Art.Machines.Intelligence

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Abstract:
I will present some thoughts about the potentials that lie at the intersection of art, machines (including AI) and intelligence. I wish not simply to give an overview of today's practice by artists using, or sometimes developing, some aspects of the use of machines in their practice, but rather discuss why there is great potential in the mixing of these disciplines. To do so, I will characterize each of the three topics. My descriptions of these topics will be far from complete overviews, but sufficient I hope to make clear how I consider the potentials offered by considering the junction or fusion of the three topics of art, machines and intelligence. I will give also some recent and current examples of practices and projects of artists I have engaged with, where the three disciplines are brought together. Finally, I suggest that rather than fixate on artificial general intelligence, we ought to focus on more reasonable objectives such as Art.Machine.Intelligence.

This article presents an overview of my thoughts about the potential lying at the intersection of three topics: art, machines (including AI) and intelligence. Besides offering a glimpse of projects by artists who use machines in their work, I shall discuss the reasons why the fusion of these three has such a large potential. For this purpose, I shall describe each theme. My descriptions will probably be skewed and far from complete, but they should be good enough, I hope, to show how this fusion might be achieved. A few recent examples will then be mentioned of projects by artists with whom I have worked, examples that bring these three topics together.[1]

But let us start with a theme at the heart of this article: artificial intelligence (AI). The *Cambridge Dictionary* defines it as: "*the study of how to produce machines that have some of the qualities that the human mind has, such as the ability to understand language, recognize pictures, solve problems, and learn*". An example would be to learn to play a musical instrument.

By the way, I make no *a priori* distinction between mind and body, as readers will notice hereafter. On this point, I am following the advice of the neurologist Antonio Damasio (1994). Since I want to deal with the very issue of what is intelligence, I would like to concentrate on the qualities or capacities that a human being has but that, to the best of our knowledge, no other species has (or at least not to the same degree), namely: language, the arts, writing, creativity, the use of tools, the sciences, the invention of mathematics and the accumulation of knowledge and continual expansion of our cognitive horizon over a long period (LEVIN 2019). I shall concentrate on the arts while not leaving aside the other capacities, since they are not completely separate from each other.

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[1] I would like to thank Arnaud de la Fortelle (MINES ParisTech) for his suggestion to submit an article on art and artificial intelligence while letting me free to choose the angle. This article, apart from the abstract, has been translated from French by Noal Mellott (Omaha Beach, France). The translation into English has, with the editor's approval, completed a few bibliographical references.
All websites were consulted in July 2021.

The arts are to be taken in a broad sense, to cover at least the visual arts (drawing, calligraphy, painting, sculpture, animation, cinema and their extensions, such as computer games) and, too, music, singing, sonification, architecture (including landscaping), literature (in all forms), and various "crafts" (such as pottery, woodwork, clock-making). The examples cited herein will mostly come from the visual arts, a personal preference stemming from my experiences and interests in research in the graphic arts, vision, perception and creativity. Besides focusing on the production of artworks, I shall examine how they are appreciated and evaluated and how they bear information. I shall not insist (too much) on the cultural or historical aspects of art (variations between cultures and periods), nor on its economic or social impact (a topic deserving a separate, deeper discussion).

Art

According to the *Encyclopedia Britannica*, visual arts refer to: "*a visual object or experience consciously created through an expression of skill or imagination […] the visual arts exist within a continuum that ranges from purely aesthetic purposes at one end to purely utilitarian purposes at the other*". Here are the themes associated with the arts that I deem relevant to this discussion:

- PRODUCTION refers to the actions by artists that involve using the body (in an expert way) and, often, extensions of the body with the help of tools (*e.g.*, paintbrushes and pencils) and techniques (Many of them developed down through history: they evolve, are forgotten, reappear) as well as the observation and feedback that take place during both the creative process and the visual evaluation of artefacts.[2]
- REFLECTION refers to the perception necessary for creating and observing artefacts. This act implies: decisions and comparisons; the planning of actions and movements; the use of tools and materials; the historical legacy that influences an artist's style and exploration of new ideas (acquired mainly during schooling, education or while in apprenticeship in an artist's studio); artists' memories of their own previous creative experiences and past production; the cultural melting pot in which we live and that influences an artist's creativity; the meanings and discourses associated with artefacts; and the interpretations and evaluations of observers.
- COMMUNICATION refers to: the representations of knowledge that can be communicated graphically, visually; the archiving of experiences, ideas, memories, messages; and the history and successive changes that lead to an artwork in the highest sense (*e.g.*, Leonardo da Vinci's *Mona Lisa*).
- FEELINGS: arouse emotions through (visual) memories; cause or represent pleasure; depict relations between human beings, or between them and their milieu or nature; and evoke a person's character (in a portrait or sculpture, such as Rodin's *Monument to Balzac*).
- ANALYSIS means: discovering the various ways of projecting an idea, a landscape, a portrait, an interpretation; making "visible" and visually comprehensible a complex phenomenon or situation (*e.g*. techniques of portrayal in the anatomical drawings of Leonardo da Vinci, Michelangelo or Vesalius); visually interpreting theories or ideas about the world (*e.g.*, in physics, medicine or chemistry); and externalizing our reasoning in sketches, diagrams, preparatory drawings.
- CREATIVITY means: pushing the limits of perception; illustrating and documenting our imagination, dreams, fears, obsessions, passions; and inventing new visual symbols.[3]

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[2] The influence of paint marks on the decisions made, as in the execution of a painting (ARNHEIM 1974).

[3] Art, we assume, was the cradle of writing. The first traces of visual art date back at least 30,000 years: the cave paintings in Altamira (Spain,) Chauvet (France) or Sulawesi (Indonesia). The carving of motifs and forms in rock dates back at least 300,000 years (BEDNARIK 2003). The much more recent origin of writing (approximately 6000 years ago), as reflected in visual symbols (logograms), appears to be a direct extension of the earlier forms of primitive art.

I would like to convince readers that art provides us with a vantage point for examining (human) intelligence. Art (its practices, media and results) evolves in hand with the advances made on our most sophisticated tools, namely: machines.

