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Implementation of a successful patterning process within the standard model

Work package 2
Patterning and Morphogenesis

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Summary

In this deliverable we describe the various patterning processes that have been realized in the Swarm-Organ project. The patterning work can roughly be divided into two main topics: exploration of pattern formation processes on the kilobot platform and modeling of Gene Regulatory Networks (GRNs), which will finally be used as a control mechanism of the robots.

The patterning processes have mainly been implemented on an open kilobot simulator called *kbsim*. The following processes have been implemented. In d*istance propagation,* every robot calculates its distance to a specially designated robot, using only communication with its neighbors. In the *skin detection* demonstration, the robots detect whether they are on the edge of the swarm or inside it, by keeping track of how many neighbors it has. The *gastrulation* pattern shows the possibilities of controlled movement, where agents interact with virtual springs. Biological cells can pull or push against each other, while our robots mainly move by exerting forces on the floor. The spring simulation is a way of mimicking a mechanical interaction between neighboring robots. The in *morphogen gradient* and *reaction-diffusion-system* simulations, each agent simulates the diffusion of morphogens, inspired by gene regulation in nature. Here, each robot keeps track of the concentration of one or more morphogens. Diffusion of these morphogens in the swarm is simulated using communication between neighboring robots: each robot transmits its own concentration and receives the concentrations in the neighbors. Each robot can then calculate the required change in its own morphogen concentrations. The *morphogen gradient* demonstration was also implemented on the actual kilobot robots, including the communication necessary for morphogen diffusion.

The remainder of the report focuses on the mathematical modeling of Gene Regulatory Networks. The connectionist model was chosen as the GRN modeling formalism for this project. In order to explore different network configurations, and to tune the network parameters, a GRN simulator was developed in C. It can simulate the behavior of a GRN with given parameters, or optimize the parameters to match specified gene expression profiles. The same simulator will also be used to infer the GRNs responsible for embryo development in biological systems, in particular in the starlet sea anemone Nematostella Vectensis.

In order to realize the goal of a swarm of robots, each controlled by a GRN, the GRN model has to be implemented in the robot program. The report is concluded with an overview of how this will be achieved in the kilobot programming environment. Since the diffusion part was already realized on the kilobots in the *morphogen gradient* demonstration, what remains to be implemented is mainly the regulation mechanism of the connectionist model.

Details on the background, methodology and results can be requested to the project coordinator if needed.