Swarm Exquisite-Corpses Games

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Abstract

The Exquisite Corpse is a game-based art form popularized by the surrealists. The final result is based on an unconscious collaboration of collective artists; each provides his or her part without knowing what the other has selected. For example, each one provides adjective, verb and noun to create poems; head, torso and legs for drawings. Actually, concerning drawings, each one draws his part in a piece of paper and folds it, so the next artist is able to see the border traces in the folded column and normally begins from there. The exquisite Corpse is a game with several interesting properties: 1. It's an example of collective creation and formation of a collective pattern; 2. We can envision a micro and macro levels, even if there are not so many participants 3. There is no unity, there is author fragmentation and so the complete outcome cannot be intended and planned in advance; 4. In fact, we are in face of an unpredictable and surprising outcome; 5. There is no direct communication between the participants, besides the fact that they are going to draw some predetermined part, they do not communicate at all or they communicate indirectly through the work (traces in the folded zones); 6. Nobody has a bird eye view of the work in progress, they are restricted to their own local zone.

Our contribution to this Symposium is an artificial painting tool that has several properties of the Exquisite Corpse Game but in a much bigger scale in the sense that we can have thousands of very simple micro-painters limited to a very narrow and local area that will try to coordinate and to make emerge a collective pattern. In this tool we can try out different types of coordination between painters and see the resulting pattern exploring the link between the macro and micro-level, In contrast with the Exquisite Corpse Game which is sequential, in our painting society, artists work in parallel and they can communicate either directly or indirectly through the painting. We will begin to describe a coordination type based only on a stigmergic form of communication between painters. The artificial canvas has dynamic properties where artificial pheromones can be produced, diffused and evaporated. They are the communication medium and they control the movements of individuals. For example, the non-painted areas will produce chemical that will diffuse and attract painters making strange and unpredictable patterns appear.

We will also describe other types of agent coordination based on imitation where some consensual attributes, like color or orientation, or position, will emerge, creating some order on a potential collective chaos. This consensus can die out, randomly or by interaction factors, and new consensual attributes can win resulting in heterogeneous paintings with interesting patterns, which would be difficult to achieve if made by human hands.

We think that our main contribution, besides the creative exploration of new artistic spaces with swarm-art, will be in the sense of showing the possibilities of generating unpredictable and surprising patterns from the interaction of individual behaviors controlled by very simple rules. This interaction between the micro and macro levels in the artistic realm can be the source of new artistic patterns and also can foster imagination and creativity.

The Exquisite-Corpse Metaphor for Creativity

The exquisite-corpse technique popularized by the surrealists [Breton 2002] is a form of collective art where several artists produce a figurative drawing. The main goal is to create something that could not be the intention of any of the participants, fragmenting the authorship concept. The exquisite-corpse artistic piece can be seen as the emergent outcome of the sequential work of several individuals, which have access only to a very small part of the work being produced. In figure 1 we can see three exquisite-corpse drawings.

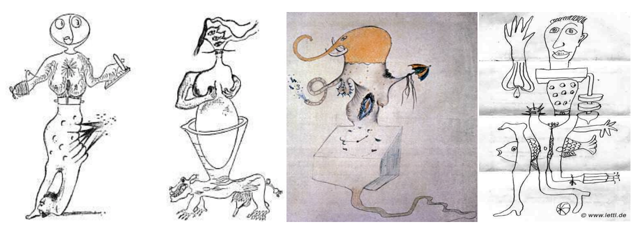

Fig. 1. Three examples of exquisite-corpse drawings.

We think that one way to produce creative artificial art is through the creation of artistic swarm systems [Bonabeau, Dorigo, and Theraulaz 1999] that share some of the properties of the exquisite-corpse game. We have a collective of interacting agents with local perception following a set of rules, able to produce global patterns, using auto-organization mechanisms. Our research consists in exploring the artistic possibilities of swarm systems, looking for different forms of interaction and coordination, where we mix order and randomness. We do not want to model creative processes but produce new expressions and forms using artificial tools. Our research is in related with what Jon McCormack called *human-computer synergistics* “where the machine enables modes of creative thought and activity currently unattainable” (McCormack 2007).

