A New Kind of Art [Based on Autonomous Collective Robotics]

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Introduction

We started working with robots as art performers around the turn of the century. Other artists/researchers in the realm of the art/technology interface have done similar experiments, and their endeavours were a potent stimulation for our work.[1] After the first trials, which relied on a bio-inspired ant algorithm running on a computer connected to a robotic arm, we decided to focus our research effort on the autonomy of the machine, i.e., the possibility of a machine creating its own drawings and paintings as a kind of *artificial creativity* stemming from *artificial intelligence*.[2]

Along these lines, *Artsbot*, a swarm of art producing robots created in 2003 (and updated to the present time), demonstrates that an interrelated group of robots can generate unique compositions that are independent from the human agent that starts the process.[3] To the best of our knowledge, *Artsbot* is the first experiment in which robotic art is understood as an emergent process based on a swarm of robots animated by a bio-inspired algorithm. By relinquishing control over the output, human creators can concentrate on 'making the artists that make the art'.[4]

It is worth noting that such machines should not be seen as mere tools or devices for predetermined human aesthetic creations, because they are (at least) partially autonomous, and the result of their actions is unpredictable. In addition, although randomness is an essential component of the process, the resulting artwork cannot be viewed as a mere random outcome, given that *recognisable* patterns emerge from a fuzzy background.[5]

The claim that the compositions produced by *Artsbot* represent a new kind of art – the art of semi-autonomous machines – may seem controversial in the context of mainstream concepts that consider art to be an exclusively human capacity. Actually, the underlying approach that drives this new kind of art is inscribed in the global advancement of robotics and artificial intelligence towards a greater autonomy of machines. Indeed, as usual, *Art* simply announces what is about to come.

Machine Art

With the rise of computers, *Digital Art* was the product of an artificial 'language' used to implement routines, trigger behaviours and run algorithms inside machines. The use of computers to make art was initially a subsidiary product of this new language. Artists used computers to generate processes and images that related mainly to the inner architecture of the machines. Through rules, protocols and algorithms, computers *created* processes and images as the result of complex calculations.

With the advent of machines as thinking devices able to perform tasks based on their own discretion, a particular form of intelligence coined *artificial intelligence* was developed, and 'computer art' took a new turn in which complexity is ubiquitous. Complexity gave rise to the possibility of simulating bio-inspired and emergent artificial systems. Hence it was possible to originate what is now known as *artificial life*; that is, *organisms* that live inside machines or explore the real world in the form of autonomous sensing robots.

In 2003, drawing on this fresh field of research, we proposed an adjustment of the principles of artificial life to elicit the production of artworks by a swarm of autonomous robots (*Artsbot*). We claim this endeavour to be a *new kind of art* because a) human creators deliberately relinquish control over their creations, and b) machines, when animated by a particular kind of *swarm intelligence*, generate a creativity of their own.

Technical Description of Each Artsbot Robot

The basic architecture of each *Artsbot* robot consists of three components: the sensors, the controller and the actuators. The sensors receive signals from the environment that are processed by the microcontroller in order to command the actuators. The RGB colour sensors, situated under the robot, can detect the entire palette of colours, but, due to the fact that *Artsbot* robots carry only two pens, colour detection is divided in just two ranges, 'warm' and 'cold'.[6] Proximity sensors assist robots to determine the area of the terrarium and to avoid collisions.[7] The actuators consist of three servomotors: two for the wheels and one to operate the pens. The controller is an on-board PIC.

Collective Behaviour

The case to be made by the proposed approach is that creativity emerges in the set of robots as a consequence of self-organisation, which is driven by their interaction with the environment. Actually, each robot's random walk – which occurs when the process starts – is only interrupted by the 'appeal' of a certain colour spot, trace or patch previously left on the canvas by another robot. Given that the robot only 'sees' a limited region of the canvas, if no colour is detected in that region, it continues on its way, putting down a mark of its passage on the canvas only if its random number generator produces a value that exceeds a given threshold. In the language of statistics, each one of the outcomes of the experiment is regarded as the realisation of a Random Function (RF). The RF is defined as the infinite set of dependent random variables $Z(u)$, one for each location u in a certain area A. In this case, the area A is the canvas, and the random variable is discrete, taking only three nominal colour values – warm, cold and white. The underlying feedback process leads to the spatial dependency of the random variables and explains why clusters are usually formed in most of the RF realisations. These realisations (paintings) are the mapping of the RF onto the canvas, depicting its fundamental hybrid structural/random constitutive nature.