Machines (and computers)

Usually designed as extensions of our body or aptitudes, machines are now, and since at least the start of the industrial revolution, our most advanced tools. Their principal constraints, which set them apart from other tools, have to do with energy requirements, the quality of available controls, and their potential for transforming matter or the environment. The autonomy and sophistication of the control of machines have increased with the invention and ongoing development of electronics and computers. Herein, I shall concentrate on machines with electronic (digital) components that enable them to "feel" the world (sensors) and "calculate" (*i.e.*, use collected data to reason about a subject). These machines are programmed to perform actions, to react to altered conditions and perceptible events, to inform, and to process data about the world, usually with a limited or narrow scope of action.

Electronic (or digital) machines must be seen as distinct from more primitive tools that cannot be programmed. The evolution of tools into programmable machines has followed the evolution of *homo sapiens*. The first evidence of artistic practices comes from hundreds of thousands of years ago, namely rock carvings.[3] Down through history, our species has developed its ability to act on the world and transform matter by using and adapting tools, partly through artistic activities. This evolution went "hand in hand" with the evolution of its intellectual aptitudes.

Intelligence

My definition of intelligence is based on a being's capacity to act in the world, react to the world and deepen its understanding of the world — in an autonomous manner. This is general enough to apply to all living beings. I think that all species have intelligence, of various levels. Human beings have a more diversified set of aptitudes than other species. In particular, they are the driving force in the evolution of their aptitudes — of their acquired knowledge, cognitive representations and even understanding of the world.

Here are a few of the major dimensions of the expression of human intelligence:

● PERCEPTION. Perception of the world via our senses is controlled by "user interfaces" integrated in our nervous and haptic systems (HOFFMAN *et al*. 2015, KOENDERINK 2019). These interfaces enable us to understand the world in- and outside our bodies. Take the example of our perception of colors. Our nervous system produces colors as it tries to understand what we have visually perceived. Another species exposed to the same electromagnetic signals will have a different interpretation based on its palette of colors (which has come out of its evolution). For human beings, colors are learned (thus related to culture) and can evolve, as finer distinctions are made with language (thus associating finer meanings to percepts).[4] We perceive objects as forms or shapes with which we associate functions. Various objects can be used as a "chair". These forms, which are part of our interface with the world (LEYMARIE 2011), are to be distinguished from the object's "physical" nature (*i.e.*, the assembly of molecules composing it). This is similar to the icon on a computer screen that represents a folder and is related to a physical space in the

[4] For instance, the color "blue" did not exist in Ancient Greek. Homer described the sea as the "color of wine". Nowadays, some tribes still lack the notion of blue. For example, the Himba make no actual distinction between green and blue; but they have many more words than us city-dwellers for variants of green (ROBERSON *et al*. 2006).

machine's memory. However there is no literal folder in the machine, but the form of the folder makes us think of its finality and potential functionality (HOFFMAN *et al*. 2015, KOENDERINK 2019).

● COMMUNICATION. We use our nervous system and haptic perception (and the rest of the body), which are interrelated, to receive and emit information. We use language, gestures, facial expressions, visual contact, bodily postures, odors and much more to express ideas and feelings and to send subtle messages.

● ACTIONS. We move in the world with our bodies. We grasp and manipulate objects in an exploratory mode.

● ANALYSIS. Reason, observe, conclude, compare and make choices.

● LEARNING. We learn through our experiences, by playing and repeating. We learn from others, through schooling, books and other forms for "archived" knowledge. We improve our skills through contacts with those who teach us. We learn through the mental representations we express via drawings and sketches. The advancement in the representation of forms and other concepts in children's drawings is typical of this learning process (GOLOMB 1994).

● MEMORY. Memorized experiences orient our future decisions and actions. We (probably) organize and prolong our memories while dreaming.

● CREATIVITY. We innovate. We associate objects and concepts in new ways. We reinterpret mental representations of the world.

● TOOLS. We design tools, as extensions of our body under the control of our intelligence. Tools enable us to better use the sources of energy found in nature. They evolve with us, under our control. Some tools can extend our range of sensations (*e.g.*, to visualize molecules or galaxies).

I hypothesize that the evolution of intelligence, which we assume to be at its most advanced stage among modern human beings, is closely related to the co-evolution of our tools. Tools have pushed us to explore the world in a more granular, powerful way. The most recent result of this co-evolution can be seen in machines, in particular those that can be programmed and endowed with autonomy — that "externalize" (part of) intelligence.

An interesting historical fact: the first programmable machines emerged in the crafts. In 1768, Pierre Jaquet-Droz, a Swiss clockmaker and the student of Daniel Bernoulli, designed and built a human shaped automat called the "writer". Among its approximately 6000 parts was a programmable wheel, in which forms could be interchanged. Each of these forms was like a memory (the ancestor of a disk with instructions) that could be deciphered so that the automat would write a message (while moving its body, eyes, etc.) — up to forty characters at a time. This "writer", along with two other sophisticated automats (the "draughtsman" and "musician", also easy to reprogram) can still be observed at work in the Museum of Art and History in Neuchâtel, Switzerland. The next major step in programmable machines came at the start of the 19th century (*ca*. 1805), when Jacquard invented the loom. Designed to make weaving more efficient, this machine's actions and patterns were programmed by using folded, perforated cards. This way of printing code was used by computers till the 1980s. The following steps made during the 19th century were the Babbage difference engine (in particular the analytical programmable motor) and the conception of algorithmic programs and code by Ada Lovelace. During the 20th century came Turing, von Neumann and the modern computer and its offspring (HEY & PÁPAY 2014).

… and AI

Some people consider that the conception of our most advanced machines and the progress made on them are distinct from the study of human nature. If we examine the origins of artificial intelligence (AI), we are led to seeing things differently. AI emerged from the following: "*conjecture that every aspect of learning or any other feature of intelligence can in principle be so precisely described that a machine can be made to simulate it*" (McCARTHY *et al*. 2006). Modern (electronic) machines can thus be seen as a natural extension of our intellectual development as a species capable of designing its own tools, means of communication and mental representations of the world.

