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Reproducing the behaviour of a complete ant colony (extended abstract)

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Motivation

Modelling the activity of an ant community based on the individual behaviour of a single ant is a very modern approach, but until now the modelling was often restricted to single phenomena, e.g. foraging or recruiting. But these activities can not be seen independently from other necessary abilities, like e.g. defending a territory from enemies. In this paper we want to present a model of an ant colony that unites different activities during a complete life cycle of an colony.

Modelling the behaviour of an ant colony as a multi-agent system

For the representation and simulation of social groups two different approaches are possible: On the one side the complete group can be seen as one system, which's behaviour can be modelled in a set of differential equations. This global view of modelling has various disadvantages (e.g. see [Ferber, 1994]). The other approach is to model the behaviour of the single entities of the group and observe and thus evaluate the emerging phenomenon from the global view. This bottom-up modelling provides apriori a better understandable, more „intuitive" representation as it mirrors directly the structure of real system.
But not only the decision to use individual based modelling for the simulation of the activities of an ant colony is sufficient to guaranty the outcome of an accessible model. The architecture used for modelled animal is also influencing various properties of the modelling process and the model itself: It determines, how explainable and accessible the modelled behaviour and how much skills in programming the researcher has to have.
We used for modelling the multi-agent simulation shell AL-OSIS (see [Kluegl et al., 1996]) which provides a rule-based architecture for the single agents. Every agent has a current activity which determines the action the agent executes on itself and on it's environment. This activity is selected via stochastic rules, that „fire" only with a certain probability when the condition situation is perceived. It is also possible to model activity sequences, even with not fixed alternative actions. The termination of the current activity may be driven by special situations or simple time-outs. It is also possible to interrupt the execution in emergency situations.

General characteristics of an ant colony

Before describing the modelled behaviour we want to present a few information about real ants. The common features of all the ant-species are summarised with the term "Eusociality": There is a reproductive division of labour, with just one or a few ants , called the queens, laying all the

eggs. The different developmental stages of the brood are cared for in a cooperative manner (cleaning, feeding, searching for food) by other non-reproductive workers [Crozier and Pamilo, 1996]. The growth of a colony follows several steps (depending on the examined species). The founding stage starts with the nuptial flight of the virgin queens. The single queen is inseminated by one or more males and starts with building a small nest by her own. The first brood is reared by the queen. When the workers reach the adult stage, they take over all the necessary work. The colony starts growing. More and more workers are produced, sometimes of different physical castes, and the nest is enlarged. Because of the number of workers, the workforce can be divided between group of workers, e.g. broodcare, patrolling, food-collecting. This is the ergonomic stage. In the last, reproductive stage the queen starts additionally with producing sexual animals (males and females). Usually during the warm season the nuptial flight happens, where the winged sexuals leave the mother colony, and start their own colonies. This is the beginning of a new reproductive cycle. With the loss of biomass during the nuptial flight in the reproductive stage , the colony enters again the ergonomic stage and cycles around this two developmental levels.

The modelled colony and emerging phenomenon

The architecture described in the second section is used for modelling almost the complete behavioural spectrum observed in an ant colony. We focused on the behaviour of colonies of the Myrmecocystes mimicus, living in deserts of the south-western United States. These ants are extensively studied for several years by Bert Hölldobler. (for a review [Hölldobler, 1983] and [Hölldobler and Wilson, 1990]). Especially their tournaments between neighbouring colonies are of particular interest.

As the ant's behaviour is situated in it's environment, the world, the modelled ant lives in, has also to be elaborated carefully. The environment is based on two-dimensional maps consisting of basic square units which can be interpreted as an area of one square meter. Every unit owns some special parameter values, e.g. it knows how many timesteps a trail takes to vanish from this soil. Every unit in such a map can carry a special amount of agents and passive objects, that may represent e.g. food resources or different forms of obstacles.

A modelled colony consists of ants belonging to different „castes“, that are groups of entities that exhibit more or less specialised behaviour. Besides the queen, ordinary and sexual brood, we represented the behaviour of honeypot ant, virgin queens, nestworkers and workers using only rules that depend on the internal state and the external situation of the respective ant. Thus we managed to cover different aspects of the life of an ant colony:

- production of new ants
- exploring new terrains and foraging
- energy storing and distribution inside the colony
- intercolony conflicts resulting in tournaments
- foundation of new colonies and colonisation of a new habitat

All these phenomenon are not considered seperately but combined in one unique model. This is necessary as the different phenomenon are strongly depending on each other. For example the production of brood consumes very much energy that must compensated by extended foraging. Thus the number of exploring workers can not be independent from the number of brood that must be feeded. The model is completely implemented and the course of important parameter of the behaviour produced by the modelled ant colony, is jugded by experts as plausible.

Our model lacks currently the structure and development of the inside of the nest. That means the nestworkers are not changing or extending the chambers and holes of the nest. This task will be the next part of our modelling.

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