Eugenie: Gestural and Tangible Interaction with Active Tokens for Bio-Design

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ABSTRACT
We present a case study of a tangible user interface that implements novel interaction techniques for the construction of complex queries in large data sets. Our interface, Eugenie, utilizes gestural interaction with active physical tokens and a multi-touch interactive surface to aid in the collaborative design process of synthetic biological circuits. We developed new interaction techniques for navigating large hierarchical data sets and for exploring a combinatorial design space. The goal of this research is to study the effect of gestural and tangible interaction with active tokens on sense-making throughout the bio-design process.

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Gestures; tabletop; multi-display environments; cross-device interaction; tangible tokens;

ACM Classification Keywords
H.5.2 [Information Interfaces and Presentation]: User Interfaces—input devices and strategies, interaction styles

INTRODUCTION
Multi-touch and tangible user interfaces offer unique opportunities for facilitating collaborative learning and discovery. However, existing interaction techniques have limitations when exploring large data sets [6]. For example, direct touch is a common multi-touch input method, but in data-intense applications, wherein data representations are often small, finger size and occlusion pose a challenge [1, 7]. In addition, WIMP-style control elements–such as scrollbars, sliders, and textfields–may not be effective in data-intense multi-touch interfaces, because they are often too small for accurate touch or consume expensive screen real-estate [1].

Recent studies have explored novel multi-touch interaction techniques that provide advantage over WIMP-style touch controls; e.g. [1, 7]. However, these techniques often suffer from low discoverability and lack of persistence [1]. Our goal is to define novel interaction techniques for multi-touch and tangible interfaces that support the construction of complex queries using large data sets. Our work draws upon Tangible Query Interfaces (TQI) [5], which introduced tangible interaction techniques for querying aggregated data using active tokens. We also build upon research by Valdes et al. on user expectations regarding active tangible tokens combined with interactive surfaces [6].

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In this abstract we present Eugenie, a tangible user interface that utilizes gestural interaction with active tokens and a multi-touch interactive surface. Active tokens are programmable physical objects with integrated display, sensing, or actuation technologies that allow users to dynamically modify the tokens' associations with datasets or controls [6]. We chose to examine the use of this technology within the application domain of synthetic biology by creating an interface that supports bio-design, the process of creating new biological constructs through the combination of well-defined genetic parts. Bio-design is an intricate multi-step process that, to date, has not been adequately supported by existing bioinformatics tools. For over three years, we have been collaborating closely with domain experts to address the need for novel user interfaces that make bio-design more tractable and accessible to a broad range of users [3, 4].

DESIGN AND CONCEPT
Eugenie is designed to support a top-down bio-design paradigm, a process in which users define increasingly specific design parameters with each iteration. The top-down approach typically consists of three stages: 1. *Research* - users search for information about the structure and function of existing biological constructs 2. *Specification* - users specify the desired functionality of their biological construct by constraining its structure and behavior. This process typically begins with general rules applied to generic parts. Currently, many synthetic biologists use Eugene [2], a domain-specific programming language, for specification; 3. *Exploration* - users explore concrete instantiations of their specification. Users then iterate on this paradigm, adding more rules until they reach the desired result.

Our application, Eugenie, is a tangible user interface that leverages the Eugene programming language's functionality for design specification. The interface consists of a tabletop multi-touch surface and a set of three to twelve active tangible tokens.

The system supports three main stages of the top-down design paradigm. The *research* stage is supported by both the surface interface and the tokens. The surface interface includes a search bar in which users can input keywords or specific part names in order to select existing biological constructs. The active tokens use a tree-like search functionality for browsing the MIT Registry, which contains over 3000 parts. Users neighbor the tokens vertically to traverse the tree; for example, when a token is neighbored below another that displays the generic biological part "promoter", sub-categories that exist within the class "promoter" are displayed (see Figure 1).

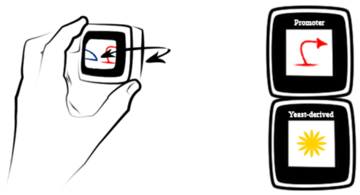

Figure 1. Tilting to scroll through categories and neighboring to display sub-categories

Both the surface and token interfaces support the *specification* stage. The surface interface implements three horizontally sliding panels that update simultaneously as users enter information (see Figure 2). The Structure View panel allows users to specify *structure* (e.g. "x BEFORE y" or "x AND y"). We created a visual language that maps manipulation of visual parts to Eugene functions. To add parts to the Structure View, users "stamp" the tokens onto the surface. Structure may also be defined using the tokens alone. Users may collapse or expand biological parts displayed by the token into one biological construct by stacking: simpler constructs stacked atop more complex constructs collapses, while the opposite expands.

