REBORN

Synthetic Biology Tools for Hackers

USTC-Software
WHY

HOW

WHAT
Reverse Engineering for Biological Regulatory Networks
Why Reverse Engineering?
Engineering

Biology
PROS

Modularity  Standardization  Encapsulation

WHY
Why

CONS

Modification

Understanding

Sharing

WHY
CONS

Why

Modification
Understanding
Sharing
Why

- Modularity
- Standardization
- Encapsulation
- Modification
- Understanding
- Sharing
Why

- Modularity
- Standardization
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?
Why

Modularity
Standardization
Encapsulation
Modification
Understanding
Sharing

REVERSE ENGINEERING
Forward Engineering
Forward Engineering

Circuits
Forward Engineering

Circuits

Experiments

Why
Forward Engineering

WHY

Experiments

Circuits

Data
Forward Engineering

Experiments

\[ \frac{dX}{dt} = f(X, t) \]

Mathematical Model
Why Forward Engineering

Mathematical Model

\[ \frac{dX}{dt} = f(X, t) \]
Why

Forward Engineering

---

Reverse Engineering

\[ \frac{dX}{dt} = f(X, t) \]

Mathematical Model

Data

Reverse Engineering
Forward Engineering

Reverse Engineering

Mathematical Model

dX
---
dt = f(X, t)

Data

Why

Experiments

Circuits

Circuits
Why Forward Engineering

Reverse Engineering

\[ \frac{dX}{dt} = f(X, t) \]

Mathematical Model

Data
Circuits

Mathematical Model

\[ \frac{dX}{dt} = f(X,t) \]

Reverse Engineering

Forward Engineering
Forward Engineering

Experiments

Circuits

Mathematical Model

Reverse Engineering

Why

Data
Professionals
Professionals

Hackers
HOW
BASIC STEPS

• Input Data
• Generate ODEs
• Generate GRNs
• Rebuild System

HOW
BASIC STEPS

- Input Data
- Generate ODEs
- Generate GRNs
- Rebuild System
INPUT DATA

System
INPUT DATA

System

Time Courses

HOW
INPUT DATA

HOW

System

Time Courses

Prior Knowledge
BASIC STEPS

• Input Data
• Generate ODEs
• Generate GRNs
• Rebuild System
BASIC STEPS

• Input Data
• Generate ODEs
• Generate GRNs
• Rebuild System

HOW
How to Generate ODEs

Data → ODE → Reactions

Generate ODES HOW
 HOW

How to generate ODEs

Data → ODE → Reactions

How?
How to Generate ODEs

How?

Data → ODE → Reactions

GENETIC ALGORITHM
GENERATE ODES

GENETIC ALGORITHM

HOW
How

GENETIC ALGORITHM

GENERATE ODES

Proteins
Generate ODEs

How

Genetic Algorithm

- Proteins
- Genes
Generate ODEs

Genetic Algorithm

Proteins

Genes

Reaction
How to Generate ODEs using a Genetic Algorithm in the Growth Phase
Generate ODEs

Genetic Algorithm

Growth Phase
How to Generate ODEs via Genetic Algorithm

Growth Phase

- Duplication
GENERATE ODES

GENETIC ALGORITHM

How

Growth Phase

- Duplication
- Mutation
  - Change degradation rate
  - Change kinetic constants
  - Add a new gene
  - Add a regulation
  - Add post-transcription reactions
GENERATE ODES

HOW

GENETIC ALGORITHM
GENERATE ODES

HOW

GENETIC ALGORITHM

Selection Phase
How to Generate ODEs using Genetic Algorithm

Selection Phase

Score
Generate ODEs

Genetic Algorithm

Selection Phase

Score

Variance

Complexity
How to Generate ODES Using Genetic Algorithm

Selection Phase

- Score
- Variance
- Complexity

→

- Rank
- Quick Sort
How to Generate ODEs (Ordinary Differential Equations) using a Genetic Algorithm:

**Selection Phase**

1. **Score**
   - Variance
   - Complexity

2. **Rank**
   - Quick Sort

3. **Select**
   - Next

**Growth Phase**
GENERATE ODES
HOW
GENETIC ALGORITHM
GENERATE ODES
HOW
GENETIC ALGORITHM

ODEs
SBML
BASIC STEPS

• Input Data
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• Generate GRNs
• Rebuild System
BASIC STEPS

• Input Data
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• Generate GRNs
• Rebuild System

HOW
GENERATE GRNS

GRN: Genetic Regulatory Network
GENERATE GRNS

GRN: Genetic Regulatory Network

- Multiple Layers
How to Generate GRNs

GRN: Genetic Regulatory Network

- Multiple Layers
GENERATE GRNS

GRN: Genetic Regulatory Network

• Multiple Layers
GENERATE GRNS

GRN: Genetic Regulatory Network

- Multiple Layers
- Simplicity
- Generalized Representation

TRENDS in Biotechnology
GENERATE GRNS

GRN: Genetic Regulatory Network

- Multiple Layers
- Simplicity
- Generalized Representation
- Matrix
BASIC STEPS

• Input Data
• Generate ODEs
• Generate GRNs
• Rebuild System
BASIC STEPS

• Input Data
• Generate ODEs
• Generate GRNs
• Rebuild System
How to Rebuild System Database
REBUILD SYSTEM

Database

- Regulatory relationships
- Comprehensive
- Feasible in experiments
REBUILD SYSTEM

Database

- Regulatory relationships
- Comprehensive
- Feasible in experiments

Regulon Data Bank
REBUILD SYSTEM

Database

- Regulatory relationships
- Comprehensive
- Feasible in experiments
- Compatible with the software

Regulon Data Bank
RegulonLib

- Original data from Regulon DB
- Regulatory information of 941 promoters, 117 genes and 772 operons
- Parts data stored in SBOL format including
  - 2652 operons
  - 4554 genes
  - 3734 promoters
  - 207 terminators

- 179 RBS
- 3731 5’-UTR & 3’-UTR
Rebuild System RegulonLib

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- 179 RBS
- 3731 5’-UTR & 3’-UTR
- Clotho App
  - From Parts to Regulations
  - From Regulations to Parts
- In use
  - USTC-China
WHAT
REBORN

Map

WHAT
What

REBORN

- Map
- Console
REBORN

• Map
• Console
• Sandbox
REBORN

- Map
- Console
- Sandbox
- Report
What

REBORN
- Clear and simple design
- Import data
- View details
- Work with Console
CONSOLE

WHAT

- Core of REBORN
- Software logs
- Parameters
- Cloud service
- Working with Map, Sandbox and Report
Sandbox

- 3D model of GRN
- OpenGL
- Interactive
What

Report

- Clean and neat design
- Tow-column layout
- Left: graph of time courses
- Right: details of the model
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DEMO
HUMAN PRACTICE
HUMAN PRACTICE