Given these considerations, the following proposal has been formulated: topics related to the arts (*e.g.*, creativity or expertise) or machines (*e.g.*, design, engineering, controls and applications) can be brought together to help us study and understand the shaping of human intelligence. This can also help us augment our intellectual capacities. More simply, this approach might duplicate or simulate some of our aptitudes as imagined in the proposal for the summer workshop on AI in 1955 (McCARTHY *et al*. 2006) or even by Turing (1950).

The rest of this article describes four flagship projects and the artists associated with each as examples of how the threesome art/machine/intelligence can be brought together (in various ways).

Art.Machine.Intelligence in practice

Organic computer art: William Latham — How to simulate and stimulate creativity?

In the 1980s, William Latham, then an art student at the Royal College of Arts in London, often walked down Exhibition Road to the Natural History Museum, where he contemplated for hours nature's creativity and the diversity of the forms produced. Thus inspired, he invented a creative method based on his interpretation of how biological evolution led to the creation such a diversity of forms. The algorithm (called FormSynth) had simple rules and was iterative (TODD & LATHAM 1992). Latham drew various trees of evolution (Figure 1) on large, long rolls of paper (*e.g.*, 2 m x 8 m). Realizing the practical limits of this approach, he joined, in the late 1980s, IBM's research center near Winchester. A new activity was launched at the junction of art, science and the fast evolving discipline of computer graphics. During his work there, he struck up a long-term (still ongoing) partnership with Stephen Todd, an inventor and computer scientist who has filed more than eighty patents. Together, they contributed to creating a discipline called "computational, evolutionary art" (ANTUNES *et al*. 2016).

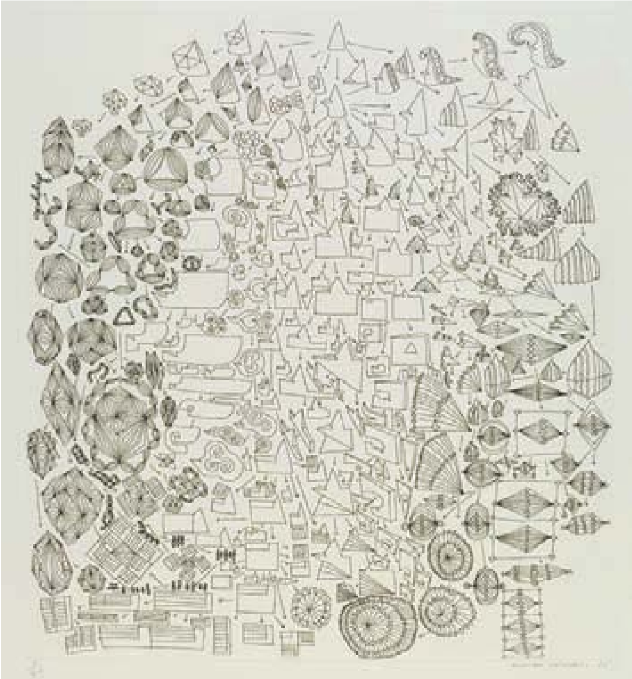

Figure 1: *FormSynth* by William Latham (*ca*. 1985): an artist uses trees of evolution to explore the diversity of forms.

FormSynth was turned into a computer program that resulted in a much more sophisticated system more closely linked to biological evolution (TODD & LATHAM 1992, LAMBERT *et al*. 2013). In this system called Mutator, mutations and marriages produced descendants in a pseudo natural way (*e.g.*, two or more "parents" providing their "genes" in the form of sequences of code with instructions for assembling forms with associated characteristics). This simulation of an acceleration of evolutionary processes was done under human control. The artist played the role of the geneticist-gardener who selects the most promising descendants as a function of their perceived aesthetic value (Figure 2).

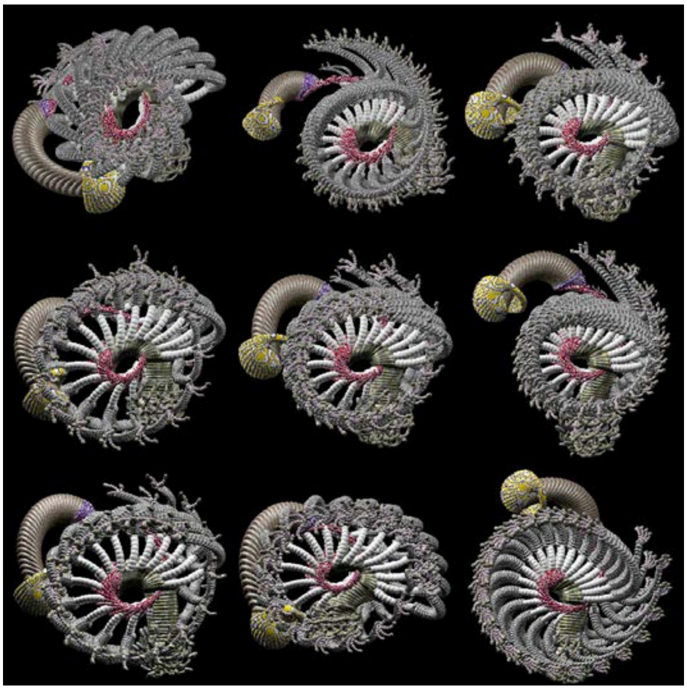

Figure 2: *Mutator* (TODD & LATHAM 1992), a computer program combining *FormSynth* with a simulation of high-speed evolution. Nine complex forms evolved, but only one subset was chosen for the next iteration-generation (through marriage and/or mutation).

In the mid-1990s, Latham turned to the fast-growing field of video gaming and set up his own studio. When I met him *ca.* 2005, I convinced him to join us at the University of London, where he resumed his pioneering work. Stephen Todd joined him, once again; and together, they returned to their original work but with new eyes. Reworking the original evolutionary system, they turned it into *Mutator VR* (Figure 3). Benefitting from the progress made in computer science over the previous two decades, artists or users/observers can immerse themselves in digital evolutionary processes (LATHAM *et al*. 2021).

