program itself is certainly not creative. What extra capabilities would be required?

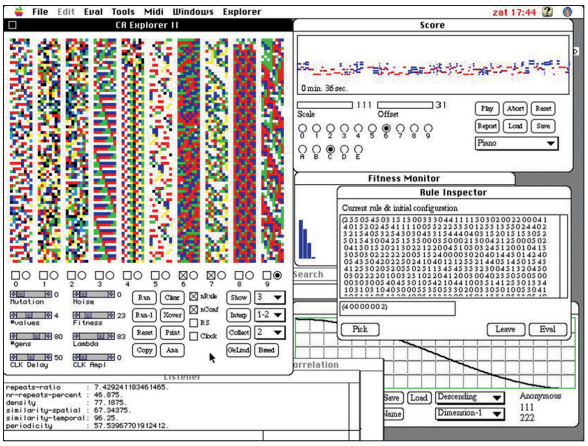
Beyls suggests that creative programs need first of all to have the capability to self-reflect on their own production using esthetic criteria, just like the painter or composer continually inspects his or her own work and then decides how to further complete it, or rejects the result altogether. This type of self-reflection is only possible if there are sophisticated processes available for recognizing patterns and for interpreting these patterns using the kinds of structures that humans use to interpret artworks. Moreover, the interpretation should then lead to a change in the style, or at least in the way that the work under construction is further evolving.

Second, Beyls stresses that great art is about meaning and often involves both physical embodiment and social grounding. In his concrete practice, Beyls has focused mostly on the self-reflection aspect, particularly in the audio domain, even though he has also worked on how motivations (Beyls 2009) or social interactions within societies of musical agents (Beyls 2011) could be integrated in the production of the artwork.

Sea/Air (1976), his first work in this direction, used a hybrid digital signal processor to extract information from the audio signal (starting from amplitude and duration) and employed the outcome as parameters of a sound synthesis program. In the eighties, the field of pattern recognition and AI developed more and more sophisticated techniques and personal computers and soundcards became more affordable, so that more and more interesting sound analysis could be done in real time, thus preparing the ground for programs that would not only produce sound, but also could listen and interpret what they were producing. Beyls followed these developments closely and was able to incorporate them in his artistic practice.

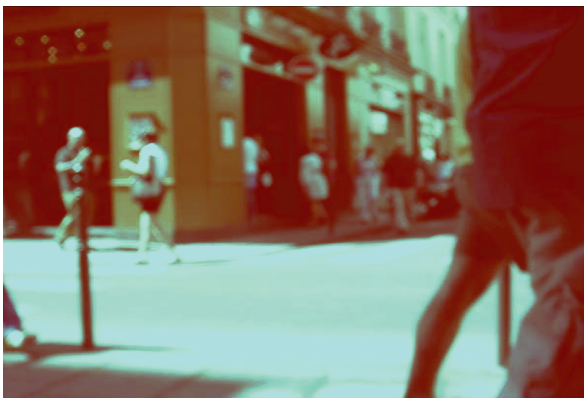
Typical for this line of work is a series of ever more sophisticated programs called Oscar (which stands for *Oscillator Artist*). These programs were designed to be companions in live performance. The first versions of the program were already being developed at the VUB Artificial Intelligence Laboratory in Brussels in the nineteen-eighties [202] and new versions are still being developed today (Beyls 2011). Oscar *listens* to the human performer and reacts, while still maintaining an internal *persona*. Oscar thus provides the platform for achieving the self-reflection that a creative computer program needs to have.

One of the most remarkable aspects of Oscar is that, internally, the musical persona of Oscar is also

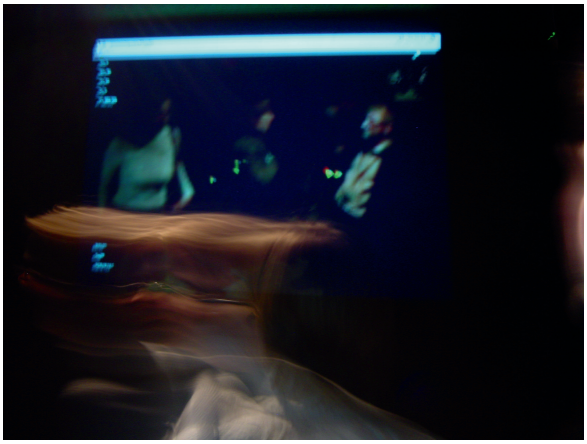


[195] Peter Beyls, 1994, *Cellular Automata Explorer II, software*

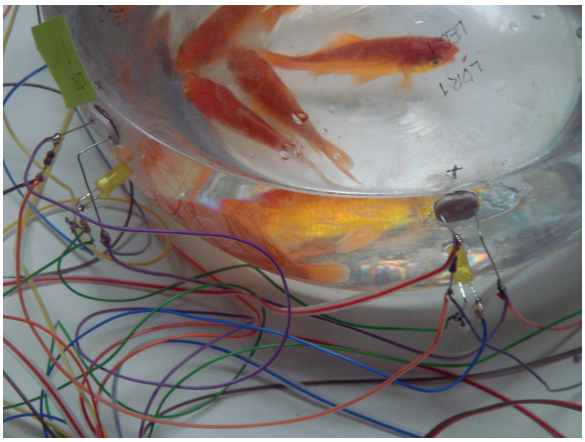
[196] Peter Beyls and Rudi Blondia, *Biotope*, 1983, software, computer, sensors, loudspeakers and amplifiers, variable dimensions



