An example for (reactive) cooperative behaviour: the Swiss robots

The Didabots are cleaning up

In what follows we summarize experiments conducted by Maris and te Boekhorst (1996) who studied a collective heap building process by a group of simple robots, called Didabots (see figure 1 (a) below). Instead of predefining "high-level" capacities, Maris and te Boekhorst exploit the physical structure of the robots and the self-organizing properties of group processes. The main idea behind the experiments is that seemingly complex patterns of behavior (such as heap building) can result from a limited set of simple rules that steer the interactions between entities (e.g., robots) and their environment. This idea has, for example, been successfully applied to explain the behavior of social insects (see below).

Look at figure 1. There is an arena with a number of Didabots, typically 3 to 5.

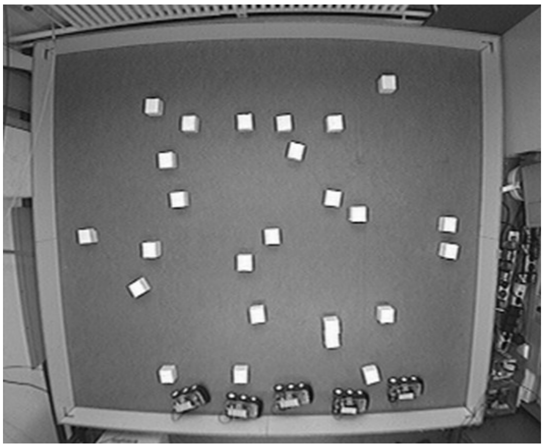

Figure 1: Didabots in their arena. There is an arena with a number of Didabots, typically 3 to 5. All they can do is avoid obstacles.

They are equipped with infrared sensors that can be used to measure proximity: They show high activation if they are close to an object and low or zero activation if they are far away. The range of the infrared sensors is on the order of 5 cm, i.e. relatively short. The sensors are located on the left and on the right side of the robots (see picture 2 (b) below). All the Didabots in this experiment can do is avoid obstacles. They are programmed with the following simple control rule: If there is sensory stimulation on the left, turn (a bit) to the right, if there is sensory stimulation on the right, turn (a bit) to the left.

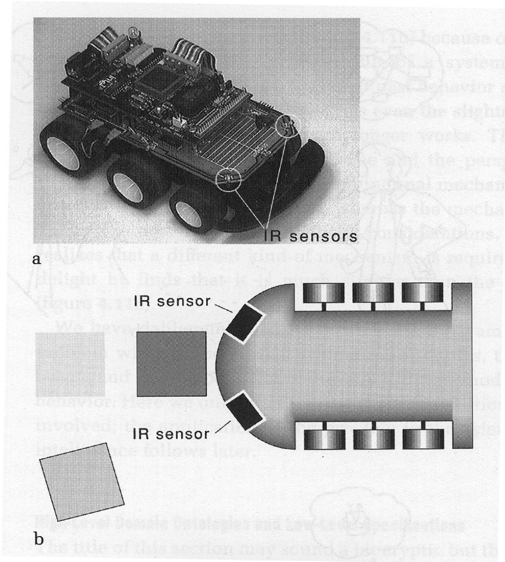

Figure 2 (a) Picture of a Didabot. (b) Infrared- Sensor configuration of Didabot.

Now look at the sequence of pictures shown in figure 3. Initially the cubes are randomly distributed. Over time, a number of clusters are forming. At the end, there are only two clusters and a number of cubes along the walls of the arena. These experiments were performed many times. The result is very consistent — there are always a few clusters and a few cubes left along the walls. What would you say the robots are doing?

“They are cleaning up”; “They are trying to get the cubes into clusters”; “They are making free space”; these are answers that we often hear. These answers are fine if we are aware of the fact that they represent an observer’s perspective. They describe the behavior. The second answer also attributes an intention by using the word “trying”. We are the designers, we can say very clearly what the robots were programmed to do: to avoid obstacles!

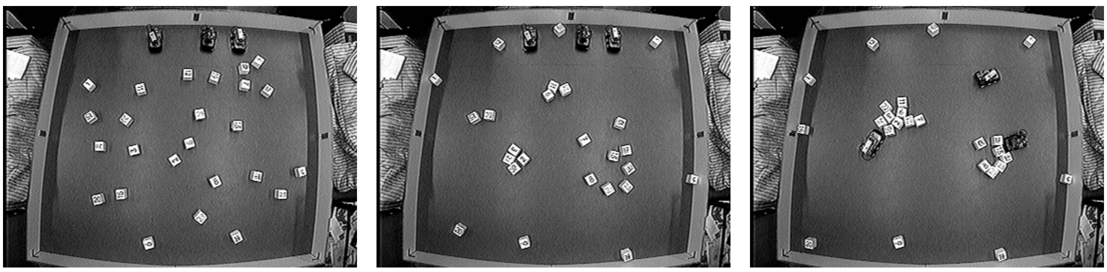

Figure 3: Example of heap building by Didabots. Initially the cubes are randomly distributed. Over time, a number of clusters are forming. At the end, there are only two clusters and a number of cubes along the walls of the arena.

The complexity of the behavior is a result of a process of self-organization of many simple elements: the Didabots with their simple control rule. The Didabots use the sensors on the front left and front right parts of the robot. Normally, they move forward. If they get near an obstacle within reach of one of the sensors, they simply turn toward the other side. If they encounter a cube head on, neither the left nor the right sensor detects an obstacle and the Didabot simply continues to move forward. At the same time, it pushes the cube. However, it pushes the cube because it does not “see” it, not because it was programmed to push it. For how long does it push the cube? Until the cube either moves to the side and the Didabot loses it, or until it encounters another cube to the left or the right. It then turns away, thus leaving both cubes together. Now there are already two cubes together, and the chance that yet another cube will be deposited near them has increased. Thus, the robots have changed their environment which in turn influences their behavior. While it is not possible to predict exactly where the clusters will be formed, we can predict with high certainty that only a small number of clusters will be formed in environments with the geometrical proportions used in the experiment.

The kind of self-organization displayed by the Didabots in this experiment is also called self-organization without structural changes: If at the end of the experiments, the cubes are randomly distributed again and the Didabots put to work on the same task, their behavior will be the same — nothing has changed internally.