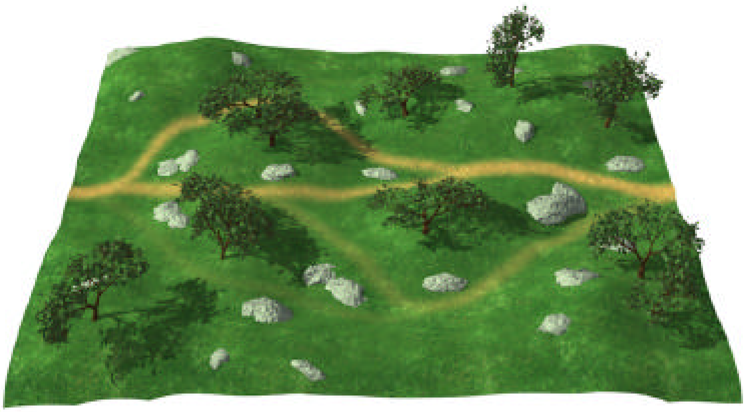

Trails, Ants and Anarchy

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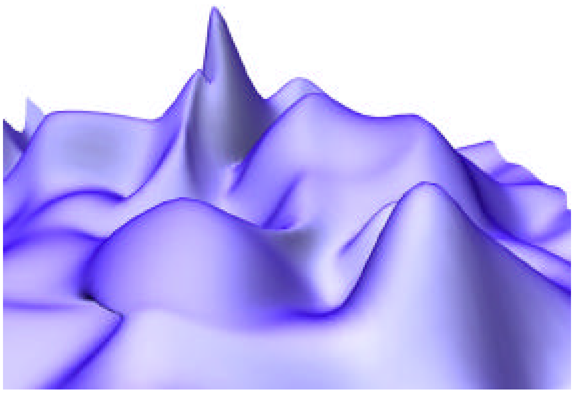
Trails

Whoever has walked through the countryside, whether wandering for fun or traveling by necessity, has undoubtedly at some time taken a trail that existed before, trails blazed by who knows whom. Some, if they are often used, are highly visible because no vegetation grows on them; others, in grassier or less often used areas, show slight traces of preview footsteps, barely sufficient to serve as orientation. In any case, we are less interested here in the configuration, consistency, or even quality of these trails, as in how they are generated. In most cases, they appear out of necessity, linking places or towns, and, naturally, the idea is either to make them as short or as safe as possible, or to follow the most scenic route. Essentially, therefore, the formation of a trail is a question of optimization.

But since we are discussing trails that were not designed by any engineering or architecture firm, but which arose *spontaneously* in the countryside, this *problem* cannot be resolved globally. In reality, the *problem* is not even understood as such, but rather as the result of a chaotic, non-lineal process.

In a first phase, different pathways arise at random. As more people walk through the area they gradually add increasingly efficient alternatives, here finding a shorter way, there an easier one. Over the course of time the earliest pathways, since they are no longer used, begin to disappear, once again becoming overgrown with grass, fading away by the work of nature. The trail *emerges*, then, both due to the traces left behind by all of those walking boots, and to the disappearance from lack of use, of less interesting alternatives. At any given moment, the trail is the result of a collective, unplanned action's impact on the environment. Moreover, the great majority of those who, with their footsteps, create these trails do not communicate among themselves, do not establish any kind of plan, nor do they previously define rules of behavior. They do not know each other, and often do not even care to do so. They all simply act upon a *given* environment, using elements that the environment itself provides for them. In its apparent triviality, this example of trail-blazing serves to show that it is possible to draw up the map of a territory in a way very different from the conventional method. Without the benefit of any cartographic tools, a map arises out of the environmental experience itself.



Ants

In ants, trail formation is based on a process of deposition and evaporation of pheromones. These pheromones are made out of a chemical element, a kind of a scent, which simultaneously has the property of being agreeable to the ants - that is, to stimulate them - and that of being able to fade away over time.