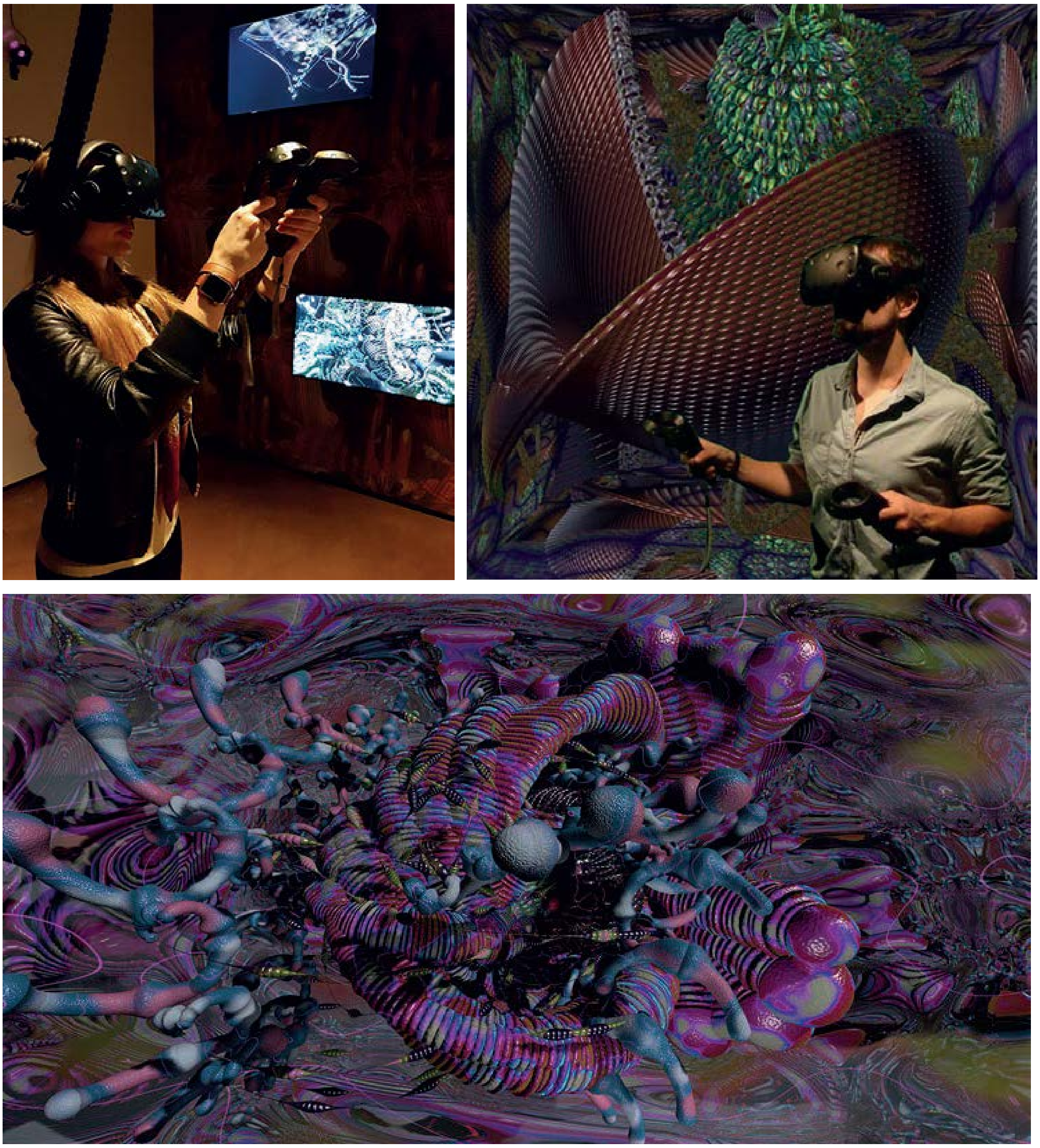

Figure 3: *Mutator VR* (LATHAM *et al*. 2021) with examples of immersive installations (top row) and an inner view of an imaginary universe (bottom row).

The history of art (and design) can be read like an evolutionary tale. The ideas and techniques of the past shape subsequent generations of creators. The skills and aesthetics of the past are part of the creators' artistic DNA. Some creators will modify this DNA, sometimes radically, while taking part in the process of evolution down through the centuries. What contemporary artists like Latham have come to realize is that computers can awesomely accelerate the simulations of a relatively slow evolution of creative processes. The use of computers equipped with sensors (cameras, microphones) and output devices (screens, loudspeakers, virtual reality headsets) or other user interfaces (such as manual virtual reality controls that provide haptic feedback through vibrations) also opens new possibilities for revealing the artist's private thoughts (or imagination): how a model of a traditional practice of art (sketches, iterations, improvements, the final product) can be made and turned into an interactive computer-run platform capable of immersing a person more intensely in the artist's creative world. Such a machine becomes a new interface with which the human mind interacts.

Portraits and robot art: Patrick Tresset — Incarnation and the body

I met Patrick Tresset, an artist on the visual arts scene in London, when I came to the capital at the end of 2004 to start the first master of science of Computing Arts (later renamed master of arts of Computational Arts) in the United Kingdom. Trained in computer programming during his studies in France, Tresset had set himself up in London about fifteen years earlier as a visual artist, who explored different genres, ranging from portraits to abstract painting. He became part of the first generation of students and researchers with whom I had the pleasure of working when I joined Goldsmiths (a satellite college of the University of London).

Tresset had come to the master's program at Goldsmiths to explore how to better combine his programming experience with his enthusiasm for the visual arts and creativity. One project he was busy on during this period stood out from the others: the attempt to build a model of his own artistic practices, his skills and style for making rapid sketches and portraits. These had a visual quality quite apart from computer artworks at the time. By trying to make a model of the principal stages during which Tresset prepared and executed his sketches, we developed a software program called AIkon, or also "Artistic/Automatic Ikonograph" (TRESSET & LEYMARIE 2005, 2006). Exploring the possibilities offered by the system and its parameters, Tresset drifted toward other styles, which more or less resembled his own hand drawings (Figure 4).