Compared to the surrealists’ exquisite-corpse games, our artistic swarms work in a much more micro-scale than the human participants in an exquisite-corpse game and will work in parallel. In the surrealistic game there is a private territory for each participant; in our swarm games each artist is not confined to a private territory. The surrealist game involve normally 3 or 4 persons, but we can use thousands of painters working on the same drawing The surrealist drawing is figurative; in contrast, our swarm artists do not have the capacity to draw figures, they just move and leave traces making drawings that are more the product of the exquisite-corpse game of social insects.

Self-Organization, Evolution and Artificial Art

The study of biological self-organization (Camazine et al. 2001) has revealed that numerous sophisticated pattern formation, decision-making, and collective behavior, are the emergent result of the interaction of very simply behaviors performed by masses of individuals relying only on local information. In particular, successful problem solving by social insects made models of their collective mechanisms particularly attractive (Dorigo, Maniezzo, and Colorni 1996; Bonabeau, Dorigo, and Theraulaz 1999). The dissemination of Artificial Life has also been an important influence in the media arts [Whitelaw 2004]. Inside Artificial Life domain, collective intelligence, and evolution, behavior robotics and virtual ecosystems (Dorin 2007), are main source of inspiration for artificial artistic creation (Romero and Penousal 2007). There are already examples of collective artistic pieces made by artificial agents. Examples of flocking based artwork include interactive musicians (Blackwell 2003) and interactive video installations (Boyd, Hushlak and Jacob 2004; Shiffman). L. Moura (Moura 2002) has used a small group of robot-painters inspired by ants’ behavior that move randomly in a limited space. Stimulated by the local perception of the painting they may leave a trace with one of their colored pens. The painters rely on stigmergic interaction (Grassé 1984; Theraulz and Bonabeau 1993) in order to create patterns with some spots of the same color. Color has the pheromone role: a spot dominated by a certain color has the capacity to stimulate the painter-robot to add some paint of the same color. Monmarché et al. (Monmarché et al. 2003) have also designed groups of painters inspired by ants’ pheromone behavior and the paintings were evolved using an interactive genetic algorithm. It is based on a competition between ants: the virtual artists try to superimpose their colors on traces made by others, creating a dynamic painting, which is never finished. Ants have the capability to “sniff” the painted color and react appropriately. The group is composed by a small number of individuals (less than 10). Monmarché et al. (Monmarché et al. 2003) have also applied their swarm algorithm to music. Greenfield (Greenfield 2005) introduced a non-interactive genetic algorithm to evolve swarm paintings. In (Urbano 2005b) we developed swarm paintings where the environment is responsible for the production and diffusion of virtual pheromones. One of the differences from the other ant-paintings is that the artistic ants are not charged for pheromone production, (the environment is responsible for that task). More, the diffusion process does not occur on any of the ant paintings we have referred. These virtual pheromones are responsible for the micro-painters movement and consequent traces. In the Colombinique paintings, the artists are attracted toward the empty spots and in the Anti-Colombinique case it is the opposite, they are attracted towards the already painted spots. We introduced also populations of numerous agents: we have experimented with groups composed of up to 2000 individuals working in the same artistic piece. Greenfield furthered the Colombinique style, introducing a multiple pheromone model (Greenfield 2006).

Following the work of Kaplan (Kaplan 2000) and Shoham and Tennenholtz (Shoham and Tennenholtz 1992) on convention emergence in multiagent systems, we have applied a collective mechanism of emergence of random convention sequences, to the generation of collective paintings (Urbano 2006). We introduced the Gaugants, a society of mimetic micro-painters where consensus (collective choice) around some attributes is the source of artistic pattern and where the continuously changing collective choices are the source of diversity and non-homogeneity. In contrast with the Colombines, the Gaugants communicate directly and do not use any form of virtual chemical for interaction. In (Urbano 2007) we made some variations on the Colombines model introducing two forms of mimetic interactions.

In the following sections we will synthesize our research on swarm painting and introduce in the end a new mimetic model where individuals’ color and position coordinates are subject to imitation.

All our swarm paintings were implemented in Netlogo, a derivation of Starlogo (Resnick 1994).

The Colombines

The Colombines are a swarm of small and homogeneous artificial micro-painters, individually very simple, which are able to paint a bi-dimensional virtual canvas, composed of small cells.

