CHEMORG

The Bio-Chemical Information Processing Metaphor as a Programming Paradigm for Organic Computing

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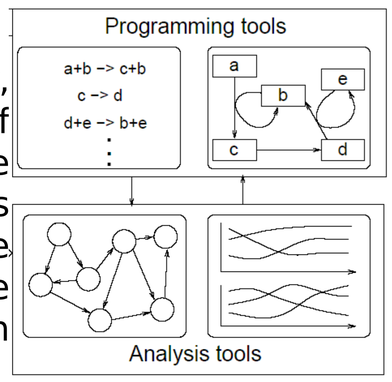
JCB Jena Centre for Bioinformatics

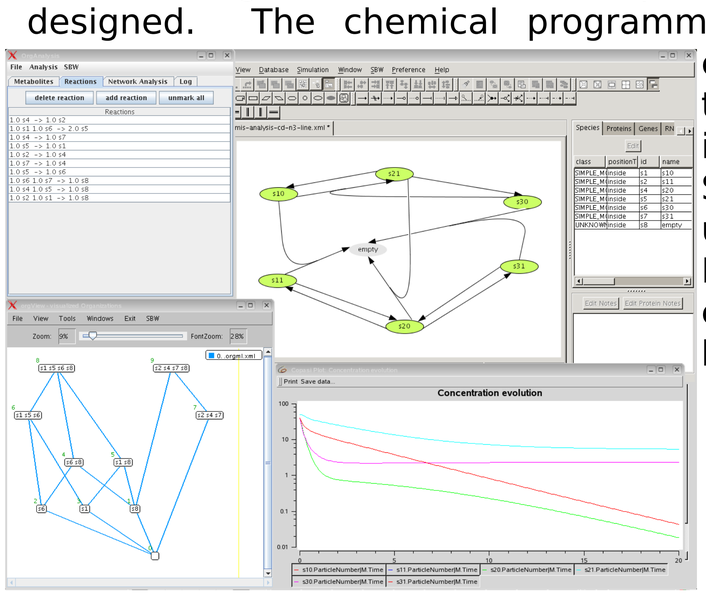
Summary

In every living organism, cellular functions emerge from the complex but orchestrated biochemical reactions. The aim of our project is to take that biochemical reactions as a metaphor of biological information processing and to harness the chemical reaction systems for computation. Bio-chemical reaction networks (or mathematical models of those) are designed to perform specific computational tasks. One of the challenges is to establish the programming methods of chemical computing systems, that is, how to fill the gap between the micro level (reaction rules) and the macro level (system behaviors). In chemical computing, we have employed chemical organization theory for this bridge [3], and organization-oriented programming principles are outlined [4]. On the other hand, an evolutionary design, as an alternative methodology, has been investigated [1].

Chemical Programming Workbench

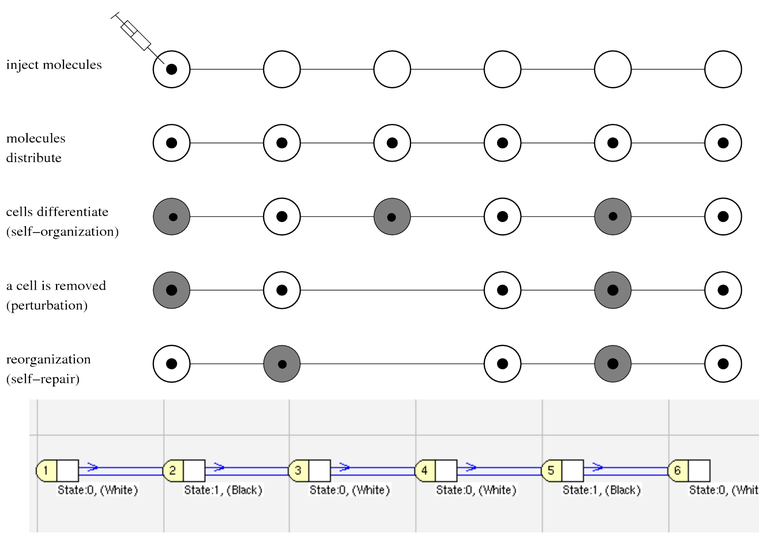
In order to program chemical reaction network, following four aspects are considered: 1) List of reaction rules, 2) graph representation of the network, 3) structural analysis, and 4) dynamics analysis. Dynamically and interactively changing the views among these, chemical computing systems are designed. The chemical programming workbench combines these four aspects and was implemented on the basis of Systems Biology Workbench using Systems Biology Markup Language as an exchangeable model description between tools.

