BioTISCH: The interactive molecular biology lab bench

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Abstract
In a molecular biology lab, scientists often need to execute strictly defined sequences of operations, typically mixing specific amounts of reagents. The exact steps require information from various sources, like manuals, websites and own notes. Direct access to a computer at the bench would be highly desirable but is rarely implemented, as computers do not fit well into a wet lab environment.
In this paper, we present BioTISCH, an interactive workbench for molecular biology laboratories. We show a prototypical setup of an interactive table which provides a sterile user interface for access to existing documentation and for common tasks such as unit conversions. The example illustrates that interactive tables blend very well into a modern biological laboratory and could improve access and exchange of information in this environment.

Keywords
interactive table, lab bench, molecular biology, user interface

ACM Classification Keywords
H5.2. Information interfaces and presentation (e.g., HCI): User Interfaces

General Terms
Experimentation, Human Factors

Introduction

In molecular biology, scientists spend considerable amounts of time in the wetlab. Their main tools are pipettes and a bench where experiments with DNA or RNA molecules are conducted. One example for such an experiment is DNA cloning. The goal here is the insertion of a linear piece of DNA into a plasmid, a circular DNA molecule replicated by bacteria. Today, preparation of such an experiment is supported by computer software and various websites: the scientist examines the chart of the target plasmid, selects a suitable cutting enzyme and calculates the required quantity of water, enzyme, buffer solution and DNA. These values are mostly printed on a sheet of paper and carried to the lab bench where these amounts are mixed. During the experiment, details and results are recorded into a paper-based notebook.

An experiment like DNA cloning illustrates that molecular biologists could greatly benefit from direct access to software tools at their bench. In addition, the physical separation between wet lab and write-up areas hinder the success of ”Electronic lab notebooks” [14]. If all experimental results were stored digitally, ”open notebook science” [3] [16], a complete sharing of experimental results similar to open source software development, would be much easier to realize in the life sciences.

However, a practical technology to reconcile the wet-lab with the write-up area is not evident and rarely addressed in the literature. Computer keyboards are hard to use with gloves and take up precious space on the bench. Pen-based Tablet PCs [15] represent a big step towards ubiquitous computing in the lab [2] [1] but do not fit perfectly into a environment full of various strong acids and solvents. Scanning and annotating paper-based lab notebooks [12] preserves the data but still does not bring the Internet and its tools and databases closer and takes time to write.

Figure 1: Real-world example of a molecular biology workbench. Visible items include adjustable pipettes, reagent containers of various sizes, Eppendorf sample tubes and a large variety of notes and printouts.

Consequently, today’s lab benches are still cluttered with hand-written sheets or printouts. To our surprise, many users even scribble calculations and notes directly onto their glass-covered bench with a pen - see figure 1 for a real-world example. This observation inspired us to try an integration of software tools directly into the lab bench itself. As it often consists of a diffuse glass surface, one can direct a projector from underneath and recognize user gestures with a camera. In particular, with this kind of setup, one can not only detect touches to the glass, but also objects on the surface such as reagent containers and tools.

Related Work

We are not aware of any previous applications of interactive tables in life science laboratories. Therefore, we will review related work regarding interactive surface technologies in general.

The primary requirement for the implementation of such a setup is the ability to track multiple objects and touch points on a tabletop surface. One very popular approach by J. Han [10] is based on FTIR (frustrated total internal reflection). However, this method requires modification of the glass surface with infrared emitters and is therefore difficult to integrate into an existing commercial lab bench. An alternative technique is diffuse illumination, which only requires a camera and infrared emitter to be mounted below the surface. This approach is used, among others, in the reacTable [11] and Microsoft Surface [13] and offers the opportunity to also track objects on the table in addition to touches. One application of this second approach is the SurfaceWare system by Dietz et al. [4] which employs this feature to track and annotate glass containers on the interactive surface.

Our prototype is based on the TISCH system [7, 8, 6] which provides a hard- and software infrastructure for rapid development of interactive surface applications. The core components are a large-scale interactive table which supports both previously described tracking modes for maximum flexibility and a widget framework for easy implementation of a graphical user interface.

BioTISCH

The core concept of BioTISCH is to provide the working biologist with data needed for the running experiment. There are four main tasks which can be supported by the BioTISCH:

- browsing through the experiment log and ticking off completed steps
- viewing plasmid charts from a web database
- performing calculations such as molarity/concentration conversions
- indicating the next reagent to be added

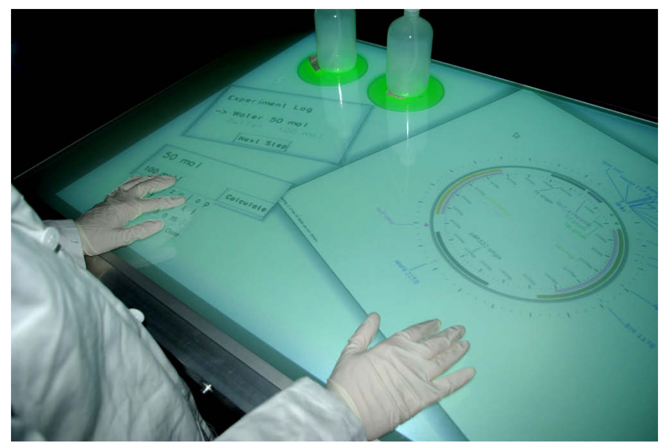

Figure 2: BioTISCH interface in use.

