Stigmergy

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Stigmergy is a mechanism of indirect coordination between agents or actions.[1] The principle is that the trace left in the environment by an action stimulates the performance of a next action, by the same or a different agent. In that way, subsequent actions tend to reinforce and build on each other, leading to the spontaneous emergence of coherent, apparently systematic activity.

Stigmergy is a form of self-organization. It produces complex, seemingly intelligent structures, without need for any planning, control, or even direct communication between the agents. As such it supports efficient collaboration between extremely simple agents, who lack any memory, intelligence or even individual awareness of each other.[2]

Contents

History

The term "stigmergy" was introduced by French biologist Pierre-Paul Grassé in 1959 to refer to termite behavior. He defined it as: "Stimulation of workers by the performance they have achieved." It is derived from the Greek words στίγμα *stigma* "mark, sign" and ἔργον *ergon* "work, action", and captures the notion that an agent's actions leave signs in the environment, signs that it and other agents sense and that determine and incite their subsequent actions.[3]

Later on, a distinction was made between the stigmergic phenomenon, which is specific to the guidance of additional work, and the more general, non-work specific incitation, for which the term *sematectonic* communication was coined[4] by E. O. Wilson, from the Greek words σῆμα *sema* "sign, token", and τέκτων *tecton* "craftsman, builder": "There is a need for a more general, somewhat less clumsy expression to denote the evocation of any form of behavior or physiological change by the evidences of work performed by other animals, including the special case of the guidance of additional work."

Stigmergy is now one of the key[5] concepts in the field of swarm intelligence.

Stigmergic behavior in insects

Stigmergy was first observed in social insects. For example, ants exchange information by laying down pheromones (the trace) on their way back to the nest when they have found food. In that way, they collectively develop a complex network of trails, connecting the nest in the most efficient way to the different food sources. When ants come out of the nest searching for food, they are stimulated by the pheromone to follow the trail towards the food source. The network of trails functions as a shared external

memory for the ant colony.

In computer science, this general method has been applied in a variety of techniques called ant colony optimization, which search for solutions to complex problems by depositing "virtual pheromones" along paths that appear promising.[*citation needed*]

Other eusocial creatures, such as termites, use pheromones to build their complex nests by following a simple decentralized rule set. Each insect scoops up a 'mudball' or similar material from its environment, invests the ball with pheromones, and deposits it on the ground, initially in a random spot. However, termites are attracted to their nestmates' pheromones and are therefore more likely to drop their own mudballs on top of their neighbors'. The larger the heap of mud becomes, the more attractive it is, and therefore the more mud will be added to it (positive feedback). Over time this leads to the construction of pillars, arches, tunnels and chambers.[6]

Applications

Stigmergy is not restricted to eusocial creatures, or even to physical systems. On the Internet there are many collective projects where users interact only by modifying local parts of their shared virtual environment. Wikipedia is an example of this.[7] The massive structure of information available in a wiki,[8] or an open source software project such as the FreeBSD kernel[8] could be compared to a termite nest; one initial user leaves a seed of an idea (a mudball) which attracts other users who then build upon and modify this initial concept, eventually constructing an elaborate structure of connected thoughts.[9][10]

The term is also employed in experimental research in robotics[11], multi-agent systems and communication in computer networks. In these fields there exist two types of stigmergy: active and passive. The first kind occurs when a robotic or otherwise "intelligent" "agent" alters its environment so as to affect the sensory input of another agent. The second occurs when an agent's action alters its environment such that the environmental changes made by a different agent are also modified. A typical example of active stigmergy is leaving behind artifacts for others to pick up or follow. An example of passive stigmergy is when one agent tries to remove all artifacts from a container, while another agent tries to fill the container completely.[*citation needed*]

In addition the concept of stigmergy has also been used to describe how cooperative work such as building design may be integrated. Designing a large contemporary building involves a large and diverse network of actors (e.g. architects, building engineers, static engineers, building services engineers and etc.). Their distributed activities may be partly integrated through practices of stigmergy.[12][13]

See also

- Ant mill
- Spontaneous order
- Swarm intelligence

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External links

- Special issue on Stigmergy (http://www.mitpressjournals.org/doi/abs/10.1162/106454699568692) at Artificial Life Journal (http://www.mitpressjournals.org/loi/artl) , Eric Bonabeau (Eds.), MIT Press, Vol. 5, No. 2, Spring 1999.
- Stigmergic Collaboration: The Evolution of Group Work (http://journal.media-culture.org.au/0605/03-elliott.php) (peer-reviewed & published article)
- Stigmergy papers published on scientific commons (http://en.scientificcommons.org/#search_string=stigmergy) (a growing list of published articles)
- wiki version (http://collaboration.wikia.com/wiki/Stigmergic_collaboration) at MetaCollab.net

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