The deposition of pheromones is an easily understood phenomenon, since it functions like Ariadne's thread in the Minotaur's labyrinth. An ant wandering about at random leaves behind a trail which enables her to find the way back to her anthill. However, should the ant find food, she will go back by the same trail depositing more pheromones and thus making the trail more clear-cut. Any ants passing by will find a stimulus stronger than their own trails, and soon they will all merge into one of those troops of hundreds or thousands of ants that we see so often.

Meanwhile, the trails with a lower level of pheromone, to which no other insect has returned, disappear; that is, they evaporate.

This is very important in terms of optimization. Let us suppose that the aforesaid ant troop was following a trail that was not the shortest route between the anthill and the food. And then a single, less obsequious ant (because a stimulus is just a stimulus and not an order) finds a shortcut. Two things happen: on this route the pheromone deposition is higher, and on the other, which takes longer to travel, pheromone evaporation is quicker. Then some ants begin to prefer the new route, and soon thereafter they perceive that the shortcut is more *stimulating*.

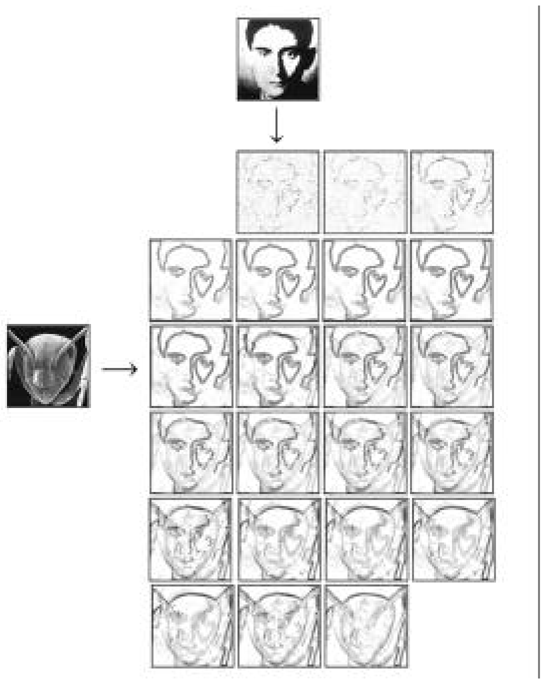
This process of pheromone deposition/evaporation, which represents a kind of *environmental computation*, really creates a kind of map very different from the ones with which we humans are familiar.
In social insects, who *draw* their spatial memories on the environment the map is collective; it is not inside the head of any individual.

In other words, there is no centralized control, no predetermined plan, no command. Everything happens through simple, individual, local behaviors, able to *collectively* produce a general behavior. Moreover, ants do not directly communicate among themselves. They do so through a message deposited in the environment; i.e., indirectly. The pheromone deposited by an individual has an effect on the activity of another individual. This process has been given the name 'stigmergy', from the Greek *stigma*, mark, and *ergon*, work.

Engaging in some intellectual fantasy, we can say that it is as if reading a book provided us with an unavoidable stimulus to write another book, and so on. Actually, this is not such a bad example, because very probably our cultural production functions in this way. For some people, ideas are *exciting*, and lead to the appearance of new ideas[1]. An aesthetic experience affects us so much that we feel impelled to paint a picture, too.

Stigmergy comprises a mechanism that, in collective terms, leads to the appearance of a map made by all of the agents involved. Ant trails *emerge*, they are not the result of a previous plan, or an order, or any kind of intentional act. Each ant really does nothing more than act on her own limited, local scale, without ever perceiving the map that appears as a result.

But although each individual lacks this capacity, the colony seems to act as a whole. This is so much the case that the *swarm* can be seen as an independent entity, a higher level of life, possessing a *collective intelligence*[2].



Computers

The simplicity of these mechanisms enables us to easily transpose them to the world of computers, contributing to the resolution of many complex problems, and introduced a new vision of complexity itself.

Today, virtual ant colonies are used in multiple-agent systems, such as the Internet or mobile phones, or which require self-organizational capacities, as in robotics.

