BacPack for New Frontiers: A Tangible Tabletop Museum Exhibit Exploring Synthetic Biology

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Abstract
We present BacPack for New Frontiers, an interactive museum exhibit that introduces core synthetic biology concepts to visitors through tangible, multi-touch, and physical interaction. The exhibit engages users in the design and engineering of bacteria, which are helpful in extreme environments like Mars. This project aims to allow museum visitors to play and tinker with biology through tangible and multi-touch interactions that bridge size and time scales. Here we present the design, implementation, and preliminary evaluation of this exhibit.

Author Keywords
Interactive Surfaces; Tangible Interaction; Tabletop

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

Introduction
Synthetic Biology is an emerging field that combines science and engineering in innovative ways to address critical real-world problems such as food shortage, waste disposal, and access to clean water. Synthetic

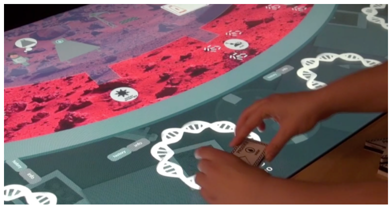

Figure 1. Visitors select genes by placing corresponding tangibles into a loop of DNA.

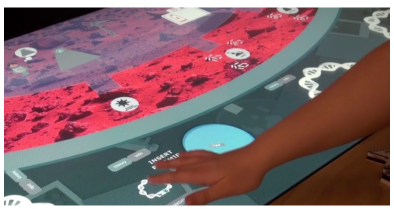

Figure 2. Visitors insert their custom designed DNA loop into a bacterium by dragging it over.

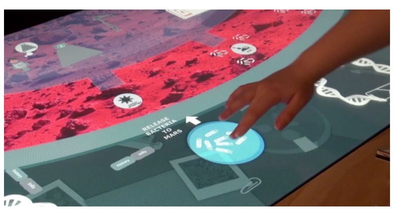

Figure 3. After custom-designed bacteria multiply, visitors can send their bacteria to Mars.

biologists apply engineering principles such as standardization, abstraction, and modularity to design and build new living organisms with particular properties or functions. To create new biological designs, complex genetic sequences are broken down into standardized biological parts called BioBricks, which are used like "Lego Bricks" based on their function and can be inserted into living cells.

The process of creating interactive and exploratory educational activities that expose wide audiences to the promise and limitations of synthetic biology is confounded by several factors, including the long time scales of biology, the complexity of the topic, and the unique behaviors of living organisms (often occurring at the nanometer level). Our goal is to create novel interfaces for exploring synthetic biology that bridge the goals of design and tinkering (tangible, responsive, and open ended) and the confounding factors of biology (invisible, unintuitive, slow, and prescriptive). In designing such activities, virtual augmentation is necessary to bring time and size scales into the range of a play session and to allow users to design with biology.

In this abstract, we present BacPack for New Frontiers, an interactive museum exhibit created in collaboration with the Tech Museum of Innovation. The system consists of a tabletop multi-touch display and a set of tangible BioBricks that allow users to collaboratively design and tinker with digital bacteria. Below we discuss how we used the tabletop and tangible interaction in this exhibit to bridge the confounds of biology through a collaborative platform for exploring biological-design. We also describe findings from a preliminary evaluation in the museum.

Related Work

A number of museum exhibits allow younger audiences to interact with biological concepts through experimentation like the observation of how bacteria react to light [2] and the analysis of multi-colored bacteria [1]. Most closely related to our work is SynFlo [7], a tangible museum exhibit for synthetic biology that utilizes active tangible tokens to simulate a biology experiment. BacPack seeks to examine how combining tabletop and tangible interaction can support collaborative open inquiry, design, and tinkering with biology.

Exhibit Design

We designed BacPack in close collaboration with synthetic biologists and educators. Informed by these professionals, as well as by the Tech Museum's constructionist educational philosophy, we defined the following design goals: G1) Supporting the development of inquiry skills through a collaborative and playful experience; G2) Conveying the excitement and application of synthetic biology by allowing visitors to design and tinker with biology. Through the exhibit, museum visitors take on the role of a scientist tasked with engineering bacteria to help an astronaut survive on Mars. This concept is inspired by a research paper that demonstrates synthetic biology can be used to harness available resources in such a scenario [3].

