Playing in the Pheromone Playground: Experiences in Swarm Painting

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Abstract. This paper is about collective artistic work inspired by natural phenomena, namely the use of pheromone substances for mass recruitment in ants. We will describe two different uncoordinated groups of very simple virtual micro-painters: the Colombines and the Anti-Colombines. These painters have very limited perception abilities and cannot communicate directly with other individuals. The virtual canvas, besides being a computational space for depositing paint, is also a pheromone medium (that mirrors the painting patterns) influencing the painters' behaviour. Patterns are the emergent result of interaction dynamics involving the micro-painters and their pheromone medium.

1 Introduction

The study of biological self-organization [1] has revealed that numerous sophisticated pattern formation, decision-making, and collective behaviour, are the emergent result of the interaction of very simply behaviours 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 [2,3]. The emphasis of this paper is on the design of micro-painters swarms, which are able to create interesting patterns in artistic terms. There are already examples of collective paintings inspired by social insects: L. Moura [4] has used a small group of robot-painters inspired by ants' behaviour, that move randomly in a limited space. Stimulated by the local perception of the painting they may leave a trace with one of their coloured pens. The painters rely on stigmergic interaction [6] in order to create chaotic patterns with some spots of the same colour. Colour has the pheromone role: a spot dominated by a certain colour has the capacity to stimulate the painter-robot to add some paint of the same colour. Monmarché et al. [5] have also designed groups of painters inspired by ants' pheromone behaviour. It is based on a competition between ants: the virtual artists try to superimpose their colours on traces made by others, creating a dynamic painting which is never finished. Ants have the capability to "sniff" the painted colour and react appropriately. The societies are composed by a small number of individuals (less than 10). We will show and analyze the types of patterns resulting from the interaction dynamics of a pheromone environment (reflecting the painted and non-painted spots) and the mass of simple micro-painters, which

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cannot communicate directly with each other. The artists have only local perception (they never see the “tableau” as a whole), there isn’t any type of social coordination, interactions are stigmergic: the painters modify the painting area which influences their movement and painting behaviour. We have designed two societies of micro-painters: the Colombines and the Anti-Colombines. The first are attracted to non-painted spots and, in contrast, the Anti-Colombines are attracted to painted ones. In both, there is a chemical medium which reflects the bi-dimensional canvas state and it is the chemical that attracts the artists (the painters try to prefer to go to patches with more chemical). They were implemented in Starlogo [7].

One of the differences from the other ant-paintings is that the 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. We introduced also populations of numerous agents: we have experimented with groups composed of up to 2000 individuals working in the same artistic piece.

The remainder of the paper is organized as follows: In section 2 we describe in detail the Colombines and making some variations on the basic painter behaviours. In section 3 we focus on the Anti-Colombines. Finally we conclude, discussing the results and pointing future directions.

2 The Colombines

The Colombines are a swarm of small 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 grided paper, with no borders, folded in every direction, in which two types of virtual materials coexist: paint and a chemical signal. Each patch can have a certain colour and can have a certain quantity of chemical. There is a fixed colour (usually grey) for the background. Any other colour corresponds to paint. As we said before, our goal is that 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 neighbours, 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 behaviour 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 neighbours; 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. Our micro-painters have a very limited perception field—they have an orientation and have access just to the three cells in front of them. Each painter is created with a particular colour and they never change to another colour. 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 colour behind them. In case of identical chemical values in their neighbouring 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 colour that is never changed. The behaviour of each Colombine is the following: 1) he 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 colour on it, otherwise, does not paint it. In detail, the painter senses his three forward neighbouring 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, rounding his coordinates. The round operation influences the patterns generated, as we will see later.

The evolution of the collective artistic work happens the following way. Initially, the virtual canvas is grey and each patch has an identical quantity of chemical (normally 0). We create a colony of Colombines, each one with its own colour 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 behaviour (chemical production, diffusion and evaporation); in the second step, the Colombines move, attracted by chemical, depositing paint.

2.1 Dynamics Responsible for Pattern Emergence

The canvas can be seen as a dynamical chemical landscape, in permanent mutation—there is a constant interaction between chemical distribution and the painters' behaviour. The chemical world is information floating both in the painted and background patches. There is a strong circularity: On one hand, the chemical information guides the movement of the Colombines, attracting them toward non-painted spots, On the

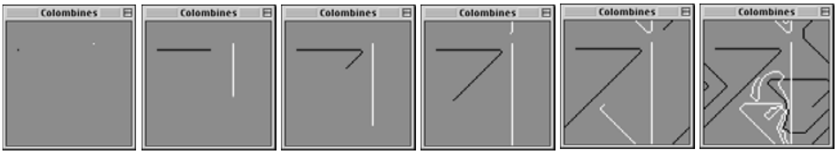

Fig. 1. The interaction between two painters. Illustration of the tendency to conserve direction and to avoid painted patches. The coordinates rounding effect is also visible: traces suffer only rotations of 45 or 90 degrees

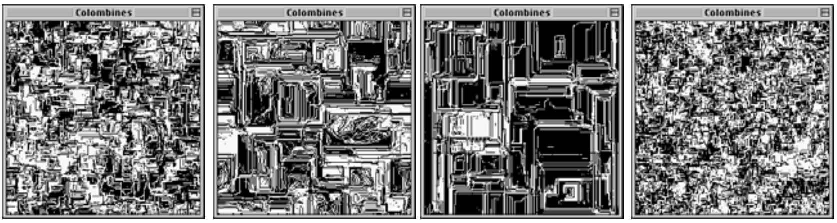

Fig. 2. Colombine black and white paintings

other hand, their painting activity change the information landscape, in an permanent auto-catalytic interaction. The patterns, the coloured forms, are the by-product of the collaboration between the Colombines and their chemical environment. Figure1 illustrates the pattern emergence.