The collective behaviour of the set of robots as it evolves on a canvas (the *terrarium* that limits the space of the experience) is governed by the gradual increase of the deviation-amplifying feedback mechanism that is the core of the programme governing the controller.

During the process, the robots show an evident behaviour change as a result of the appeal of colour, triggering a kind of excitement – which can be seen as a bifurcation – that does not occur during the initial phase corresponding to the random walk. Once a robot 'sees' a trace of a given colour – classified into the above-defined two classes (warm and cold) – the pen of the same colour class is dropped by the corresponding actuator, and consequently this colour class is accentuated in the vicinity of the trace that was previously left on the canvas.[8] As the interaction between robots is not direct, but driven by the positive feedback mechanism triggered by a signal left in the environment (this signal causes the robot to turn in the direction defined by the point where its sensor has detected the colour that corresponds to the received signal), we can posit that what is occurring when one robot reacts to what

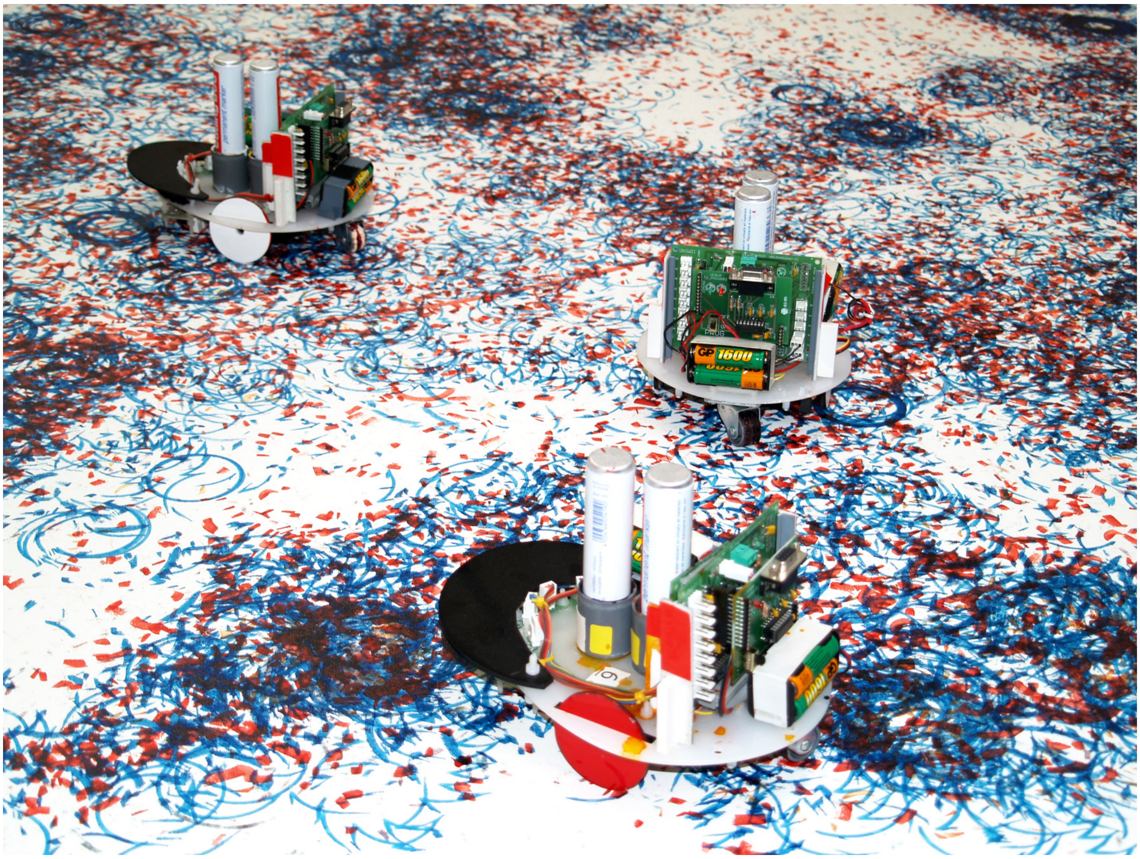

Fig. 1: Swarm of Artsbot robots working on a painting. © Author

other robots have previously done in the *terrarium* is a stigmergetic interaction between the robots.[9]

In fact, while developing *Artsbot*, we have tried to artificially reproduce an emergent behaviour similar to the natural behaviour of ants, bees, termites and other social insects. These insects communicate among themselves through chemical messages produced by the release of pheromones, which lead them to effect certain patterns of collective behaviour, such as following a trail, cleaning up, repairing and building nests, and defending, attacking or invading territory. Although pheromones are not the exclusive means of communication among these insects (the touch of antennas in ants or the dancing of bees are equally important), pheromonal language does produce complex cognition via bottom-up procedures. As previously stated, these procedures are obviously an indirect form of communication, coined stigmergy by Grassé, from the Greek stigma/sign and ergon/action.

Following these principles, we 'replaced' the pheromone with colour. The marks left by one robot trigger a pictorial action in another robot without any direct relation between them. Through this pseudo-random mechanism, abstract paintings are generated that reveal well-defined shapes and patterns. *Artsbot* creates abstract paintings that at first sight seem to be mere random doodles, but after careful observation, colour clusters and patterns become patent. When the coloured marks left by one robot are recognised, the other robots react to these by reinforcing certain colour spots. The process is thus anything but arbitrary.