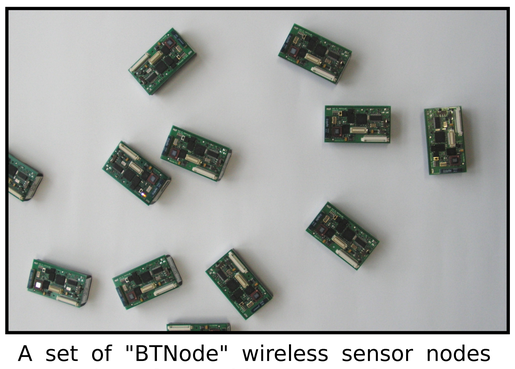




Organization-oriented Programming [4]

Toward quantitative evaluation, a scenario of self-organizing and self-repairing phenomena is sckethced. Nodes are connected linearly, and each node differentiates the color (white or gray) from the neighbors through self-organizing processes. Against perturbation of node removal, the whole network still sustains the alternating color property. This process can be realized with implementing the maximal independent set problem. Based on two predicates, a chemical reaction network is designed for this problem with the help of chemical organzation theory [6,7]. Then, the program is adjusted specially for distributed computing environments such as wireless sensor networks [2]. Simulation environment EmStar is employed to test the program, and we decided to use BTnode as the test-bed.



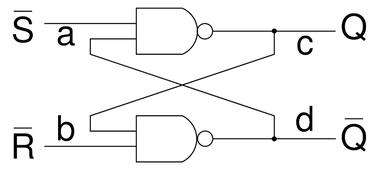


A set of "BTNode" wireless sensor nodes consisting of an 8 bit ATmega System-on-Chip, 238 KiB RAM, a Bluetooth unit for wireless network and a battery life time of up to 1-year.

Hybrid Design Methodology

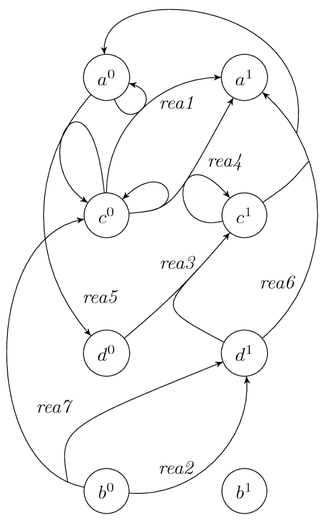
ESIGNET

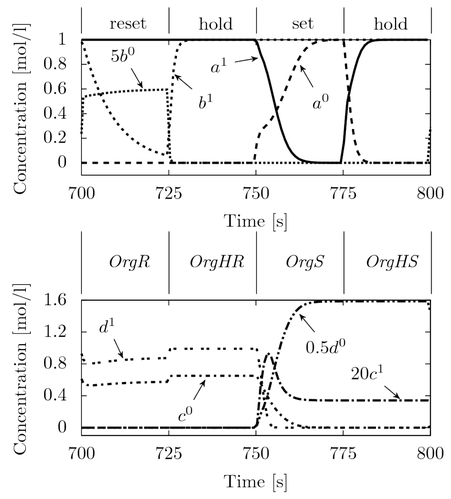
As an alternative design/programming method of chemical reaction system, evolution has been suggested. The project, ESIGNET, has investigated how to evolve chemical reaction network for desired tasks. We, together, obtained a chemical reaction system functining as RS flip-flop [1]. On the other hand, we built manually a chemical reaction network for the same function based on the structure of the logic circuit [3,9]. Comparing these reaction networks, we expect further to develop a hybrid design method such that evolutionary designs and manual constructions are merged.



$\bar{S}$	$\bar{R}$	Q_{t+1}	$\bar{Q}_{t+1}$	
0	0	1	1	
0	1	1	0	set
1	0	0	1	reset
1	1	Q_t	$\bar{Q}_t$	hold