The canvas is bi-dimensional space with a toroidal format, divided in small squared sections, called patches or cells, it is a kind of reticular paper, with no borders, folded on every direction, in which two types of virtual materials coexist: paint and a chemical signal. Each patch can have a certain color and can have a certain quantity of chemical. There is a fixed color (usually grey) for the background. Any other color corresponds to paint.

The non-painted cells have more attraction power (more chemical). Therefore, every cell has the potential ability to release chemical, but only the non-painted cells (the background ones) are chemical producers. The squared canvas is a kind of chemical medium where every cell is permanently diffusing chemical to their immediate neighbors, independently of being painted or not. The chemical evaporates at a constant rate. Without evaporation, the attraction power decay of recently painted spots will last more time, disorientating the painters, attracting them to painted spots. Foremost, the evaporation phenomenon increases the painters' efficiency: the painting will be completed sooner.

The cells behavior is the following: 1) if it is not painted increase its own chemical quantity by a certain amount, otherwise the chemical level is maintained intact; 2) diffuses a percentage of its chemical to their 8 immediate neighbors; 3) delete a percentage of its chemical (evaporation). The chemical constant produced by non-painted cells, the evaporation and diffusion taxes are parameters modifiable by the user.

Initially, we launch these painters in a non-painted background, each one occupying a particular cell, and they will move along, depositing a trace of ink, until the canvas is completely fulfilled. Note that each painter is constrained to paint only non-painted cells and when there isn't any non-painted cell left, the artistic work cannot change and is considered finished. Of course, the user can stop a painting before the cells are exhaustively painted or we can end it after a fixed number of iterations.

Our micro-painters have a very limited perception field—they have an orientation and have access just to the patch they are on and also the three cells in front of them. Each painter is created with a particular color and they never change to another color. It's the empty spots that guide the painters. They prefer to move towards empty spots.

If each Lilliputian painter just acted on its own, without any interactions, either with the world or with the others, interesting phenomena would never arise. They do no more than moving on the virtual canvas, visiting preferentially cells with more amount of chemical, (preferring to move towards non-painted spots) and painting cells still unpainted, leaving traces of color behind them. In case of identical chemical values in their neighboring cells they have a tendency to preserve its current direction. Each Colombine has a position (real Cartesian coordinates), an orientation (0..360), and can only inhabit one cell, the one that corresponds to their coordinates. They see just their own cell and also the three cells immediately in front of them. On the other hand, the painters are created with a particular color that is never going to be changed.

The behavior of each Colombine is the following: 1) it senses the three immediate cells in front of him and chooses the one with more chemical, changing his orientation towards that winning cell and moving to it; 2) if that cell is not yet painted, stamps his color on it, otherwise, does not paint it. In detail, the painter senses his three forward neighboring cells and if there is no better patch than the one in front he remains with the same orientation and go forward one step (rounding his coordinates). If the left path is the most attractive he rotates 45 degrees to the left and moves forward one unity, rounding both position coordinates; the same happens when he prefers the right cell: he rotates to the right 45 degrees, moving forward one unity.

The evolution of the collective artistic work happens in the following way. Initially, the virtual canvas is grey and each patch has an identical quantity of chemical (normally 0). Next we create a colony of Colombines, each one with its own color and orientation, distributing them in the environment. The painting process will begin in a sequence of iterations until every patch is painted completing the plastic work.

Each iteration is divided in two steps: in the first, every cell executes its behavior (chemical production, diffusion and evaporation); in the second step, the Colombines move, attracted by chemical, depositing paint. The paintings are only declared finished when there are no grey patches, but, alternatively, we could finish the collective work after a random or fixed number of iterations.

Fig.2 illustrates four snapshots of the work done by 300 hundred Colombines with initial random colors and positions.

Fig2. The progress of a painting made by 300 Colombines. Each one has a color chosen randomly from a 140 possibilities.

We can see clearly that traces are trapped and forced to fold, creating spots of the same color. These spots will be bigger when there is more free space, due to a smaller number of painters. We can confirm this on the paintings showed in figure 3 where we vary the number of painters. We can play with initial colors, limiting them to a certain subset, creating some variation from painting to painting besides the scale dependence on the group size.

Fig. 4. Four Colombine colored paintings. From left to right: 50, 100, 500 and 1000 painters with a random initial color.

