SynFlo: An Interactive Installation Introducing Synthetic Biology Concepts

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Abstract
SynFlo is an interactive installation that utilizes tangible interaction to help illustrate core concepts of synthetic biology through outreach programs. This playful installation allows users to create useful virtual life forms from standardized genetic components, exploring common synthetic biology concepts and techniques. The installation consists of Sifteo cubes, which are used to modify virtual *E. coli* to serve as environmental biosensors. The modified bacteria can then be deployed into an environment represented by a tabletop computer, where they detect environmental toxins. The goal of this research is to explore ways to develop effective interactive activities for outreach in STEM and to communicate the excitement and constraints of cutting-edge research.

Author Keywords
Tangible user interfaces; Sifteo cubes; Microsoft Surface; E. chromi; synthetic biology

ACM Classification Keywords
H.5.2 [Information Interfaces and Presentation]: User Interfaces.

General Terms
Design, Human Factors.

Introduction
Synthetic biology is an emerging research area at the intersection of science and engineering that enables the

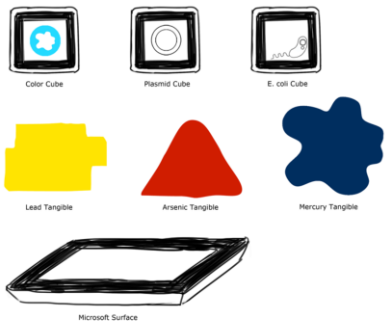

Figure 1: The components of SynFlo

Figure 2: "Contamination" between two *E. coli* cubes

design and construction of new biological systems. The field applies engineering principles such as abstraction and modularity into biological research, treating genetic material as standardized parts, "BioBricks," which can be combined and swapped in a plug-and-play manner before they are inserted into host organisms. The ability to create tailored biological systems can shed light on particular phenomena or solve specific problems. For example, synthetic biology is used in the development of low-cost anti-malarial drugs, in the production of alternative energy or biofuel from bacterial, and in the study of infectious diseases such as tuberculosis [2]. However, considering the ethical and social questions that the field raises, the public and media has eyed the field with concern and slight skepticism. Making synthetic biology more accessible and transparent to the public will allow better understanding of the fields' promises and challenges.

SynFlo is an interactive installation, designed to illustrate core concepts of synthetic biology through a playful tangible interface as well as making the ideas behind synthetic biology more accessible to the general public. SynFlo mirrors actual protocols used in wet labs to manipulate the genome of *E. coli*, the most common model organism in synthetic biology and microbiology. SynFlo consists of triplets of Sifteo cubes, which can be used to modify the genome of virtual *E. coli* to serve as biosensors for environmental toxins. The virtual bacteria can then be deployed into an environment represented by a tabletop computer. In this environment, the *E. coli* can interact with other bacteria and with environmental toxins. The remainder of this paper discusses the design, implementation, and preliminary evaluation of SynFlo in informal science learning settings.

Related Work

Numerous artists have embraced synthetic biology as a theme, tool, and an inspiration. Oron Catts and Ionat Zurr created their sculptures *Semi-living Worry Dolls,* consisting of cells grown on a scaffolding of degradable polymers, as an exploration of the relationship between the living and the non-living [3]. Tuur van Balen designed bacteria that turn pigeon feces into window soap as a commentary on the ethical issues surrounding synthetic biology [1]. However, while these projects have attempted to emphasize the societal and ethical questions raised by the field, we seek to communicate both the opportunities and the challenges of synthetic biology while making its methods more transparent to non-scientists. The visual and interactive components of SynFlo were inspired by several interactive games. Thatgamecompany's *flOw* and Japan Studio's *LocoRoco* informed the simple aesthetics and engaging quality that aimed for [10] [6]. Maxis's *Spore* was also a game that we looked at for the creature creation aspect of SynFlo [8]. The bright colors of the installation were inspired by Brainbow, Harvard's research project on fluorescent neurons [7], and the block interaction was inspired by Zigelbaum and Coelho's *Six-Forty by Four-Eighty* [4].

Design and Concept

SynFlo's design is a result of close collaboration with synthetic biologists. Our design goal for SynFlo is to help illustrate core concepts of synthetic biology in outreach programs. We focus on three core concepts including 1) *abstraction*, the representation of genetic materials with known functionality as standard biological parts with common interfaces, called BioBricks; 2) *modularity*, the construction of biological systems composed of reusable mix-and-match BioBricks; and 3) *protocols*, the use of predefined standardize laboratory procedures to ensure

Figure 3: Clicking through the BioBrick library

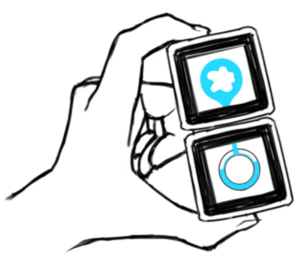

Figure 4: Shaking the DNA material into the plasmid cube

safety and successful replication of results by others. We also aim to provoke further inquiry about the everyday implications of synthetic biology while experiencing some of its excitement and constraints.