Museum visitors use tangible representations of BioBricks from the Registry of Standard Biological Parts [5] to design bacteria that can produce necessary materials from existing resources, and through touch gestures release their bio-designs to a virtual Mars (see Figures 1 – 4). Our design choices were informed by an iterative design process, as well as by design frameworks for learning with tabletop and tangible user interfaces [6]. We encountered several design challenges as we built our system:

Supporting parallel and collaborative work – To facilitate the flow of museum visitors, BacPack provides four virtual workbenches where users can work in parallel on different biological designs. The application invites all users to release their designs to a common environment (i.e. Mars) and observe the impact. Users are encouraged to collaborate on solving pressing problems, such as severe lack of oxygen and dwindling fuel supplies.

Fostering strategy development – The goal of the exhibit, survival on Mars through efficient utilization of resources, aims to encourage strategy development. We provide users with contextual hints, as well as dynamic representations of resources and state, to help them develop a strategy within the activity's short time span.

Facilitating group dynamics – Virtual workbenches are required to support each visitor group as a whole. Visitor groups vary in size, composition, and age. Through the use of tangibles, visibility of actions, and a visualization of previous interactions, we aim to facilitate group dynamics that allow visitors to learn together.

Bridging time and size scales – We use animation to bridge the size and scale of biology. Animations allow us to expose visitors to essential biological processes (e.g. transformation) and provide a dynamic simulation of resource consumption and production.

Figure 4. Children interact with the BacPack exhibit in a museum setting. (Bottom picture curtesy of Ashley McCabe, Ashley Daubenmire Photography.)

Museum setting – Interactions with museum exhibits are typically short and casual. To draw users in and to ensure their success, we present intuitive controls and provide clear, immediate feedback.

Implementation
BacPack for New Frontiers was developed for the 55" Multitaction Cell. It was programmed in JavaScript using the Multitouch Cornerstone 2 SDK. Tangibles were assembled from laser-cut layers and incorporated into the design using the MultiTaction fiducial markers.

Evaluation
We conducted a preliminary evaluation of BacPack at the Tech Museum of Innovation over the span of 4 days. The 67 visitor groups that interacted with the exhibit varied in composition and size: the largest group had 7 active participants, while over half of groups (55%) consisted of a single user. Adults not directly engaged with the exhibit often provided direct and indirect support to groups with children. User ages ranged from 4 to adulthood, and they collaborated not just within, but also across visitor groups.

Visitors were briefed about the general premise of the exhibit, but were not given explicit step-by-step instructions unless it was clear they needed support. Most visitors engaged with the system for over 4.5 minutes, with 20% interacting for longer than 7 minutes and a couple for over half an hour. All but three groups completed at least one round of interaction successfully.

Through observations and video data, we established that the exhibit was successful in facilitating collaborative engagement. For example, we found evidence of verbal strategizing, as well as passing and sharing tokens. In addition, in about 24% of groups, visitors observed someone else at least briefly interact with the exhibit before starting to interact with the exhibit themselves. In 14 out of the 26 groups with more than one member, we observed physical interventions like pointing or directly interacting with someone else's station, and in 2 groups, visitors actively shared stations.

After completing the interaction, users reported their age and rated how difficult and enjoyable they found the application on a scale of 1 to 10. They found the exhibit not particularly difficult to figure out and interact with (M = 3.40) and in general enjoyed their experience with it (M = 7.41). One 8-year-old chose to break the difficulty assessment into two parts, explaining that the tangible tabletop functionality was really easy (1) but the concept it taught was really hard (10).

We also asked open-ended questions about the exhibit's content to gauge learning. Visitors used terminology introduced by the exhibit and showed a grasp of learning goals through their overall response to post-task questions. For example, "I'm making bacteria to go on Mars, so I choose something and make something else. Yeah. Telling you what we need" (age 9). Visitors were also able to describe aspects of the process: "We made poop bricks.; We put genes together" (age 13); "I found that the poop is the best thing to make ... the water and the energy" (age 11) and "There's a DNA, and then you put the DNA into those thingies, and then you send it to Mars" (school age girl).

Conclusion and Future Work

BacPack for New Frontiers is an interactive installation that incorporates tangible and tabletop interaction to illustrate core concepts of synthetic biology to non-expert users. We will continue refining BacPack to provide more complex inquiry and interaction. We also plan to conduct a further evaluation at the Tech Museum before its launch fall 2016.

Acknowledgements

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