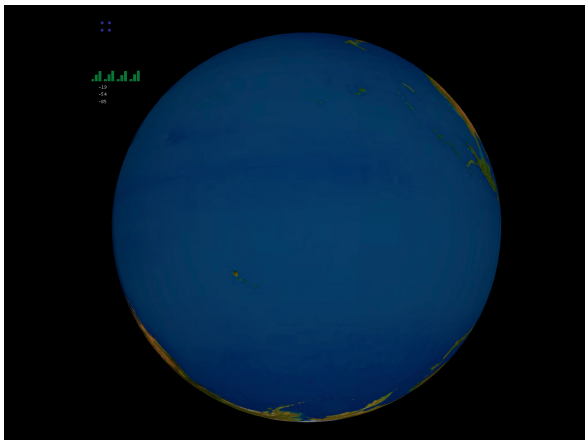
[197] Peter Beyls and Jerry Galle, *DataScript*, 2010, audiovisual installation, variable dimensions



[198] Peter Beyls, *Fingertips*, 2005, audio-visual installation, variable dimensions



[199] Peter Beyls, *Fish*, 2013, software, live fish, display, audio, variable dimensions

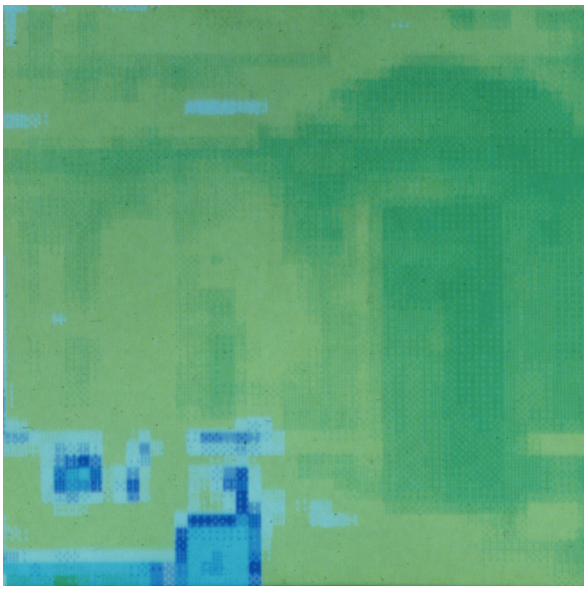


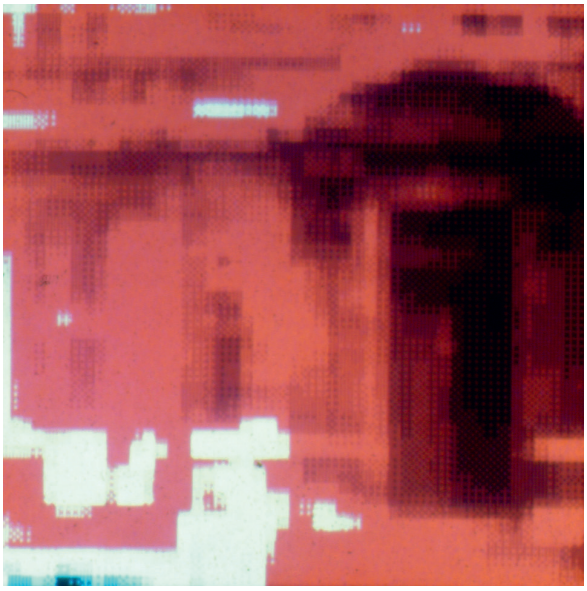
[200] Peter Beyls, *SpinningGlobe*, 2010, audio-visual installation, variable dimensions

implemented as a *society of agents*, inspired by Minsky's *The Society of Mind* (Minsky 1988). Agents are autonomous software entities that operate according to a specified rule (just like the cells in a cellular automata), but the agents are not bound to a particular cell. They freely move around in space and have internal states, in particular an internal energy state that is affected by their own internal rules and by the state of the environment. Beyls imposes rules that reflect cooperation and antagonism among the agents. They may occasionally cluster together or disperse. They may take turns in producing a melody or some visual animation, or interfere with each other. They thus create highly complex nonlinear temporal superstructures of great plasticity, opening up landscapes of visual animation and sound that constitute an entirely new experience. It is like watching and listening to a society of living creatures, or to the complex molecular processes that sustain life.

Figure [202] documents Peter Beyls in 1988, performing with Oscar on a piece called *The Headless Horseman*, at the computer music festival that was organized by the VUB Artificial Intelligence Laboratory in Brussels in 1988. Beyls uses a saxophone enhanced with electronics as an input device. He engages in a dialog with a computer music system that has its own persona.