To accomplish these goals, SynFlo draws upon a well-known synthetic biology experiment called E. chromi [5], in which genetically engineered *E. coli* bacteria act as biosensors, indicating the presence of certain environmental toxins. This experiment has three basic procedural tasks: 1) Combining biological parts to create a genetic element capable of producing a particular color in response to the presence of a particular toxin; 2) Inserting the selected BioBrick into a plasmid, a circular DNA strand that replicates independently from chromosomal DNA; 3) infusing *E. coli* bacteria with the engineered plasmids; and 4) deploying the modified bacteria into a testing environment.

SynFlo utilizes tangible and embodied interactions to allow users to experience an interactive and playful simulation of the E. chromi experimental process. The installation consists of triplets of Sifteo cubes, a tabletop computer (Microsoft Surface SUR40), and tangible objects that represent environmental toxins (see Figure 1). Each triplet of Sifteo cubes consists of a BioBrick cube, a plasmid cube, and an *E. coli* bacterial cell. We chose to use Sifteo cubes [9] to implement the interaction with BioBricks because Sifteo Cubes support a variety of gestures and actions including moving, shaking, flipping, rotating, and neighboring. These allow us to mimic physical aspects of laboratory work. Also, the form factor of the cubes communicates the idea that BioBricks are modular. We represent the testing environment using a tabletop computer. Multiple users can deploy modified *E. coli* into the surface and interact with the deployed bacteria through touch. In addition, users can add tangibles that represent different environmental toxins and observe their effects on the existing bacteria. Following, we describe interaction with SynFlo.

When two *E. coli* cubes are placed next to each other, the *E. coli* interact by "contaminating" the neighboring cube (see Figure 2). Then, following SynFlo experimental protocol users choose a BioBrick from a library of biological parts that encode for a particular color the *E. coli* turns when detecting a certain toxin. The user presses the Sifteo cube screen to scroll through a library of three colors and toxin shapes (see Figure 3). Similar to the biologists preforming the E. chromi experiment, users add the BioBrick to a plasmid and mix by vortexing: the BioBrick cube is placed on top of the plasmid, then the two are shaken together while the color drips into the plasmid (see Figure 4). Then, just as a biologist would pipette, mix, and eject the newly-infused plasmid onto the waiting biological vessel, SynFlo allows the user to place the now colored plasmid cube next to the awaiting *E. coli* cube and then flip the plasmid cube as if pouring or pipetting into the *E. coli*.

Finally, users can deploy their *E. coli* to the testing environment by placing the *E. coli* cube on the Microsoft Surface and flipping the cube (see Figure 5). Users can then interact with the *E. coli* by adding tangibles to the surface that represent different environmental toxins (see Figure 6); the modified *E. coli* sensitive to particular toxins will respond by changing their color. Touching the *E. coli* results in a color change (see Figure 7).

Figure 5: Flipping the *E. coli* cube on the Surface

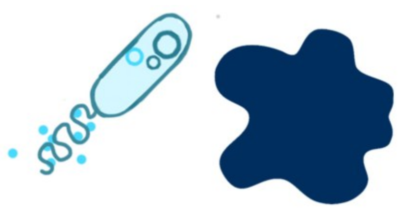

Figure 6: Placing a tangible on the Surface

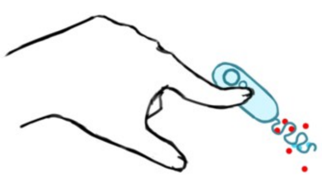

Figure 7: Touching the *E. coli* on the Surface

Implementation

SynFlo uses Sifteo cubes [9], a commercially available, clickable 1.5 inch block micro-computers that can interact with each other. Sifteo cubes communicate with a computer via proprietary 2.4GHz radio protocol. The current prototype of SynFlo supports up to 6 Sifteo cubes. The interaction and animation is programmed using the Sifteo SDK written in C#. The tabletop application is implemented on the Microsoft Surface SUR40 device using the Microsoft Surface 2.0 SDK. The communication between the Sifteo cubes and the SUR40 is implemented using Client-Server communication between the Surface and Sifteo applications.

Evaluation

We conducted preliminary user studies with 18 high-school students (10 female) participating in a science outreach program. The students were given a 10-minute presentation explaining basic synthetic biology concepts, then interacted with SynFlo for about 20 minutes. The users picked up the interaction quickly and found the Sifteo and tabletop interaction especially engaging. While in the first few minutes the users were focused on experimenting with the technology, later in the session they also reflected on the connection between SynFlo and the synthetic biology concepts discussed.

Conclusion and Future Work

We present SynFlo, an interactive installation that utilizes tangible interaction to help illustrate core concepts of synthetic biology in outreach programs. We plan to further refine SynFlo to more accurately portray the scientific protocol used in E. chromi. We also plan to evaluate the effectiveness of SynFlo in informal science learning settings.

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