BioBricks’ Model Generator for electronic simulator

How to generate Biobrick models understandable by conventional electronic simulators

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Overview

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Team presentation
Project introduction

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Context
Project overview
This year

III. Software
Principle
How it works

IV. Demonstration

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I. Introduction

Our team

Project

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VI. Thank you

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Biobricks model generator for electronics simulator

Team Presentation
Introduction

• There is no Automated Design Tool yet in biology

• This type of tool could be helpfull for biologists because:
  – More and more complex systems = more and more difficult to design
  – Building a system is time and money consuming

This type of tool already exists in electronics
Context

• Electronics:
  – For over 40 years, strong experience in building more and more complex systems

Improvements of the design flow and the technology, creation of automated and reliable tools to help designers to build extremely complex systems

First microprocessor
  Intel 4004 (1971)
  2300 transistors

Nowadays processor
  Intel Xeon (2010)
  2 billion transistors
Two analogies are possible between electronics and biology

- Level 1: Design approach
- Level 2: Electronic and Biologic mechanisms can be modeled by ODE (Ordinary Differential Equations)
Our project - aims

- Adapting the powerfulness of electronic tools for biologists in creating a complete automation design tool

Source: http://blog.mckuhn.de
Idea

Designing your best biosystem’s diagram

Simulate your best Biosystem

Increase the level of abstraction

Biosystem’s function & requirements

System’s specifications

I. Introduction
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  Elec VS Bio
  Our Goals
  Global project
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11/6/2011
IGEM 2011 World Jamboree
ENSPS Strasbourg
Idea

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Biobricks model generator for electronics simulator

Our project

Biosystem’s function & requirements

One function = several biobricks
You have to find the most suitable BioBrick assembly for your application

Find the best BioBricks

Simulate your best Biosystem

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Our project

Idea

To validate the proof of concept of your system, you need a qualitative and a quantitative simulation.

Powerfull electronic tools can help you

Simulate your best Biosystem

Finding the best BioBricks

System’s specifications

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Biosystem’s function & requirements

BIOBRICK FINDER

BioBrick parts registry

BioBrick Assembly

DESIGNER

System Analyzer

Automatic Synthesizer

Block diagram of elementary function

BioBricks Compiler

SIMULATOR

Behavioral Simulator

‘0’-or-‘1’ Behavioral Model

Simulation Results (Qualitative)

Continuous – time simulator

Simulation Results (Quantitative)

Model Synthesizer BIOLOGY ELECTRONICS

BIOLOGY

ELECTRONICS

System’s specifications

Validation Proof of concept

Idea
Behavioral model

- Based on boolean algebra (logic description)
- Written in VHDL (electronic description language)
- Each block is linking to each other by the names of the species
- Quantitative information only

Simulation Results (Qualitative)

Simulation Results (Quantitative)

Simulation Simulator

Continuous – time simulator

Behavioral Model

‘0’-or-’1’ Behavioral Model

Conservative Model

System’s specifications

Validation
Proof of concept

Biosystem’s function & requirements

Idea

BioBrick parts registry

BioBrick Assembly

BioBrick Compiler

'0' or '1'

Behavioral Model

Results

(A qualitative)

Simulation

Simulator

Block diagram of elementary function

Automatic Synthesizer

System Analyzer

DESIGNER

BIOBRICK FINDER

SIMULATOR

BIOLOGY

ELECTRONICS

Conservative

Model

Synthetizer

Validation
Proof of concept

Simulation

Results

(Quantitative)
**Biobricks**

**model generator for electronics simulator**

**Biosystem’s function & requirements**

**BioBrick parts registry**

**System’s specifications**

**Idea**

**BioBrick parts registry**

**BioBrick Assembly**

**BioBricks Compiler**

**'0' - '1'**

**Behavioral Model**

**Simulation Results (Quantitative)**

**Behavioral Simulator**

**Conservative Model**

- Based on ODE and analogy SYNT H SYNTHETIC BIO  ELEC

\[
\frac{d[mX]}{dt} = \frac{k_{tr}}{1+(\frac{K_R}{[A]})^n} - d_{mx}[mX]
\]

- Written in VHDL-AMS (electronic description language)

- Qualitative information (concentrations)

**Continuous – time simulator**

**Validation**

**Proof of concept**

**DESIGNER**

**BIOBRICK FINDER**

**Block diagram of elementary function**

**Automatic Synthesizer**

**System Analyzer**

**Conservative model**

**Backbone**

- **Complex reaction**
- **mRNA synthesis**

**Conservative model**

\[
C_A \quad C_B \quad C_{AB} \quad C_{mx}
\]

**Continuous – time simulator**

**Behavioral Model**

**Simulation Results (Quantitative)**

**Conservative Model**
Our first year

- Convincing the biologist’s community that electronics and biology can be combined to improve biosystem’s design
- Creating a software which simulates a biosystem as an electrical circuit
Graphical User Interface

- **Input species**
- **Output species**
- **Mechanisms**
  - Inhibition
  - Association
  - Synthesis
- **Reactions parameters**

**Simulation Results**
- Qualitative
- Quantitative

**Behavioral Simulator**

**Continuous-time Simulator**

**Model Synthetizer**
- **BIOLOGY**
- **ELECTRONICS**
  - Using of an electronic description language in the automatic code generator

**Block diagram of elementary function**
- S
- a
- b
- Input species
- Output species

**Mechanisms**
- Inhibition
- Association
- Synthesis

**Reactions parameters**

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Software

Software core written in C++
Qt framework for the Graphic User Interface

Two BioSystem models’ generator with one architecture
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Software

Graphical User Interface
- SYSTEM
- MECH.
- SPECIES

Main Window

Manager

Engine
- Syst.vhd
- Entities.vhd
- TestBench.vhd
- Simulation file

Pattern files
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Demonstration

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Video available on our wiki

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Next Version

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Achievements
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Graphical User Interface

Input species
Output species
Mechanisms
- Inhibition
- Association
- Synthesis
Reactions parameters

Block diagram of elementary function

Model Synthetizer
BIOLOGY
ELECTRONICS
Using of an electronic description language in the automatic code generator

Simulation Results (Qualitative)

Simulation Results (Quantitative)

Behavioral Simulator

Continuous-time Simulator

More Parameters

Drag & Drop Interface
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Perspectives

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System specifications

Idea

Biosystem's function & requirements

System Analyzer
Automatic Synthesizer

Block diagram of elementary function

BioBrick parts registry

BioBricks Compiler

BioBrick Assembly

Validation
Proof of concept

Simulation Results (Qualitative)

Behavioral Simulator

‘0’-or-‘1’ Behavioral Model

Simulation Results (Quantitative)

Continuous – time simulator

Conservative Model

What we have done yet

Model Synthesizer
BIOLOGY

ELECTRONICS

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Achievements

✓ Showing the usefulness of the electronics for synthetic biology
✓ Building models and analogy between the two fields
✓ Allowing the biologists to simulate their systems before creating it
✓ Suggesting an Automated Design Tool project for synthetic biology
Acknowledgements