Peter Beyls has traced out a fascinating trajectory in his artistic work. Thanks to his engineering background in both hardware and software, he is able to grasp the most advanced and novel concepts in computer science and appropriate them for his artistic work, in a way that is similar to a sculptor who researches the most novel technical materials and production processes and translates them into novel experiences. His intellectual and artistic growth has been remarkable, moving from plotter programs to responsive interactive systems and instruments, then towards more adaptive systems that are able to sense their own environment or their own production, to evolutionary systems that themselves explore a landscape of possible styles and constraints, and finally to systems that contain a machine-learning component and exhibit motivation and social interaction. This evolution went in parallel with incredible advances in computer technology and computer science, and in entirely new ways in which our society interacts with information technology. Beyls' work is already awe-inspiring and stands as testimony to how creative art and creative technology can go together and mutually benefit each other—but his work is far from finished. It will be fascinating to see how he will be able to appropriate and push forward new ways of marrying computation with artistic practice.





[201] Peter Beyls, *Untitled*, 1981, 35mm color slides, 24 mm x 35 mm

[202] Peter Beyls, 1988, *The Headless Horseman*, live performance at VUB, Brussels

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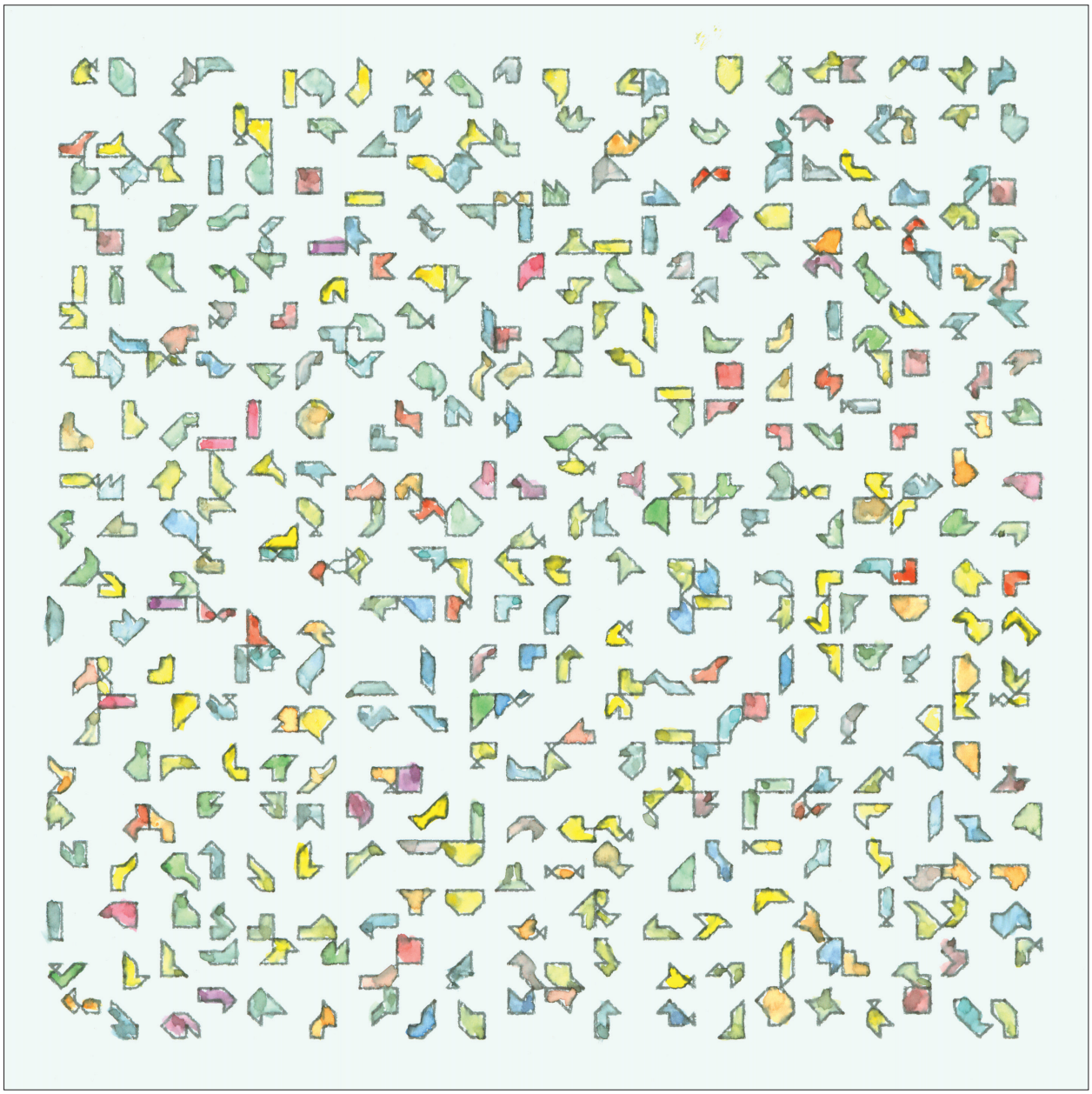

[203] Peter Beyls, *Untitled (GTT)*, 1992, drawing, ink on paper and watercolor, 690 mm x 590 mm