Figure 4: *Alkon-1* by P. Tresset — automatic portraits with
— in the first row: initial results with rounded traces; the stele of Allat, or Al-Uzza, from the Temple of the Winged Lions (Petra, Jordan); Isaac Asimov, writer, biochemist and humanist; and Stephen Hawkins, physicist.
— in the second row: Ada Lovelace, creator of the first computer program; Buster Keaton, legendary actor and pioneer of silent movies; Hedy Lamarr, actress, producer and inventor; and Alan Turing, mathematician and pioneer of computer science.

At the end of this first project (*Alkon-1*), we were both dissatisfied. We had a working model based on the characteristics of the image or photograph on which we had concentrated during the rapid drawing of lines; but we could not recreate the subtle details in the strokes made by the artist's hand. It was hard to make a model of the hesitations, the unique nature of each gesture and the manipulation of a drawing tool or brush. After a break of a few years and with the financial backing of Leverhulme Trust,[5] Tresset was able to work with me once again. We started a second, long-term research project, *AIkon-2*.

It was 2009, and a major change had occurred in robotics. Arms could now be made at a reasonable price (a few hundred euros); they were simple, controllable devices for manipulations. Meanwhile, the international scientific community had set up platforms for programming robots. The task of sending commands to a robot thus became much easier.[6] These two advances created the conditions so that nonspecialists (in robotics) with scant funding could make and test "serious" prototypes.

[5] https://www.leverhulme.ac.uk/
[6] YARP ("yet another robot platform": www.yarp.it) was one of the software platforms popular at the time; and ROS (now the operating system most widely recognized by the international robotics community) had just been set up (www.ros.org).

Tresset ordered the first servomotors and other components. He designed and built an arm with an articulated shoulder, elbow and wrist and with a simple clip for the hand, which could hold a ballpoint pen. He also designed a robotic platform with a small camera, an “eye” that had 2 degrees of freedom of movement. He named the whole system “Paul the drawing robot”. The arm, eye and laptop computer were solidly fastened to a table, the laptop (or “brain”) underneath (Figure 5). In February 2010, Paul made his first public demonstration at the Kinetica Art Fair in London. He immediately caught the attention of the public. Long waiting lines continually formed day after day. One of the videos produced during this period for an art gallery exhibition (in London in 2011) has been visited on the Internet more than 3.4 million times. It still attracts viewers and spawns comments, some of them emphasizing the “uncanny” nature of the experience.

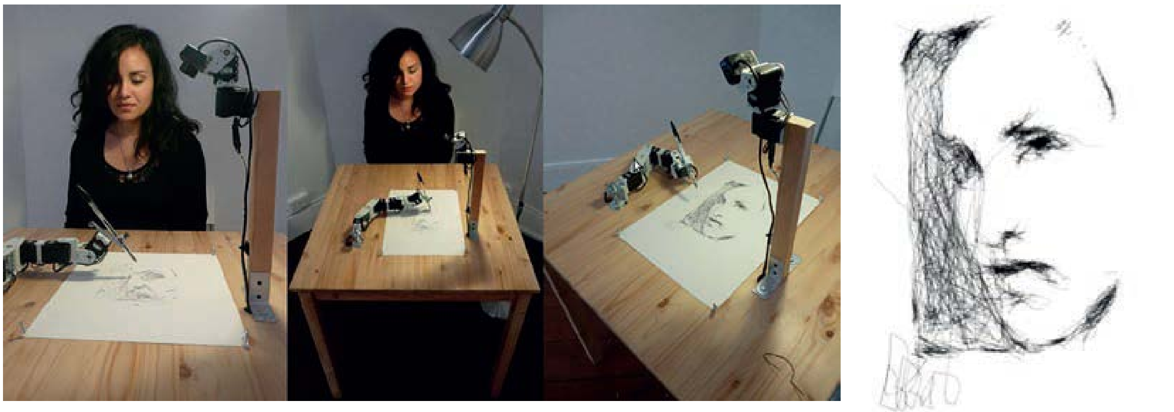

Figure 5: *Alkon-2*: *Stella*, one of the first (signed) portraits products by Paul the drawing robot, London, 2011. See: https://youtu.be/bbdQbyff_Sk.

This robotic platform more closely imitated a human hand’s subtle movements (TRESSET & LEYMARIE 2012). While designing the arm, Tresset realized that it did not need to execute a movement too well (as traditional robotic applications were doing). The robot’s arm could “naturally” tremble and not systematically reach the objectives (*i.e.*, the positions set by its control routines). Having an articulated movement in the form of a simple arm allowed for variations in the strokes produced that resembled the uncertainty observable in the output from a human artist. This research, after further explorations, ended with a publication, where we reported our first attempts to introduce direct visual feedback. Like the human artist, Paul the robot could observe his strokes and gestures via his camera-eye, which, till then, had been used only to take a view of a face of someone nearby. Its artificial brain could evaluate in real time the quality of what was drawn in order to decide on what it was to concentrate its attention while drawing (TRESSET & LEYMARIE 2013).

Figure 6: Patrick Tresset and his drawing robots. The first is a classroom full of robots, each with unique characteristics; they are following the instructions of a master robot (*ca*. 2017). The second is of five robots named Paul with the artist (*ca*. 2015).

Tresset has turned away from academia and toward art fairs, art-science demonstrations and art galleries in the United Kingdom, Europe and even worldwide (Figure 6). He recently moved his workshop from London to Brussels. In the years after our work together (in 2013), he continued improving his robots (KLUSZCZYŃSKI 2016, MADDOX-HARLE 2017). He has collaborated with other researchers and even helped firms to add drawing features to their robots.[7]

The passage from software to hardware in the form of the robot's body was an important stage in the evolution of Tresset's practice of the arts. The differences in stylistic signatures were spectacular during this passage from software solutions (Alkon-1) to a robotic system (Paul). By using this robotic body, Tresset detected a movement's subtleties and their relation to the quality of the lines drawn, while he was concentrating on designing the platform and seeing to its effectiveness.

From the viewpoint of art and performance, Paul the drawing robot became a theatrical experience for human beings. Someone stands or sits near the robot, while moving as little as possible for about twenty minutes; and the robot conducts a series of observations and drawing gestures, which end with its signature. During this "performance", the robot makes unusual noises, hesitates, looks again at the subject, seems to be reflecting, then continues drawing while watching what it is doing. This unique person-machine experience makes a lasting impression on the human subject.

