SIMFLY:
The Simulation of a Fly Embryo

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Abstract

GEISHA (Genomic Environment for Interaction Simulation and Hypothesis Approximation) system verifies and revises the rules of pattern formation in Dorosophila embryogenesis. The system consists of three parts: rule-based simulator, evaluator, and user interface. The simulator tests all the possible rule patterns, and the evaluator qualitatively evaluates results of the simulator. The user interface is named SIMFLY and provides a real-time graphic viewer and a rule-controller. We can do most of these operations using GUI.

1 Simulation

Segmentation of Dorosophila melanogaster (D. melanogaster) is regulated by the pattern of segmentation genes comprising four groups: *maternal-effect, gap, pair-rule, segment-polarity.* These groups form a hierarchy of control relationship in this order. GEISHA system [1] simulates the first two groups independently.

Maternal-effect Genes Diffused *bic* protein from the localized deposit forms a gentle slope from the anterior end to the middle of an embryo.

Gap Genes Gap proteins, whose distribution falls sharp like a cliff, require less diffusion cycle than *bic* protein. The simulator simulates the distribution of gap proteins from the fixed distribution of maternal-effect proteins. Exhaustive search found many patterns of protein distribution.

These two groups, maternal and gap proteins, form different diffusion patterns (Figure 1, left). To simulate this difference, simulator repeats the cycle in Figure 1 with different rate of diffusion cycle for each group of proteins.

2 GUI

GUI comprises three parts: Simulation Controller, Protein Editor, and Viewer. All the operation can be done with a mouse.

Simulation Controller sets how many time-rounds the simulation runs and how fine the simulation models an anterior-posterior axis of an embryo. It can also set waiting time to slow the simulation.

We can revise the simulation rule by Protein Editor. This Editor can specify every feature of protein required by the simulation, like *lifetime* or *diffusion rate.* It can also restrict when and where the rule becomes effective,

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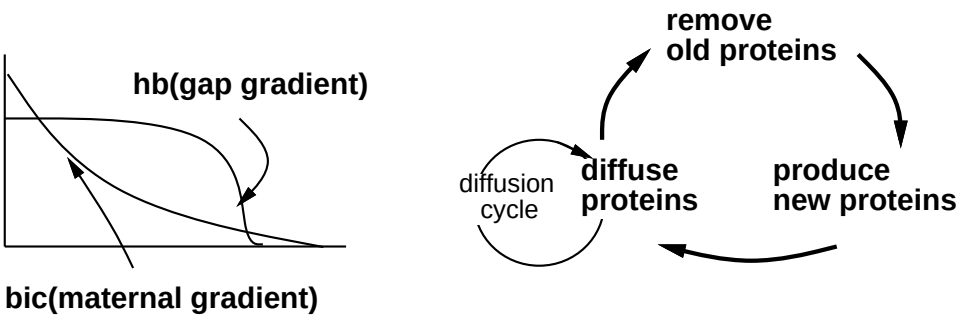

Figure 1: Gradient Patterns, Simulation Cycle

though this restriction is applied only to *bic* protein. We can change threshold-values, relations between proteins, and rules for each protein.

For Viewer, there are two types: one is bar chart and the other is embryo-like chart. In the former type, you can see the state transition as the ups and downs of bars. In the latter, the amount of protein is shown as the depth of color. This makes the expression of proteins seem just like an embryo stained with fluorescence in a laboratory. In both Viewers, you can see the simulation in full color. Up to 6 proteins at a time can be displayed in these Viewers.

3 Conclusion

We implemented GEISHA system for searching the optimal rules of pattern formation in embryogenesis of Drosophila melanogaster. GUI provides us the following operations.

- Input, revise, or save rules.
- Input, revise, or save the protein expression.
- Show animation of the simulation.
- Examine simulation results interactively.

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References

[1] M. Arita, M. Hagiya, and T. Shiratori. Geisha system: an environment for simulating protein interaction. Full paper is included in this volume.