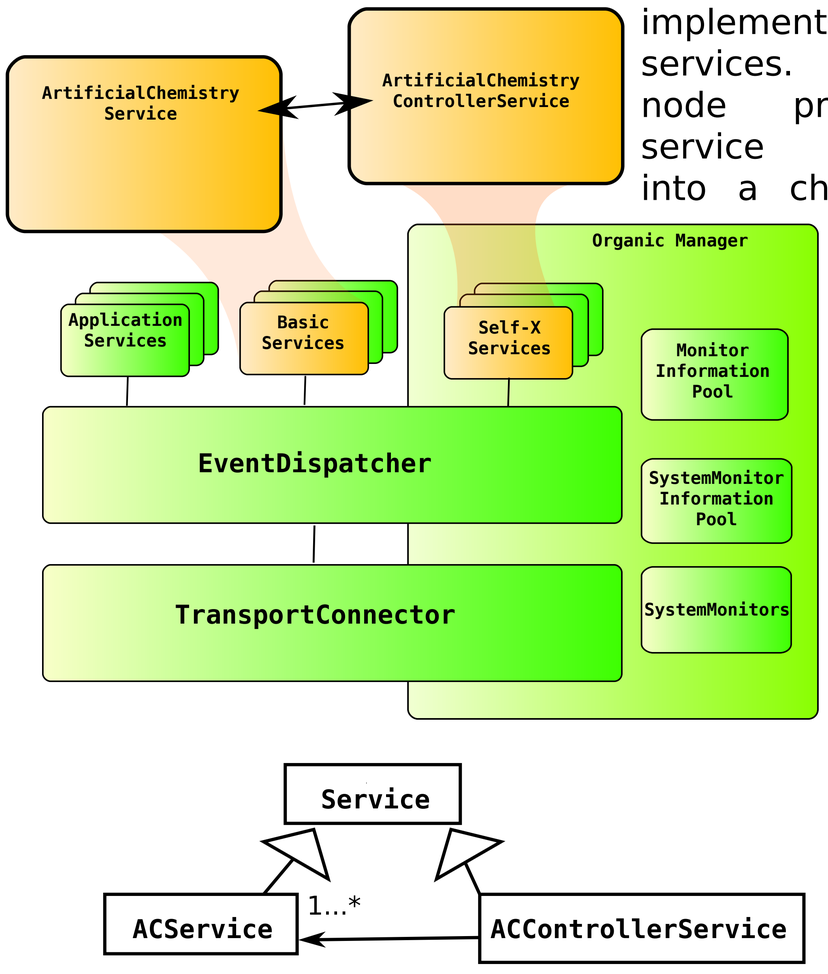
A | B





A chemical service for OCμ

In order to achieve self-configure, self-optimize, and self-healing system across a network of nodes, the OCμ framework offers a Java middleware to implement organic services. In the OCμ system, "Services" are the most fine-grained software component. We have developed an OCμ service providing (artificial) chemical computing. Our chemical service "ACService" is derived from the OCμ Service class. It also offers diffusion of molecules across nodes. Another service class "ACControllerService" implements Self-X services. It translates node properties and service dependencies into a chemical system simulated by chemical services. The actual implementation depends on the desired self-X property to achieve.



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Primary Results

1. T. Lenser, N. Matsumaru, T. Hinze, P. Dittrich: **Tracking the Evolution of Chemical Computing Networks,** In *Proc. of Alife XI*, 2008 (submitted)
2. N. Matsumaru, J. Huwald, T. Hinze, P. Dittrich: **A Distributed Chemical Program for the Maximal Independent Set Problem,** In *Proc. of 2nd IFIP Conference on Biologically Inspired Collaborative Computing*, 2008 (submitted)
3. N. Matsumaru, F. Centler, P. Speroni di Fenizio, P. Dittrich: **Chemical Organization Theory as a Theoretical Base for Chemical Computing,** *International Journal of Unconventional Computing*, 3(4), 285-309, 2007
4. P. Dittrich, N. Matsumaru: **Organization-Oriented Chemical Programming**, In *Proc. of 7th International Conference on Hybrid Intelligent Systems,* 2007
5. N. Matsumaru, T. Lenser, T. Hinze, P. Dittrich: **Designing a chemical program using chemical organization theory,** *BMC Systems Biology*, 1(Suppl 1):P26, 2007
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9. N. Matsumaru, F. Centler, P. Dittrich: **Chemical Organization Theory as a Theoretical Base for Chemical Computing** In: *Workshop on Unconventional Computing*, p. 71-82, Luniver Press, Beckington.

Secondary Results

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12. T. Hinze, S. Hayat, T. Lenser, N. Matsumaru, P. Dittrich: **Biosignal-Based Computing by AHL Induced Synthetic Gene Regulatory Networks**. In *Proc. of the First International Conference on Bio-Inspired Systems and Signal Processing (BIOSIGNALS2008)*, Vol. 1, pp. 162-169, IEEE Engineering in Medicine and Biology Society, Institute for Systems and Technologies of Information Control and Communication, INSTICC press, 2008
13. T. Hinze, S. Hayat, T. Lenser, N. Matsumaru, P. Dittrich: **Hill Kinetics Meets P Systems**. In *Membrane Computing*, *LNCS* **4860**, pp. 320-335, Springer Verlag, 2007
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16. N. Matsumaru, F. Centler, P. Speroni di Fenizio, P. Dittrich: **Chemical organization theory applied to virus dynamics,** *it - Information Technology*, **48**(3), 154-160, 2006
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