Tresset has chosen to make his robots clearly recognizable as articulated machines. He is the human artist, the engineer in chief who has designed the robots and is exploring how to use them to expand his scope as an artist. The body of Paul the drawing robot has become a possible incarnation for Tresset, an incarnation that the human artist can access, control and reprogram. The robot's body is a sophisticated tool whereby the artist explores new creative possibilities.

Electronic calligraphy and graffiti: Daniel Berio — Kinematics and body movements, expertise and aesthetics

The work on robotics and portraits with Tresset attracted attention from various communities, ranging from computer science and robotics to the arts, art fairs, museums, artistic and scientific events, multimedia and museums.[8] It also attracted the attention of several would-be innovators in the arts and sciences. One of them, Daniel Berio, an Italian graffitist, decided to join my team at Goldsmiths in 2015. He had solid knowledge about programming graphics, and had just received a diploma from the Royal Academy of Art in The Hague, where he had developed his first drawing machines.

To move beyond of the results of the AIkon (1 and 2) projects with Tresset, Berio and I decided to focus on movements in the execution of the traces drawn by hand or designed. Our main hypothesis was to see how speed and acceleration affect the drawing of a trace by an artist's expert hand. Given Berio's background, we started out by concentrating on graffiti.

As a modern art form, graffiti emerged in New York City in the early 1970s before spreading around the world, in particular to big cities where new styles were invented. In its simplest form, graffiti is a sort of speed-writing with a signature or tag, or a series of forms of letters without any distinct, *a priori* meaning as a word or group of words. The goal was to make a spectacular graphic, usually on a wall outdoors.[9] This strongly affected the styles developed in which speed of execution was a key characteristic. After years of practice, the most talented street artists ended

[7] Such as the humanoid robot, Sophia de Hanson Robotics at the end of 2019: www.hansonrobotics.com.

[8] The prestigious Victoria and Albert Museum in London acquired a portrait.

[9] The first graffitists were often considered to be vandals or activists. As pointed out in the introduction, this article does not dwell on social and political issues. My comments herein focus on graffiti not as a form of protest or youth emancipation but exclusively on the graphical qualities of graffiti and the processes of producing this form of art.

up developing their own style and acquiring a mastery in the making of their artworks (ARTE 2015, FERRI 2016).

By analyzing the writing and drawing as well as the aesthetic appreciation of these activities, we came upon significant contributions from other disciplines that we had to take under consideration in order to better understand the production of graffiti and, more broadly, calligraphy. In psychology, scientists had begun at the end of the 20th century to closely study the relations between kinematics and the quality of traces (BABCOCK & FREYD 1988, PIGNOCCHI 2010). Some findings described the characteristics of the movements involved in drawing or writing. In particular, the hypothesis had been formulated that an observer could evaluate the traces seen in calligraphy by reconstructing in his brain the probable series of movements used to produce the original (FREEDBERG & GALLESE 2007). In other words, a naif observer (someone not necessarily an expert or artist) activates neurons in the part of his brain that controls motor activities, and this activation is very similar to what would happen were he to physically perform the movements (LEDER *et al*. 2012). What you see stimulates your nervous system as if you were performing the movements needed to make the sketch. Furthermore, the recognition of the use of fast, fluid movements leads to a better appreciation of the artwork; and this might, in turn, lay the grounds for a theory of aesthetics.

In computer science, a new field of scientific research had arisen during the 1980s: graphonomics (KAO *et al*. 1986). Initially focused on the engineering and building of models for recognizing or duplicating signatures and detecting counterfeits (especially counterfeit checks), graphonomics had matured to the point of proposing a few very descriptive mathematical models of the kinematics of fast movements made by the upper part of the body (torso, arms, hands) during the actions of drawing or writing (MAARSE *et al*. 1989, PLAMONDON 1995, TEULINGS 1996). To follow up on these findings, we explored the state of the art in robotics, where control routines examined, planned and executed movements on the basis of probabilities (CALINON & LEE 2019). However we did this in imprecise or adaptative contexts and using robotic architectures closer to the human body — flexible (not too rigid) in design and control. These flexible robots are often designed to conduct actions in the vicinity of human beings, in scenarios of collaboration with people. Berio's work has integrated knowledge from all these sources (BERIO *et al*. 2020a, 2019, 2017, 2017a, 2017b, 2017c, 2016 & 2015).

As we showed, it is possible to recuperate the parameters of movements (kinematics) from static traces so that the movements to be generated and the new traces will be similar to those of human experts (Figure 7) (BERIO *et al*. 2020b). We demonstrated a first learning method that enables collaborative humanoid robots to make a calligraphy of human quality (Figure 8) and produce a user interface, wherewith the human artist can easily generate and control calligraphic traces in a more natural manner that leads to a kinematics similar to that of a human expert (BERIO *et al*. 2018 & 2020a).

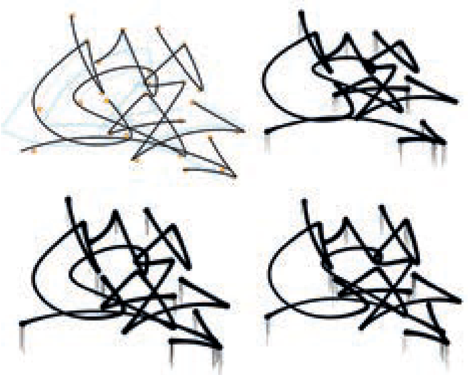

Figure 7: Examples of automatically generated tags based on a small number of targets and on variations of the parameters guiding the kinematics of the movement and trace (BERIO & LEYMARIE 2015).