Anti-Colombines

What patterns are produced if we change the Colombines model a little bit? We want now that the micro-artists they prefer painted cells and go towards already painted areas. We are not going to change the agents' behavior — they can continue to climb the virtual chemical gradient. We are going to change cells' behavior instead. Now, cell produce chemical only when they are painted which means that painter will be attracted towards painted spots. We can see some images produced by a group of Anti-Colombines in fig. 4. We find very distinct patterns compared with the Colombines model. Painters have the tendency to come back to places they were before and it will be more difficult to finish completely a "tableau" so it is better to declared it finished after some time. The Anti-Colombines model appeared in (Urbano 2005b).

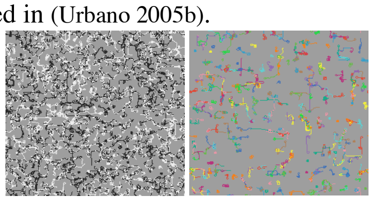

Fig. 4. Two Anti-Colombinique paintings, on the left a black & white and on the right a colored one.

Mimetic Colombines

We introduce now the mimetic Colombines (Urbano 2007); their movement behavior is left unchanged, it still depends again on stigmergy, but this time they can change color. Thus, they can imitate the color of other neighboring partners. Neighborhood can vary from a very narrow circle to the whole canvas. The vision radius is global parameter.

This imitating behavior can be generalized to other attributes as well. We name these the mimetic attributes, which are a subset of the painters' attributes. We will show in the end of the paper some examples of micro-painters that use other mimetic attributes besides color.

Simple Imitation

In this model, each painter, before moving, chooses randomly a neighboring partner to interact and imitates his color. Interaction is unilateral, after interaction they both have the same color. Then it moves and paints the floor in case it is not yet painted. So, movement is controlled by stigmergy as before and color is controlled by mimetic interaction.

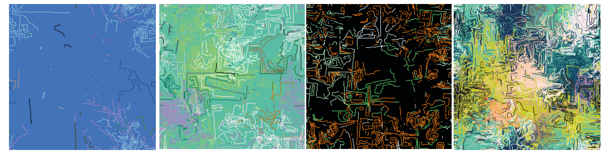

Fig. 5. The first painting made with 50 painters with a random initial color and a vision radius of 10. The other 3 paintings are made by a group of 100 painters where we vary the vision-radius, respectively (20, 30 and 10).

Fig. 6. Four mimetic-estigmergic multicoloured paintings made from groups of 200, 500, 500 and 1000 micro-painters with vision-radius of 50, 20, 30 and 30.

In figure 5 and 6 we show 8 paintings for different 140-colored populations and different vision-radius. Imitation behavior is very unstable and converge to a consensual color is not very fast. Things get slower with the increase in the size of the group and if we decrease neighborhood radius. In simple imitation behavior, after some time, two colors begin to dominate and finally one of them wins, but eventually there is not enough time to achieve convergence and also it can happen that when convergence is achieved there are not many non-painted spots left. Therefore, we can find some 2 or 3 dominant colors. If convergence is premature a color dominates the "tableau"—our eyes see it as a background color. In conclusion, with this mimetic variation on stigmergic painters we have arrived to create new patterns that were not possible before.

Double imitation of stronger agents with reinforcement

In the context of convention emergence research we have designed a very successful behavior in what concerns speed of collective choice convergence (Urbano 2004) and we adapted it to swarm painting (Urbano 2004, Urbano and Coelho 2005; Urbano 2006; Urbano 2007). We introduced force as a new attribute. Painters only imitate other agents as strong or stronger. In this behavior, we will have imitation of color and of force. The mimetic behavior is divided in two parts: in the first one force is compared and there will be imitation eventually; in the following part, there is positive reinforcement.

Part 1: In case the painter is weaker or it has the same force, it will imitate both the force and color of interacting partner. But if it is stronger it will conserve both force and color. This way, the new recruited agents will have their force increased and will be more powerful recruiters than they were before the interaction started. Agents with more power impose their colors and recruit others, making them stronger.

Part 2: if the chosen partner had the same color when they met, it will now reinforce its force in 1 unit, independently of loosing or winning the interaction in part 1.

We name the attributes used in reinforcement the sameness attributes. In this case it is color and it is also a mimetic attribute, but we will see cases where mimetic and sameness attributes are not coincident. To be the considered “equals” two painters have to possess exactly the same values of the sameness attributes.