An important constraint which is usually not present in other interactive surface applications is that the interface must be easily usable with latex or rubber gloves. As toxic and carcinogenic substances such as bromine compounds are routinely used in molecular biology laboratories, the use of gloves is absolutely required. Moreover, the interface should be easy to clean after an experiment, which is the reason why glass plates are mostly used as bench tops. Both requirements are already fulfilled by our prototype shown in figure 2.
A closeup of the screen contents is shown in figure 3. The main elements (clockwise from top left) are:

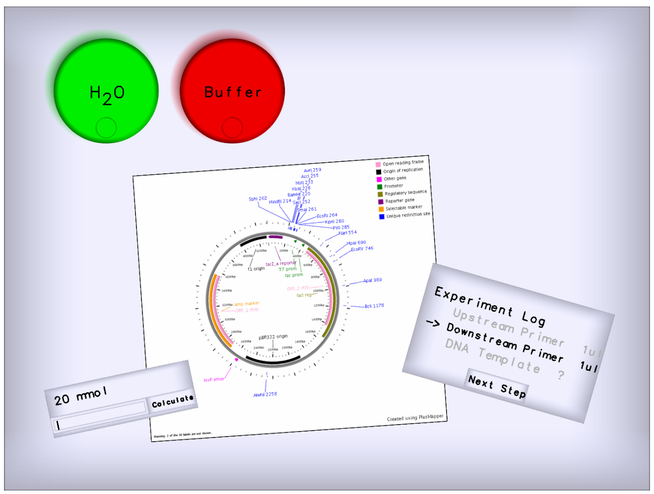

Figure 3: BioTISCH user interface screenshot. Shown are, clockwise from top left: reagent sensors, experiment log, plasmid viewer and concentration calculator.

- **Reagent Sensors** These areas provide dedicated table space for common reagents such as purified water or buffer solution. When the current step in the experiment log requires one of these reagents, the corresponding reagent sensor will highlight the substance containers.

- **Experiment Log** This object provides a simple viewer for the current steps in the experiment protocol. A button is available to switch to the next step when the current one has been completed.

- **Plasmid Chart** In this area, a bacterial plasmid can be selected and viewed to identify, e.g., suitable enzymes for cutting the DNA ring. The plasmid map is generated from the web-based PlasMapper tool [5].

- **Concentration Calculator** As some steps in the experiment log may require on-the-fly conversion of values such as molar weights or substance concentrations, quick access to such calculations is provided through this UI element.

Figure 4: Closeup of concentration calculator and on-screen keyboard. Note that the system is still usable with latex gloves which are required in a wetlab.

All UI elements can be freely scaled and repositioned on the table as seen fit by the user. Commonly used one- and two-finger gestures ("pinching") are available for this task. Data entry is performed through on-screen keyboards such as the one shown in figure 4.

Outlook & Future Work

In this paper, we have presented BioTISCH, an interactive workbench for molecular biologists. BioTISCH offers the opportunity to replace physical notes and documentation by a virtual representation, thereby uncluttering the workbench while preserving sterility. In addition, objects such as reagent flasks on the table are also tracked and annotated in order to help the user to avoid time-consuming mistakes. The most important next step for BioTISCH is to evaluate the presented concepts with other life science researchers, first on the prototype in our "drylab". Insights gained from this evaluation can then influence the design of a true interactive lab bench and its subsequent evaluation in a real wetlab.

Two future extensions to the system can be easily envisioned. The first one is the integration of motorized pipettes. Systems like the Gilson Pipetman Concept [9] can be programmed remotely to take up or dispose a certain quantity of liquids. BioTISCH's protocol viewer could control the pipette directly, avoiding the manual setting that has to be repeated for each step otherwise.

Another possible extension is a connection to a laboratory inventory system which is already in place at many institutes, with sample containers tagged with barcodes. By adding a barcode scanner to the BioTISCH, the sample contents could be used to display annotations or instructions automatically, without user intervention, for all containers within the range of the scanner.

BioTISCH is one step towards getting digital tools to the place where life science researchers spend most of their time: at their bench. In this article, we have shown that interactive tables fit into the work environment of life science laboratories particularly well. The hardware and software tools to implement them exist now, at a price that is similar to a set of standard pipettors. Building on our prototypical implementation, we will continue to evaluate and refine the BioTISCH system based on the real-world constraints and requirements in the wetlab.

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