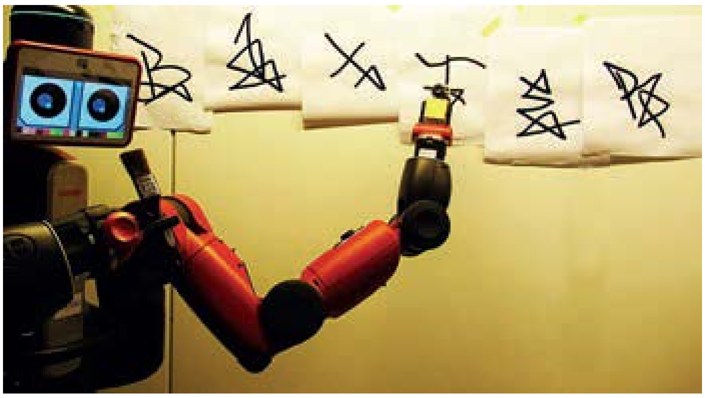

Figure 8: Baxter, a nonrigid humanoid robot designed by Rethink Robotics, learned to write its own tags of a quality close to what a human being can do (BERIO *et al*. 2016).

A current project is moving beyond unidimensional traces to the form of 2D letters (BERIO *et al*. 2019). New findings in psychology (about the perception of forms) are being taken into account in order to systematically recuperate the "skeletons" of strokes from any 2D symbol that resembles a letter. The hypothesis is that a distinctive, common characteristic of the forms of letters in all languages (whether from kanji or Western alphabets) is that they are produced through a series of movements from one target position to the next, whenever a pen or brush is used. This series of traces (Figure 9), including sinuous and looping forms, has potential applications in 3D-printing and weaving (Figure 10). Another theme in current research is oriented toward the learning processes necessary for artificial neural networks to set the parameters for controlling computerized or robotic calligraphic systems.

Figure 9: The production from graphic letters of graffiti in various styles (BERIO *et al. 2019*).

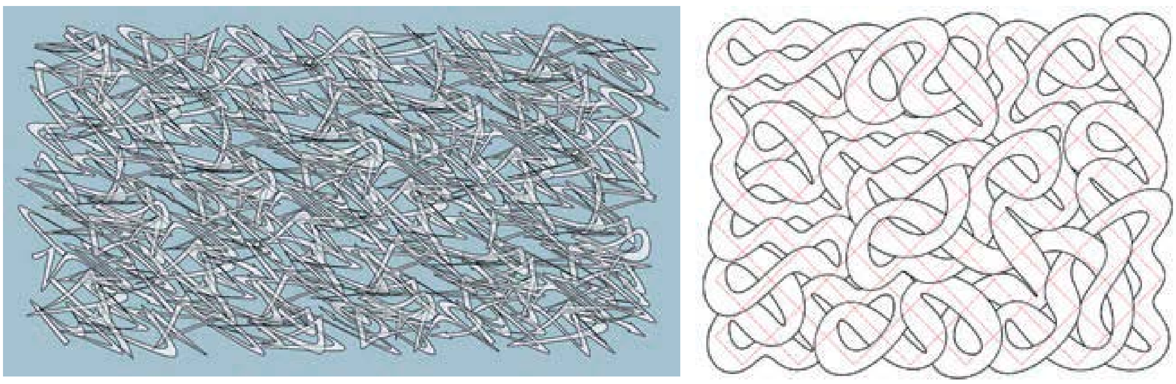

Figure 10: The production from graphic letters of woven traces in the form of graffiti (BERIO 2020).

Deep learning and inner worlds: Terence Broad — Exploration of the internal operation of artificial neural networks

A new generation of artists-programmers are exploring how to use deep learning methods in the arts (BESSETTE *et al*. 2019, AKTEN 2020). This is a special moment in the history of science and in the sharing of knowledge. The scientific communities implicated in developing deep learning (and more generally AI) normally (at least during the past decade) publish the "usable" code and data sets (with their tags or semantic makers). These databases are still piecemeal, but the situation is novel. Enough information is now available so that others (not necessarily experts in computer science or AI) can immerse themselves in this technological trend.

This availability of cutting-edge software along with the related data has opened the possibility for the artists interested in programming to explore this thriving field of activity.[10] An artist seeks not only to master the use of a technology but also to apply it for new purposes. He might completely change how the technology is put to use or how it behaves, with possibly surprising or interesting results. An engineer or data scientist uses deep learning to respond to specific needs, such as the production of plausible solutions based on a given set of data. In contrast, an artist takes interest not necessarily in the plausible but in the extraordinary, which might arouse new emotions in response to images or artefacts that have never been observed beforehand.

In classical applications (with a utilitarian objective set *ex ante*), deep learning systems are treated like black boxes. Their internal operations remain incomprehensible as long as the output is useful. In the context of the arts, the reverse often prevails: understanding (part) of the system's internal operations is often the key for the artist to obtain more creative control. Various strategies are adopted. The artist might try to "break" the system by using different data, modifying the usual parameters or "recabling" the system. This is done to see what happens or to obtain unexpected results. Another strategy is to try to find out how to better control the system (*e.g.*, paint with the assistance of an artificial neural network under the artist's direction) and create a user interface adapted to the artist's needs.

The word that often comes to mind when appreciating artworks created with the assistance of deep learning is "dream"; but visual indeterminacy, a more technical phrase, has been proposed for this visual effect (HERTZMANN 2020). The results evoke imaginary worlds, which we associate with dreams or even fantastic inner worlds, the figments of our imagination. It is worthwhile pointing out that an artificial neural network's objective is to construct simulacra of what we observe in our biological nervous system. Following its exposure to a massive quantity of data with an associated semantics, such a network is designed to learn to react to other data coming from outside sources. Likewise, human dreams often result from creative constructions out of memories (recent or old). New scenarios with origins in previous real situations are restaged in our inner theater.

To illustrate these thoughts, let us look at a few recent works by a young artist-programmer, Terrence Broad. In *Blade Runner — Autoencoded*, Broad, in collaboration with Mick Grierson, used a type of artificial neural network called "auto-encodeur" to recreate images from a film (BROAD & GRIERSON 2017). The auto-encoding device was made by coding a flow of input, in this case original images from *Blade Runner* (1982), a science fiction movie. Approximately half the network's architecture was used to "compress" into a "black box" the information contained in the film. The other "half" decoded this "latent" space in order to regenerate the input as much as possible. After having set the system's parameters and run several learning cycles on different scales, the authors were able to ask the system to recreate a version of the film from its (encoded) "memory". While some scenes, usually static ones, were

[10] This brings to mind another turning point when photography, a technique initially invented by engineers, was adopted, following a few years of exploration, by the arts: at first for portraits and then as a full-fledged artistic medium (AGÜERA & ARCAS 2017).

recreated as are, most of the other recreated scenes were recognizable approximations but in a "dreamy", "blurred" style.[11] The authors then tried reconstructing other films by using the parameters derived from *Blade Runner*; they thus obtained variants of this style (Figure 11).

