

An FPGA-Based, Multi-model Simulation Method for Biochemical Systems

WHY is this simulator required?

The HOT TOPIC:
Computer Simulations in Biology

Problems:
Insufficient throughput,
Expensive system cost and...

It's TIME TO CHANGE:
Cost-effective, compact and
high-throughput architecture

Characteristics of the Cell and Other Computational Models
(Takahashi et.al,2002)

Target	Compartments	Components	Component types	Interaction Modes
E.Coli	$\sim 10^1$	$\sim 10^{13-14}$ molecules $\sim 10^{3-4}$ species	$\sim 10^1$	$\sim 10^{1-3}$
Human	$\sim 10^{3-4}$	$\sim 10^{17-18}$ molecules $\sim 10^{4-5}$ species	$\sim 10^1$	$\sim 10^{1-4}$
LSI	Usually 1	$\sim 10^{6-7}$	A few	1
CFD	Usually 10^{0-1}	$\sim 10^{5-6}$	1	1
MD	1	$\sim 10^{2-6}$	A few	A few

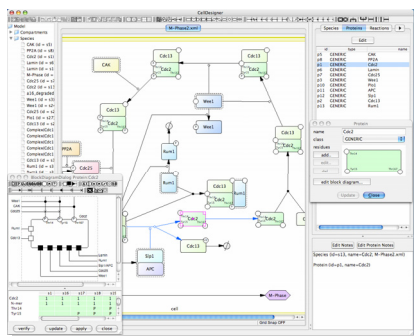
WHAT is biochemical simulation?

Model Description:
List of Substances and Reactions

ODE-Based Process:
Numerical integration of rate-law functions

The Behavior of the Model:
Time-series change of Concentration

HOW does it work?



Pathway Description in SBML:
SBML is the standard markup language for biochemical networks.

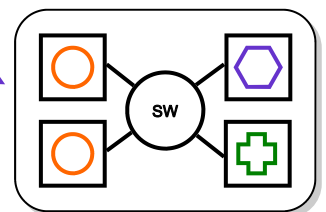
List of Reactions

List of Parameters

Solver Core Library:
HDL implementation of Rate-law functions.
Statically scheduled and fully pipelined.

Solver set:
Core + Integration module + Switch:
Optimal circuit for given target system is **automatically** generated.

Schedule and Dataset:
Variables and reactions are placed and scheduled on the solvers. Solver-to-solver communication is also statically scheduled.



CAN it make breakthrough?

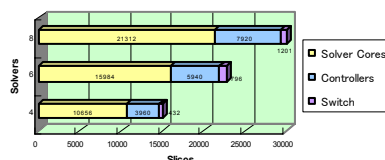
Throughput :

- Static scheduling of all arithmetic operations and data transfers maximize the throughput.
- Operates at 100MHz+
- **More than 60-fold speedup to μ Ps, enough power to replace clusters!**

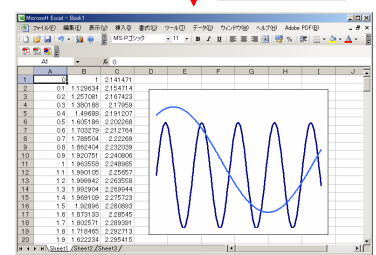
Area Overhead:

- Solver cores: 66% in area
- Integration modules: 30%
- 8-ports Crossbar: 4%
- Reasonable resource requirement compared to single-model system

System	Frequency (MHz)	Throughput (Mreactions/sec)
Pentium4 (gcc 3.4.2-O3)	3200	5.75
PentiumM (gcc 3.4.2-O3)	2000	6.78
ReCSiP (8 MM solvers)	107	428



FPGA



The Result

The ReCSiP Project Team

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