Supporting Cutting-Edge Synthetic Biology Research with Advanced Human Computer Interaction

WELLESLEY HCI
iGEM 2013

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Our Vision

To apply engineering and human-computer interaction methodologies to promote collaboration and problem solving in the synthetic biology experimental process.
HCI and Synthetic Biology

- Create rich visual tools to make complex synthetic biology concepts and ideas more accessible
- Reduce error in the bio-design process
- Improve workflow by integrating resources across multiple platforms
- Move towards automation
“Can you support top-down design?”

This Time Last Year
User-Centered Design
Our Goals

**Goal 1**: Simplify the research and information-gathering process

**Goal 2**: Streamline the design and specification of complex constructs

**Goal 3**: Convey basic synthetic biology concepts to non-scientists
Our Projects

**Eugenie**
Multi-touch application that uses a visual language to aid in the design of novel genetic devices

**zTree**
Interactive 3D Visualization of the iGEM Registry

**Bac to the Future**
Interactive installation teaching synbio concepts to broad audiences
Eugenie
A collaborative design tool for genetic devices
Goals

• Support top-down design
• Enhance sensemaking
• Integrate resources
• Support flexible work styles
Bottom-Up Design:

L0: Basic Modules
L1: Transcriptional Units
L2: Multigene Constructs

Top-Down Design:

Specify generic parts → Generate permutations → Add rules to prune results
/** PROPERTIES ***/
Property Name(txt);
Property Sequence(txt);
Property Represses(txt);
Property InducedBy(txt);

/** PART TYPES ***/
PartType InduciblePromoter(Name, Sequence, InducedBy);
PartType RepressiblePromoter(Name, Sequence);
PartType RBS(Name, Sequence);
PartType Repressor(Name, Sequence, Represses);
PartType Terminator(Name, Sequence);
PartType Reporter(Name, Sequence);
PartType Molecule(Name);

/*** Signaling Molecules ***/
Molecule mol1("mol1");
Molecule mol2("mol2");
Molecule mol3("mol3");

/*** Inducible Promoters ***/
InduciblePromoter pBad(
.Name("pBad"),
.Sequence("acattgattatttgcacggcgtcacactttgcctatgccatagcagatagtccataagattagcggatccctacctgacgctttttatcgcaactctctactgtttctccataccgtttttttgggctagc"),
.InducedBy("mol1"));

InduciblePromoter pDntR(
.Name("pDntR"),
.Sequence("ATAC"),
.InducedBy("mol2"));

/*** Repressible Promoters ***/
RepressiblePromoter pLux(
.Name("pLux"),
.Sequence("acctgtaggatcgtacaggtttacgcaggtgtttttacaacaaatggtttgttatagtcgaatacctctggcggtgata"));

RepressiblePromoter pTetR(
.Name("pTetR"),
.Sequence("tccctatcagtgatagagattgacattcctatcagtgatagagatactgagcac"));

RepressiblePromoter pCI(
.Name("pCI"),
.Sequence("taacaccgtgcgtgttgactattttacctctggcggtgataatggttgc"));

/*** Repressors ***/
Repressor cI(
.Name("BBa_C0051"),
.Represses("pCI"),
.Sequence("atgagcacaaaaaagaaaccattaacacaagagcagcttgaggacgcacgtcgccttaaagcaattatatgaaaaaaagaaaaatgaacttggcttatcccaggaatctgtcgcagacaagatggggatggggcagtcaggcgttggtgctttatttaatggcatcaatgcattaaatgcttataacgccgcattgcttgc
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ccaaaaaagccagtgattctgcattctggcttgaggttgaagtttattccatgaccgcaccaacaggctccaagccaagctttcctgacggaatgttaat
","mol1"));

Repressor LuxR(
.Name("LuxR"),
.Represses("pLux"),
.Sequence("atgaaaaacataaatgccgacgacacatacagaataattaataaaattaaagcttgtagaagcaataatgatattaatcaatgcttatctgatatgacta
aaatggtacattgtgaatattatttactcgcgatcatttatccattctatggttaaatctgatatttcaatcctagataattaccctaaaaaatggaggcaatattatgatgacgctaatttaataaaatatgatcctagtagtagattattctaactccaatcattcaccaattaattggaatatatttgaaaacaatgctgtaaataaaaaatctccaaatgtaattaaagaagcgaaacatcaggtcttatcactgggtttagtttccctattcatacggctaacaatggcttcg
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","mol1"));

Repressor araC(
.Sequence("ttatgacaacttgacggctacatcattcactttttcttcacaccggcacggaactcgctcgggctggccccggtgcattttttaaatacccgcgagaaa
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","mol1"));

Repressor araC(
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","mol1"));

Repressor araC(
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","mol1"));

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","mol1"));

Repressor araC(
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","mol1"));
Microsoft Visual Programming Language

Scratch (MIT)
EUGENIE RULES for TREE + BEHAVIOR

CONTAINS A
A^*

A AFTER B
B(\approx=A)

A BEFORE B
A(\approx=B)

STARTS WITH A
^A

ENDS WITH A
A$

DIRECTION

NOT A
(?!A)

A NEXT TO B
A?w+(?:\!w+\!w+)?{0}B

A THEN B
(?=AB)

A AND B
(?=A)(?=B)

A OR B
(A|B)

A XOR B
\!(A\!B){1}$

A REPRESSIONS B

A > n
grep\('.*A\{'n+1'\}'}
Inverter Example

Name: Repressible Promoter pLux
Represses: 
Repressed By: 
Induces: 
Induced By: 
Produced By: (small molecules only)
Direction: forward

Edit Properties  Cancel
Demo video
Implementation

- **Microsoft PixelSense:**
  - Surface SDK 2.0
  - Support for direct touch manipulation
  - Support for mouse manipulation

- **Languages:**
  - User Interface: XAML
  - Backend: C#

- **Eugene:**
  - Constraint-based permutation

- **Integrating Resources:**
  - Parts Registry
  - Clotho Database
  - Local Database
  - Pigeon
Evaluation

- **Participants:** 15 users from Boston University and MIT iGEM teams, as well as students from Wellesley College
- **Task:**
  - Read and draw SBOL diagrams
  - Translate SBOL diagrams into our visual language
  - Use Eugenie to specify one of the genetic devices they had translated
Results

Did the visualization language help you in understanding how the devices worked?