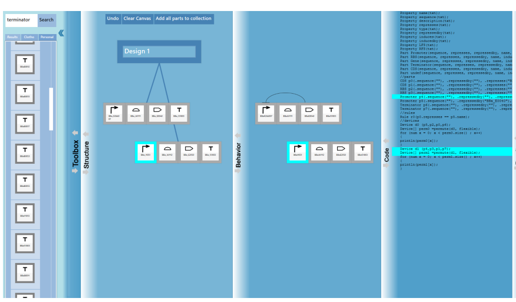

Figure 2. The tabletop interface

The Behavior View panel allows users to specify *relationships* between structures. For example, x INDUCES y is expressed by dragging from x to y and choosing "induces" from a pop-up menu. This relationship is expressed on the surface using standard synthetic biology notation. Users may also use our token-based language for behavior specification. For example, NOT x is expressed by clicking the token; clicking again undoes the operation. The Code View panel automatically generates Eugene code as the user inputs information in the Structure and Behavior Views. When users select a part in the Structure or Behavior Views, the relevant Eugene code pertaining to the part is highlighted. Eugenie supports the final paradigm stage, *exploration*, using the surface interface. Results that adhere to the specified structural and behavioral constraints are populated in a fourth panel, the Results View. The design process outlined here is repeated until a suitable list of results has been generated.

IMPLEMENTATION

Eugenie uses Sifteo cubes ver. 2.0: commercially available, clickable 1.7-inch block micro-computers that can interact with each other. We programmed the cubes using the Sifteo SDK and C++. The tabletop application is implemented on the SUR40 device using the Microsoft Surface 2.0 SDK and written in C#. Synthetic biological circuits are created using the domain-specific programming language, Eugene [2]. We implemented Client-Server communication between the SUR40 and Sifteo applications using PyUSB, a Python module that supports USB access.

CONCLUSION AND FUTURE WORK

We presented Eugenie, a tangible user interface for collaborative bio-design that utilizes gestural interaction with active tokens and a multi-touch interactive surface. We developed new interaction techniques for navigating large hierarchical data sets and for exploring a combinatorial design space. Future work includes evaluating the interface with users, as well as further expanding and implementing our gestural language.

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REFERENCES

1. Drucker, S., Fisher, D., Sadana, R., Herron, J., and Schraefel, M. Touchvix: A case study comparing two interfaces for data analytics on tablets. In *Proc. CHI 2013*, ACM Press (2013).

2. Huang, H., Oberortner, E., Densmore, D., and Kuchinsky, A. Eugene's enriched set of features to design synthetic biological devices. In *Proc. IWBDA 2013* (2013).

3. Shaer, O., Valdes, C., Liu, S., Lu, K., Chang, K., Xu, W., Haddock, T. L., Bhatia, S., Densmore, D., and Kincaid, R. Designing reality-based interfaces for experiential bio-design. *Personal and Ubiquitous Computing* (November 2013).

4. Shaer, O., Valdes, C., Liu, S., Lu, K., Haddock, T. L., Bhatia, S., Densmore, D., and Kincaid, R. Moclo planner: Interactive visualization for modular cloning bio-design. In *Proc. Symposium on Biological Data Visualization 2013*, IEEE (2013).

5. Ullmer, B., Ishii, H., and Jacob, R. J. Tangible query interfaces: Physically constrained tokens for manipulating database queries. In *Proc. Interact 2003* (2003).

6. Valdes, C., Eastman, D., Grote, C., Thatte, S., Shaer, O., Mazalek, A., Ullmer, B., and Konkel, M. Exploring the design space of gestural interaction with active tokens through user-defined gestures. In *Proc. CHI 2014*, ACM Press (2014).

7. Voida, S., Tobiasz, M., Stromer, J., Isenberg, P., and Carpendale, S. Getting practical with interactive tabletop displays: Designing for dense data, fat fingers, diverse interactions, and face-to-face collaboration. In *Proc. the ITS 2009*, ACM Press (2009).