In sum, the stronger ones recruit weaker agents (these will be at least as strong as the winners imitating their choices, and they can even overpass them in case their options were the same) enlarging the influence of their options.

This behavior manifests fast convergence compared with simple imitation.

The difference towards the simple mimetic painters is on the speed of collectively choosing a color. The consensual color will be found earlier with the ForceMimeticColombines, which is perhaps not very desirable for artistic societies composed of a small number of agents, unless they have a small vision-radius. Otherwise, one of the color dominates very early and once it dominates the whole population nothing will change until the end, which means a lot of homogeneous pattern—a super minimalism; a big background color and some Colombine style traces on it. It’s why we choose to show only images made by big groups of painters.

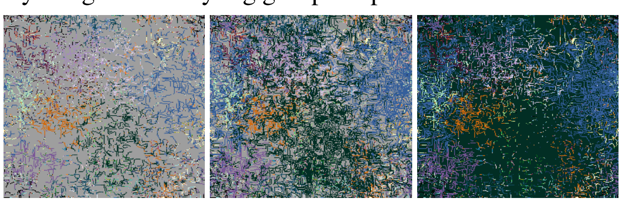

Fig. 7. Evolution of a painting with 1000 painters (random chosen from 140 possibilities). The vision radius is 20 units.

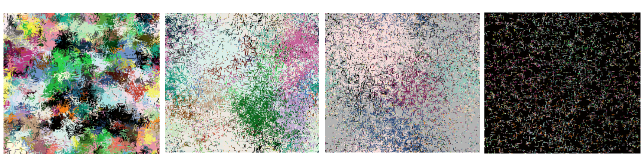

Fig. 8. Four paintings made with 2000 painters with different vision-radius (from left to right, 5, 15, 30, 50.

In figure 8 we show images made by societies composed by 2000 painters, where color convergence varies with the vision-radius attribute. We can compare these pieces with simple mimetic ones made by 1000 or 2000 thousand painters and the difference is obvious. We see have much more spots with the same color due to the fact that imitation is more effective. We can turn the knobs of population size and vision-radius in order to obtain a wide variation on pattern besides the fact that the collective choices on color are different from simulation to simulation.

One form of creating diversity is narrowing the vision or interaction radius, but anyhow it can happen that a consensual situation appears prematurely. Sometime it can be useful, for example, in case want a background color. But it also can be the source of too much homogeneity.

Consensual Variations

So, in order to explore diversity space, it can be useful to develop a process of random “consensual” succession along some attributes (Urbano 2004; Urbano 2006). In fact, the mimetic interaction based on force is adapted to that task. If one painter has much more force than its neighbors, it will be certainly imitated by them, in a fast epidemic way. So what we need is to make some of the painters change their attributes after some stable situation.

But when does an agent adopt the dissident behavior? After he has consecutively seen, at least, a reasonable number of agents with the same option. This number is called the *dissidence threshold* and is a local attribute. After having seen at least a certain number of consecutive equals an agent will be a dissident with some probability, which is called the *dissidence probability*. The local or global consensus duration, depending on the neighborhood radius, varies along with these parameters. But we also want to avoid equal consensual periods, even though there are attributes changing. For that, the dissidence parameters are also copied during interactions and changed during dissidence actions.

In resume, facing a stronger partner, a painter imitates some of his attributes (mimetic attributes), his force also his dissidence parameters. Positive Reinforcement is also necessary. In each turn, it tries to be a dissident, but only after seeing more than a threshold number of “equals”. There is always an attribute or more that one that are used for testing that painters are “equals”, for example color. The dissidence behavior is just randomly changing the attributes that are imitated, not forgetting the dissidence parameter and increasing force in 200 units (this increase was enough in all experiences we have made).

Fig. 9. Paintings made with 50, 100, 371 and 2000 painters with global vision-radius (from left to right). Dissidence probability was the 0,001 in all 4 cases.

The paintings in fig. 9 are the result of the consensual dynamic process we have just described for different initial settings, where neighborhood is global. Note that even if neighborhood is global, each painter has only access to the attributes of one partner at each step, i.e., a kind of local perception in terms of the whole painting.