Actually, what is crucial in the *Artsbot* experiment is the concept of *emergence* applied to a process that drives the swarm behaviour. Indeed, in the swarm behaviour, emergence arises when multiple agents that are interacting with each other and the environment in a rather haphazard way begin to generate order as a consequence of some form of *swarm intelligence*.[10] The process by which these mechanics can produce a novel behaviour, (quasi-) independent of the human that implements and starts the process, cannot be analytically modelled, but it should be understood as producing a new *gestalt*, along the lines of the complex dynamic theory, known commonly as 'chaos theory'.

For some authors, emergence is just a deterministic mechanism. According to this view, the set of rules or initial conditions determine the behaviour, and unpredictability is an emergent property of a system that may be predictable on a lower level of analysis. But, since no *complex system* can be understood by examining its individual parts, we claim that the deterministic view underestimates important components of the emergent process, which is the backbone of the collective behaviour produced by *Artsbot*, as displayed in the illustration.[11] [fig. 1]

Discussion and Conclusion

In our approach, the human artist creates the process but not the resulting drawing or painting.[12] Although the set of rules is changeable according to certain parameters, the most determining component of the process lies in the fact that the robots are driven by the data they gather from the environment. In *Artsbot*, our painting robots were designed to paint (not a specific painting but their own paintings). [fig. 2] Their creations stem from the machine's own interpretation of the world and not from its human description. No previous plan, fitness, aesthetic taste or artistic model is incorporated. Our robots are machines dedicated to their art.

Such an endeavour addresses some of the most critical ideas on art, robotics and artificial intelligence. According to the new advances in neurobiology, intelligence is understood as a basic feedback mechanism. If a system – any system – is able to respond to a certain stimulus in a way that

Fig. 2: 201004, 2004, acrylic on canvas, 75 x 75 cm.© Author

changes it or its environment, we can state that some sort of intelligence is present. 'Pure' intelligence is therefore something that does not need to refer to any kind of purpose, target or quantification. It may simply be an interactive mechanism of any kind, with no other objective than to process information and to react in accordance with available input characteristics.