We have two painters, one white and one black. They have an initial orientation (black moves east and white goes south). They both tend to preserve their directions. The black suddenly changes direction, avoiding the trace left by the white painter. After a while the white painter reaches his own trace and avoids it, changing direction and having to avoid later the black trace and the painting history goes on. Sometimes, the painters have to cross already painted spots, due to the fact that the three immediate neighbours are painted. Notice that we can find spots with the same colour due to the fact that a painter can be on a non-painted area which is surrounded by traces, constraining him to be inside, painting that enclosed spot.

In figure 2 we show four examples of finished paintings made by groups of Colombines of different sizes (from left to right, 1000, 100, 50 and 2000 painters) in a world of 125*125 pixels. There are only black and white painters equitably distributed by each of the colours and which are randomly scattered on the "tableau". The painters were created with random orientations. If we increase the number of micro-painters, the possibility of encountering traces also increases. The resulting effect is that the spots with the same colour have a smaller area and we find less rectilinear traces.

In reality, these 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.

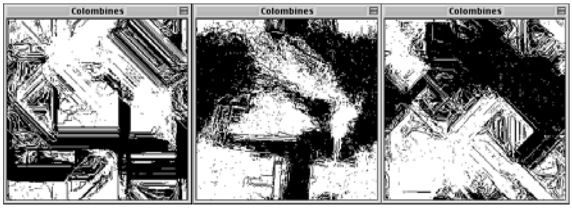

Fig. 3. Three paintings, from left to right: 2000 Colombines divided in groups of 200, 300, and 100 individuals

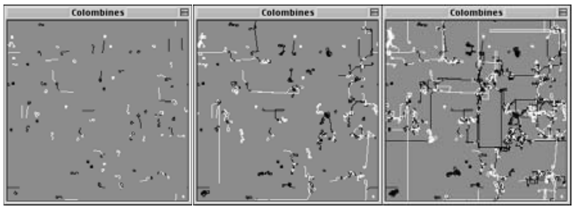

Fig. 4. Evolution of a painting made by 100 b&w Anti-Colombines, not clustered, with initial random positions and orientations

2.2 Variation: Clustering Painters

Now, we will make a slight variation on the Colombines initial settings. We will divide them in groups (the groups number is a global parameter) and put each group in the same patch. The painters in the same group have the same colour but have different directions. We introduce also a variation on the painters' behaviour. We do not want that the group will remain in the same patch forever. Each painter will make a small random jump (for example, up to three cells) to a neighbouring patch every time he senses another mate in his cell. This behaviour allows a kind of dispersion inside a group before a group invades painted zones. Figure 3 shows the final paintings of other clusters of Colombines. As we can see, these initial clusters will make the painting with more spots of the same colour.

3 The Anti-colombines

We want to introduce an inversion on the patches behaviour. Our goal now is that, instead of being attracted by the empty spots, the painters shall be attracted by the painted ones. The new painters, the Anti-Colombines, will maintain their behaviour (they continue to go up-hill in the gradient field) but now the non-painted patches are not chemical producers—the producers are the painted ones. Since the painters are attracted to the painted spots it is not wise to expect that the canvas is going to be fulfilled with paint. Thus we are obliged to choose a random or fixed number of iterations, and so after finishing them the painting is considered finished.

In figure 4 we show three snapshots of a plastic work made by a colony of 300 Anti-Colombines, scattered randomly on the grey "tableau" (they have initial random orientations and positions). The painters do not apply a round operator to their coordinates after making their moves. What happens is that the painters will be trapped inside painted spots, circling around, and occasionally they can get out of these traps slowly enlarging them. When they have the three neighbouring patches (their perception field) non-painted they will choose one of them for occupation. The probability of getting out of the painted traps decreases with the increase of their areas.

4 Future Work

We have designed two types of swarm micro-painters, the Colombines and Anti-Colombines, relying only on local perception and with no coordination, being able to produce interesting patterns, which can be seen as a kind of artificial art. Due to the regularities of the resulting patterns, we dare to say that there is what we can name, a Colombine or Anti-Colombine style. We have only showed black and white paintings for obvious reasons, but we could have made experimentations with different colours.

We are already working with what we may call consensual painters. The painters are able to interact with each other and achieve a decentralized consensus about certain attributes, like the colour they are painting, the position they are occupying, the velocity they possess or the direction they are facing, creating different type of structure and patterns. These consensual painters are able to randomly alter their attributes, shifting from a unanimous situation forcing the others to converge to a new consensus, in cycles consensus, cycles of order and chaos reflected on the patterns formed.

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