Imitation of Orientation and Color

We will now change our model and introduce orientation as a mimetic attribute along with color (Urbano 2004; Urbano 2006). Cells do not produce chemical anymore and painters will not move following chemical gradients. Moving is just going forward a number of speed units and rotating a small random number of degrees. The painters are divided in groups and the group elements start with the same position and orientation. Each element begins with a random color. Thus, in the beginning we start with some homogeneous parameters per group (position and orientation) and also some diversity (color). Speed is a global parameter but it could also be local and a mimetic one. The agglomeration process could also be the fruit of a mimetic process.

The dissident will change its color and orientation. Color is the only sameness attribute because orientation, in spite of being a mimetic attribute, is slightly changed by each painter.

In figure 10 we show the evolution of a painting made by a population of 2000 elements divided in 30 groups where everybody can choose any other as a partner to interact. We can see clearly the sequence of consensus (specially due to color, the change of orientation was very light).

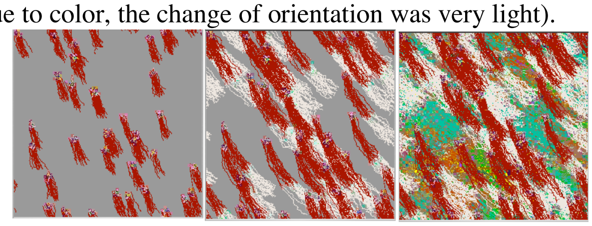

Figure 10. Three snapshots of a painting by 2000 agents that imitate both colour and orientation.

Looking at figure 11, showing a painting that we call *The Swans* we can see clearly that orientation is changed due to dissidence. There is also an increase of dispersion that is understandable due to starting conditions and individual behavior. Painters begun very concentrated, in the same position has everyone in the same group, but as they change their orientation slightly, in a random way, they will disperse and this dispersion will increase with time, creating a diffused background.

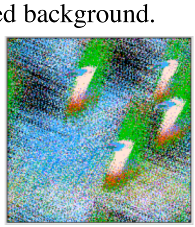

Figure 11. The swans. Four initial groups of 500 agents each.

Imitation of Position and Color

Let's describe our last model. Initially individuals are randomly distributed with random colors. This time, painters imitate color and position coordinates (the mimetic attributes) of neighboring agents. Because they move after imitating color and position coordinates, it means that position cannot be a sameness attribute, only color. Speed and orientation are global parameters now. Painters jump to the chosen neighbor coordinates and then move forward a number of units (speed is a global parameter) after rotating a random value less than a certain number of degrees (also a global parameter). Agents count the number of consecutive painters with the same color and after seeing a number bigger than the dissidence threshold they execute the dissidence behavior with a dissidence probability. Dissidents chose a new random position and a new color.

We can see examples of paintings in figure 12. Inside a consensual situation, the collective behavior that emerges is a kind of coordinated one color flock, leaving a thick line of paint behind. These lines are abandoned and new ones are created due to dissidence and consequent recruitment. With more numerous populations we can see that convergence towards a consensual group takes more time—the resulting paintings show very small spots, that were created in the beginning of the painting.

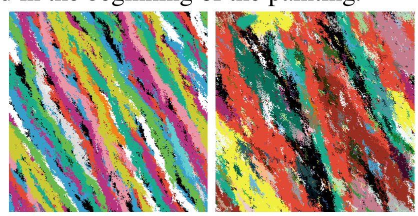

Figure 12. On the left, a painting made by 291 individuals; speed is 1 unit in each step. On the right, a painting made by a group of 3671 painters; speed is 1.5 units. In both cases direction is 150º and after they rotate random 78º - random 78º. Neighborhood is global.

We can create more diversity if we turn speed and orientation into mimetic attributes. We have improved the canvas coverage increasing force in 5 units when a painter is on a non-painted cell, independent of interactions. This way, the flock tend to avoid moving along already painted spots.

Conclusion

In this paper we have synthetized our research on exploring the artistic possibilities of artificial collective artists that rely on auto-organization mechanisms. We think that artificial swarm art, mixing concepts of collective human art like the exquisite-corpse games and decentralized biological systems that rely on auto-organization, can be a path towards the production of new artistic patterns. We showed several forms of interaction and coordination between individuals at the micro level, using stigmergic communication and mimetism, consensus and variation, shared parameters and randomness, and we have presented their emergent artistic global patterns. It's clearly very ambitious to call them autonomous creative artificial systems, but, anyhow, they have the power to surprise us with their unintended final artistic forms and expand human creativity.

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