Although the starting point of *Artsbot* was bio-inspiration (in particular, modelling social insects' emergent behaviour), its basic idea has evolved into constructing machines that are able to generate a new kind of art with a minimum of fitness constraints, optimisation parameters, or real life simulations. In this sense, we are not so much concerned with controlling manufacture as with taking the human out of the loop. The statement that machines can make art has implications far beyond the simple machine ability to mimic human behaviour. It opens the concept of art to all kinds of living forms, both natural and artificial.

Notes

1. Since the 1960s, with cybernetic art and in works by Nam June Paik, Jean Tinguely and others, artists have been using machines, and later robots, to produce art. Some were simply mechanical devices, but with the proliferation of computers they have become more and more 'intelligent' and increasingly autonomous. For an informed approach to the history of art and robots see Eduardo Kac, 'Origin and Development of Robotic Art', <http://www.ekac.org/roboticart.html> [accessed 19 April 2014]
2. This algorithm, coined ACO (Ant Colony Optimization), was developed by Marco Dorigo in 1992 in his PhD thesis. M. Dorigo, *Optimization, Learning, and Natural Algorithms*, Ph.D. dissertation (in Italian), Department of Electronics and Information, Milan Polytechnic, Italy, 1992.
3. The first results of the *Artsbot* project, including its rationale and underlying process, are reported in Leonel Moura and Henrique Garcia Pereira, 'Man+Robots, Symbiotic Art' (Villeurbane, France: Institut d'Art Contemporain, Collection Écrits d'artistes, 2004).
4. Leonel Moura, *Symbiotic Art Manifesto*, 2004, <http://www.leonelmoura.com/manifesto.html> [accessed 19 April 2014]
5. The concept of emergence as we view it is comprehensively addressed in S. Johnson, *Emergence: The Connected Lives of Ants, Brains, Cities, and Software* (New York: Scribner, 2001).
6. In our work, colour is the analogue to pheromone in ants.
7. The terrarium is the area in which the set of robots travels, executing the action of painting through the interdependence of their paths. It consists of a canvas lying on a horizontal surface and bounded by small (10 cm) vertical white walls that delimit the space where the robots can move.
8. This procedure is analogous to the case made by Herbert Simon where he describes the situation in which a moving agent reinforces known paths once previous choices have proved satisfying. Put forward in H. Simon, *The Sciences of the Artificial* (Cambridge, Mass.; London: MIT Press, 1996).
9. Stigmergy is the production of certain behaviours in agents as a consequence of the effects produced in the local environment by a previous action of other agents. It is worth noting that the biologist P. P. Grassé was the first researcher to develop this concept in the scope of his study of social insect behaviour, as reported in P. P. Grassé,'La réconstruction du nid et les coordinations inter-individuelles chez Bellicositermes Natalienses et cubitermes sp. La théorie de la stigmergie: Essai d'interpretation des termites constructeurs', *Insectes Sociaux, 6,* (1959), pp. 41-8.
10. For the development of this concept see Eric Bonabeau, Marco Dorigo and Guy Theraulaz, *Swarm Intelligence* (New York; Oxford: Oxford University Press, 1999).
11. This point is strongly made by Daniel Dennett on the basis of his concept of intentional emergence as the main property of complex systems. See D. Dennett,

'Intentional Systems Theory', in *Inside Art and Science* (Lisbon: LxXL, 2009), pp. 58-81.

12. This assertion embraces the approach discussed in Edward A. Shanken, 'Art in the Information Age: Technology and Conceptual Art', in *Invisible College: Reconsidering 'Conceptual Art'*, ed. by Michael Corris (Cambridge: Cambridge UP, 2001).

Biography

Leonel Moura is an artist working in field of Artificial Intelligence and Robotics. One of his robots is on permanent display in the American Museum of Natural History, New York. He has created several Art Robots and a Robotarium: a kind of zoo for robots. Henrique Garcia Pereira is full professor at the Instituto Superior Técnico, Lisbon. His topics of research include Applied Statistics, Environmetrics and Epistemology. He has written over one hundred scientific papers and seven books.