However, their scope is much wider than that. We now have models that are able to explain individual and crowd behaviors in human beings, social organization or cultural evolution. Or things as difficult to quantify as taste or consensus.

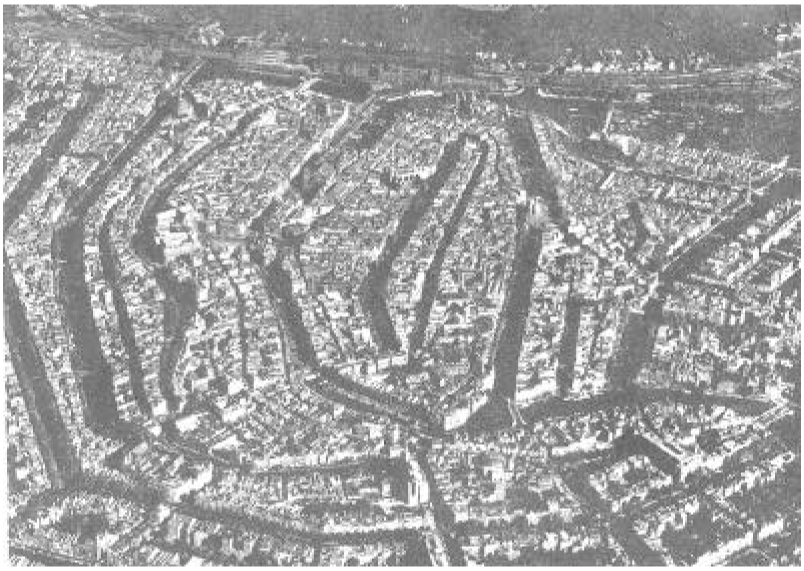
These models are tested and simulated in computers.

In 1995, Dante Chialvo and Mark Millonas[3] presented an algorithm able to reproduce the behavior of ant colonies in trail formation. Essentially, the algorithm simulates ant perception, movement through the environment, a capacity to recognize pheromones (stimuli) and to deposit it, as well as accumulation and evaporation over time (iterations). The pioneering experiment was conducted in a monochromatic environment i.e. without any previous stimuli. Even so, *out of nothing*, and after a few iterations, a collective map emerged.

We should highlight that both the pheromone trails and the resulting map are based, in the computers, on levels of grey. In reality, each ant alters the pixel level where it passes. To simplify further: darker means more pheromone, lighter means more evaporation.

The environment of these ants can thus be seen as a landscape with mountains and valleys, filled with very high peaks and very low canyons.

In 1996, based on the model by Chialvo and Millonas, Vitorino Ramos[4] developed a new idea and created a new algorithm. Instead of working on a monochromatic base, he decided to introduce an image. In one of these experiments, he set loose a (virtual) ant colony onto an image of Kafka's face. In other words, a *stimulated landscape*. The colony adapted to this environment, creating a cognitive interpretation of it. But then, after a few iterations, Kafka's face was removed, and substituted by an image of a red ant head. Something like pulling the rug out from under someone's feet, and replacing it with another one with a different design pattern. In the following iterations, Kafka's face remained as a sort of *memory* of the colony, until it gradually adapted to the new image. This memory, shared by all the ants, introduced a higher-level dynamic into the model. Something that, implicitly, we can call a *culture*.



Stigmergy

Paths in the woods, ant trails, and their respective artificial models are based on the same mechanism that we are trying to understand here: stigmergy. The concept was introduced by Pierre-Paul Grassé[5] at the end of the 1950s, in studies that he carried out on social insects, to describe a particular form of indirect communication among individuals.

It can be defined as a particular example of environmental or spatial synergy. The alteration of an environment by an individual sparks a stimulus in other individuals who, in turn, tend to intervene in (and modify) this environment.

Termites use this mechanism to build their enormous clay cathedrals. In the first phase, the insects randomly deposit little balls of clay impregnated with pheromone. The formation of a pile stimulates other termites to add more clay, and the higher the piles, the greater the stimulus. Little mounds are abandoned. Some columns grow and come together until they touch, forming arches. The result is an intricate and very solid structure.