Figure 11: Auto-encoded films (BROAD & GRIERSON 2017): images from the original film (on the left) as reconstructed (on the right): *Blade Runner* (1982) in the top row, *A Scanner Darkly* (2006) in the bottom row.

For *(Un)stable equilibrium* (Figure 12), Broad and Grierson used another type of artificial neural network: generative adversarial networks (GANs) but in an unusual way, namely without any learning data (BROAD & GRIERSON 2019). A GAN is usually made up of two deep learning networks that try to outdo each other. Subtle changes in the parameters, the details of the architecture or the optimization produce interesting, innovative twosomes that remind us of the minimalist movement in the arts during the 1960s. For the creativity and artistic quality of this work, Broad was awarded the winning submission of the ICCV 2019 Computer Vision Art Gallery.

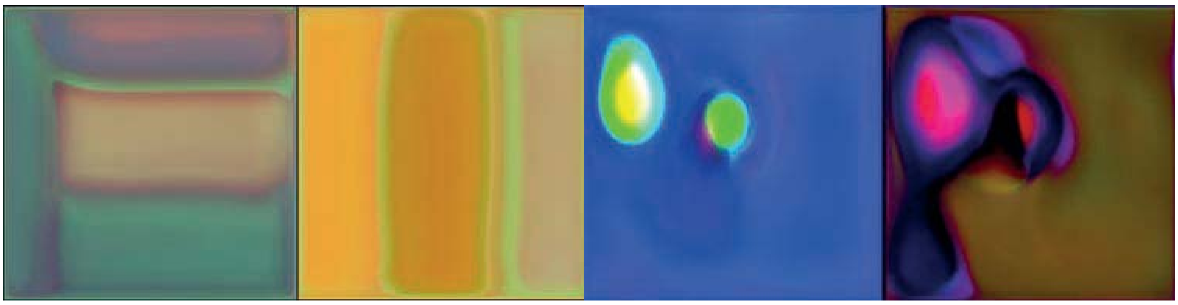

Figure 12: *(Un)stable equilibrium* (BROAD & GRIERSON 2019): pairs of transitional results from coupled neural networks (GAN), which are trying to outdo each other. See: https://computervisionart.com/pieces2019/unstable-equilibrium/.

[11] A video on this project has been viewed 260,000 times: https://youtu.be/3zTMyR-IE4Q.

The next project also used GAN but "slyly". GANs are currently being used to produce "deepfakes" (KARNOUSKOS 2020). The objective is to let the bicephalous deep learning architecture hone its skills so as to generate images that cannot be told apart from real photographs or films. But what will happen if, overturning this objective, you let the GAN surpass itself by creating unnatural contents that have never been seen before? Broad, in collaboration with Grierson and myself, explored this possibility in "Amplifying the uncanny", an article that describes a system leading from what is real to what is surreal or unknown, what might be frightening or strange (BROAD *et al*. 2020a). By using this method, Broad produced *Being Foiled* (Figure 13). The uncanny opens a way to study and depict certain human emotions, which psychology and robotics have explored (MORI 1970).

Figure 13: *Being Foiled* (Broad *et al*. 2020a): two series that, based on a natural/realistic photograph (on the left in each row), move toward the uncanny (on the right). For further examples, see https://terencebroad.com/works/being-foiled.

In his more recent work, Broad has sought to open the hood on the black box of deep learning. By identifying layers and parameters in a GAN (in charge of the representation and manipulation of the eyes, nose or mouth in portraits or on photos), the artist has begun taking control over the neural architecture. The next step is to introduce specific transformations via filters installed in the GAN's upper layers. Broad explored in detail such a tool in recent artworks, *Disembodied Gaze* and *Teratome* (figures 14 & 15). A report explains the technical aspects of this work, which has come of the collaboration between Broad, Grierson and myself (BROAD et al. 2020b).

Figure 14: *Disembodied Gaze* by Terence Broad uses a "network bending" architecture (Broad *et al*. 2020b). These results of a generative adversarial network (GAN) were obtained by keeping constant only the parameters for reconstructing the eyes while letting the network freely, creatively, reconstruct the rest of the face and the background. See: https://terencebroad.com/works/disembodied-gaze.

Figure 15: A few examples from the *Teratome* series by Terence Broad that uses a "network bending" architecture (BROAD *et al*. 2020b). Filters were installed in the upper layers of a neural network (GAN) to disrupt, reverse and distort the image-forming process. See: https://terencebroad.com/works/teratome.

A.M.I., a vanishing point

I have argued that the natural "fusion" between the threesome art/machine/intelligence (A.M.I.) should be explored. By "natural", I am referring to the meaning of this word in biology and the theory of evolution: selection is productive, *i.e.*, well adapted (herein, to the study of intelligence itself). The objective of exploring the process of artistic creation via our most sophisticated machines is ambitious. The argument presented herein and the few examples provided from contemporary artists are intended to demonstrate the feasibility of: *1)* studying the levels of intelligence from this vantage point; and *2)* simulating and eventually extending the associated levels of intelligence. Let me emphasize that, at this time, I consider that these extensions can be directly used only by human beings.

Figure 16: Graffiti produced by Daniel Berio and the AutoGraff system (BERIO 2020) of the tag A.M.I. (Art.Machine.Intelligence) at the intersection of the "arrow" and "machine" styles in the words of Dadio, an artist and theoretician (FERRI 2016).

Rather than wishing or hoping for an artificial general intelligence (AGI) to "emerge" out of complex (mathematical and algorithmic) constructions, I prefer prospecting A.M.I. for its potential in the study and extension of human beings. Focusing on the advances made in research (especially when studying and simulating artistic skills of an ever higher level) can, I claim, lead to major, concrete breakthroughs in understanding intelligence itself.

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