- Yes: 11
- No: 1
- Undecided: 3
Results

Was using the application easier than drawing?

- Strong Yes
- Yes
- Slight Yes
- Neutral
- Slight No
- No
- Strong No
Results

I want a visual indication of which promoters are active under a specific condition.

I want to be able to scale the part according to how many base pairs it has.

I want to see all of the relationships between parts in one panel.

I want a visual indication of which promoters are active under a specific condition.
zTree

An interactive 3D tool to visualize large data sets
Goals

- Enable visualization of a complex, hierarchical structure in its entirety
- View individual parts in context of the whole data space
- Create a unique user experience

zSpace: Holographic Computing
2D vs 3D Display
Implementation

- Unity for 3D Graphics
- C# for backend
- Registry API for part information
Evaluation

- **Participants:** 9 users from Wellesley College
- **Task:** Compare user experience and understanding using zTree versus Registry website.
  - Browse for a specific part
  - Estimate the number of parts in a category
  - Compare two different part types
Results

<table>
<thead>
<tr>
<th>Activity</th>
<th>zTree</th>
<th>Registry Website</th>
</tr>
</thead>
<tbody>
<tr>
<td>See hierarchical relationships</td>
<td>8</td>
<td>1</td>
</tr>
<tr>
<td>Make comparisons between parts</td>
<td>9</td>
<td>3</td>
</tr>
<tr>
<td>Browse for a specific part</td>
<td>5</td>
<td>2</td>
</tr>
</tbody>
</table>
Feedback to Inform Future Improvement

- Improve Search
- Improve Visuals/Layout
- Include Detailed Part Information
Bac to the Future

An interactive installation introducing synthetic biology concepts
Goals

- Facilitate learning of Synthetic Biology concepts
- Engage users through interactivity and visual feedback
- Target application to non-scientists
- Reach broad audiences through the use of social media
What is Bac to the Future?

1. Encode message into DNA codons
2. Insert part into plasmid
3. Insert plasmid into E.coli
4. View backwards translation of the bacteria’s message database
Welcome to Bac to the Future!

Bac to the Future is an art installation and web application that aims to communicate core concepts of Synthetic Biology to non-scientists by engaging users in a fun and interactive environment. Specifically, we aim to communicate the concepts of DNA as a powerful encoding language, and bacteria as a means of archival data storage.

In our application, users will walk through the translation process and perform the subsequent lab procedure, thus mimicking the protocol followed in a genuine lab environment. These steps are detailed in the application itself.

Inspired by the experiment done by the Church Lab at Harvard Medical School, we hope you enjoy our app!
Implementation

- HTML5
- Javascript
- JQuery
- Python
- Google App Engine
- Twitter
Evaluation

- **Participants:** 15 high school students from the MIT-Wellesley Upward Bound Program
- **Task:**
  - Evaluate user knowledge of synthetic biology before and after the study
  - Note user engagement and enjoyment during interactive with our project
Results

The content of this activity incited my curiosity

- Strongly agree: 6
- Agree: 7
- Neutral: 2
- Disagree: 1
- Strongly disagree: 0

Number of students
Results

This experience was fun

- Strongly agree
- Agree
- Neutral
- Disagree
- Strongly disagree

Number of students
Summary

Simplify the research process and make Eugene more accessible

3-D visualization of multi-tiered data structures

Convey basic synthetic biology concepts to non-scientists
Future Work

Eugenie
• Support rule creation between devices
• Implement option for including device backbone
• Create a web application version of Eugenie

zTree
• Animate carousels on and off screen
• Improve search function for specific parts
• Allow use of data sets from other databases

Bac to the Future
• Create interactive installation using gesture technology
• Explore potential education applications
Acknowledgements

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Traci Haddock, Ernst Oberortner, the Doug Densmore lab, and the BU iGEM Team.

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MIT-Wellesley UpWard Bound

Wellesley College
Catherine Summa, Wellesley College Science Center Summer Research

Agilent Technologies
HHMI Howard Hughes Medical Institute
NSF
Wellesley
Questions

Thank you!
Wellesley HCI Lab

- Tablet, desktop computers, laptops
- zSpace, Microsoft Surface
- Eugenie, zTree for synthetic biologists
  - Novice and advanced users
- Bac to the Future - general audience
Microsoft PixelSense

- Multi-touch surface platform
- Collaboration
- PixelSense technology, can detect touch and tags
Eugenie

- Pulls from Registry of Standard Biological Parts
- Clotho, local databases
- Can design inverters
Bac to the Future

- Adding gesture technology in the future
- Art installation
Safety

• How did you consider safety?
  
  • Wet-lab experience
  • Feedback from experts
  • Upward Bound user studies
zSpace

- Holographic computing system
- Runs for about $1500
- zSpace.com
zTree Implementation

- What do you see being the applications for this?
- Is there a non-3D version available for download?