As we can see, this system can be applied both to co-operation mechanisms in animals and to urban, social, cultural or political phenomena.

The formation of cities is based, to a large extent, on processes of self-organization and stigmergy. Streets, houses, squares appear as the result of a construction/destruction process in a constant give-and-take of interests and expectations, the products of individual actions and of temporary collective consensus. Even when we consider planning and political decision-making, the development of a city, as a whole, results from the activity of multiple agents, all of whom act on a local level. In a wider context, the cities themselves can be seen, for the human race, as high peaks of social pheromone (stimuli) able to attract everything and everyone around them. In cultural production, there is also a clear stigmergetic effect. The cultural pheromone is a simultaneously quantitative and qualitative stimulus. In other words, in culture we never start from a *monochromatic environment*; on the contrary, whatever approach we take, we will always have an environment *loaded* with memory (pheromone peaks). From this point of view, contemporary cultural production is characterized by the reinforcement of certain trails and the abandoning of others, in a permanent reconstruction of the collective cognitive map.

This model's interest clearly resides in the fact that, for the first time, it is possible to understand cultural evolution without the need to emphasize moral or ideological concepts, aesthetics or ethics, beauty or intentionality.

Anarchy

When we talk about anarchy, we tend to have an image of mad bombers, destruction, chaos. In everyday language, the word is used to describe confusion, lawless or violent situations. The term's true meaning, a non-hierarchic system, is rarely invoked.

The word *anarchy*, like so many good things, comes from the Greek, combining the prefix *an* (negation) with the noun *archós* (government, rule). It literally means *without government*; i.e., a system not needing a leadership, or a hierarchy.

The systems we have discussed in this essay can be characterized by their capacity for self-organization. Neither God nor master could be their motto, after the old anarchist song.

In spite of the common bad image, non-hierarchic systems are much more functional and efficient than hierarchical systems, which are based on predetermination, and overvaluation of leadership. Optimization, in human groups, presents two major obstacles. The first stems from the imprecision of language. The second is linked to power games and the tendency to favor hierarchies. In a group, not only is communication highly inadequate, because even when someone claims to have understood what another has said, it might not be *exactly what was meant*; as in addition, the very ideas of the leaders are given pride of place, and the observations of subordinates are undervalued.

Consequently, groups tend to be unable to achieve more than what could previously be obtained via the individual decisions of the superiors. In such cases, optimization is based essentially on a stupid principle: trial by error. And there is also a tendency to resolve primarily those problems affecting the most powerful, and forget about all other issues. Ants are more intelligent than that...

Paths through the woods, or trails designed by ants, can be seen as maps that emerge from a *collective intelligence*. Nobody planned them, nobody gave an order. They are produced by the action of many individuals who communicate indirectly, through the very environment on which the map is being drawn. All of these individuals maintain their own autonomy, and act according to their own will, reacting to stimuli - which means that any behavior is possible, since a stimulus is exactly that, a stimulus, not an order. That is why we can use the term *anarchy* to describe this collective intelligence, which emerges *without any government*.

April 2002

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[4] Vitorino Ramos, Filipe Almeida, Artificial Ant Colonies in Digital Image Habitats - A Mass Behaviour Effect Study on Pattern Recognition, Proceedings of ANTS'2000 - 2nd International Workshop on Ant Algorithms (From Ant Colonies to Artificial Ants), Marco Dorigo, Martin Middendorf & Thomas Stüzle (Eds.), pp. 113-116, Brussels, Belgium, 7-9 Sep. 2000.

[5] Grassé, P.-P. "La Reconstruction du nid et les Coordinations Inter-Individuelles chez *Bellicositermes Natalensis* et *Cubitermes sp*. La théorie de la Stimergie: Essai d'interprétation du Comportement des Termites Constructeurs" *Insect Soc.* 6 (1959): 41-80.