Using Virtual Embryogenesis for Structuring Controllers

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Abstract. One possibility to increase the efficiency of classical controller paradigms is to implement substructures with different tasks and abilities (heterogeneous controller structure). To automatically develop these structures it is necessary to use a process, that is on the one hand easy to evolve, and on the other hand rich in different solutions. One inspiration for such processes can be found in the biological process of embryogenesis. By using virtual embryogenetical processes in combination with artificial evolution we develop a novel method for controller structuring.

With rising complexity of the tasks standard controllers like "classical" Artificial Neural Networks (ANNs) soon become inefficient due to increasing complexity of learning or adaptation processes. One solution to increase the adaptivity of such controlling structures is to implement substructures with different tasks within the controller. The structuring of the controller can be manually predefined [1], or shaped by artificial evolution [2]. To solve the task to develop evolutionary shaped controllers it is important to find an evolution friendly method to decrease calculation cost and predict evolution from finding local optima. To reach this goal we developed the concept of Virtual Embryiogenesis (VE) by modelling the biological process of embryogenesis.

During biological evolution the processes of embryogenesis showed to be an ideal tool for shaping the bodies (including the control structures) of all multicellular lifeforms. The mechanisms shaping an lifeform are known as EvoDevo [3], which are perfectly able to work as a substrate for evolutionary processes. In biology, four phases can be observed in the evolution of multicellular organisms:

1. Optimisation: A morphometrical structure (including controlling structures, such as neural ganglia) are optimised by evolutionary processes.
2. Serialisation: Due to changes on genetic level the optimised morphological structure is built identically several times within an animal.
3. Exploration: Former identical morphological structures start to differ in their shape and function.
4. Specialisation: If a new shape becomes advantageous for a new function, the optimisation process is repeated. Disadvantageous structures are discarded.

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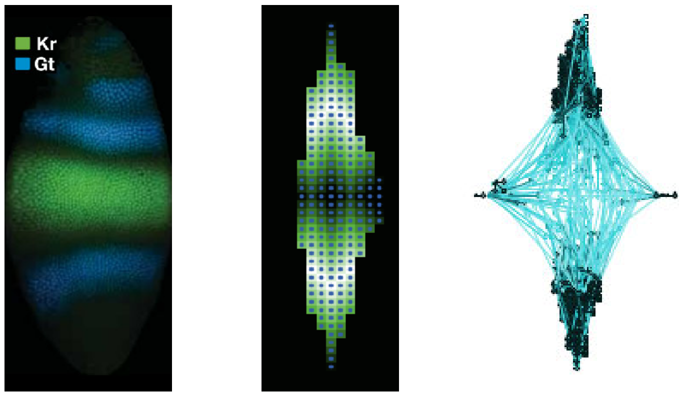
The structuring process of the biological embryos is controlled by morphogens, which are emitted by the cells of the embryo (see Fig. 1(a)). The cells themselves react to different concentrations of morphogens, e.g., with duplication or emission of morphogens. The reaction of the cells is encoded in the genome of the cells. By modelling these processes (see Fig. 1(b)) we are able to develop controller structures (see Fig. 1(c)) and test them regarding defined abilities (for details see [2]). Although VE was developed to shape ANNs, we plan to adapted to different kinds of controllers, that can be described by graphs.



(a) biological embryo (b) virtual embryo (c) VE-ANN

Fig. 1. Biological and virtual embryos. (a): Different morphogen concentrations in a biological embryo (from [4]). (b): Morphogen concentrations in a hand-coded virtual embryo. Dots indicate single cells, colours indicate morphogen gradients. (c): Structured ANN developed inside a virtual embryo. Dark lines indicate short distance connections (local sub-networks), light lines indicate long distance connections (global network).

References

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