From Digital to Physical: Learning Physical Computing on Interactive Surfaces

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ABSTRACT

We want to investigate the benefits of interactive surfaces for guiding novices in the learning process of physical computing. As interactive surfaces can augment physical objects with digital information, we utilize these to foster the learning experience in three ways: (1) by supporting multiple users for collaborative learning, (2) providing in-place knowledge mediation about physical prototyping and electronics and (3) by digitally guiding users from exploring physical components to creating a physical prototype.

ACM Classification: H5.1[Information interfaces and presentation]: Multimedia Information Systems. - Artificial, augmented, and virtual realities.

General Terms: Experimentation, Human Factors

Keywords: Physical computing, interactive surfaces

PROBLEM STATEMENT & RELATED WORK

Novices in the field of physical computing (e.g. researchers, product designers) face two major challenges when building a prototype: (1) *hardware development*: sensors and actuators need to be properly connected to a microcontroller in an electrical circuit. This requires a basic understanding of underlying electrical principles (e.g. Ohm's Law) and knowledge of the right tools (e.g. breadboard, multimeter). (2) *software development*: a microcontroller has to be programmed to read out and control attached hardware components. Various approaches towards simplifying prototyping are already available:

Simplifying Software Development: Visual programming eases software development by letting users arrange program blocks visually [4], but they also limit application possibilities. Thus, users may not learn the needed programming knowledge to face more complex projects. BrickLayer tackles this problem by empowering users to program an Arduino application visually, while the resulting code is simultaneously displayed for modification [1].
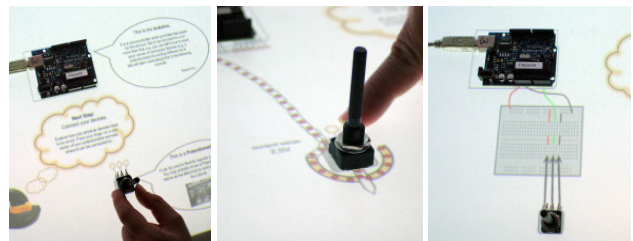
Fig. 1. A user places a potentiometer on an interactive surface to receive related information (left). The user can connect components digitally (middle) and learns how to rebuild the setup physically (right).

Simplifying Hardware Development: Toolkits like Lego Mindstorms[1] include a lot of ready-made components that can be connected easily. However, as well as with software toolkits, users may soon encounter several limitations (e.g. if a specific sensor or actuator is not included), because the simplified hardware components are too generic and the required knowledge to employ hacked or new components may not have been acquired. More sophisticated IO-Boards such as Arduino[2] allow users to create more complex projects, but in turn, require basic electrical engineering know-how to build a prototype (e.g. use of breadboard and analog components). Online tutorials (such as for the Lilly-pad Arduino [3]) or digital representations of hardware setups (e.g. with Fritzing [2]) help users in learning the needed skills, but do not provide information in situ.

We are interested in seizing the benefits of interactive surfaces for guiding novice users in physical prototyping. As demonstrated in the Luminous Room [5] and with Wellner's DigitalDesk [6] users can profit from augmenting physical objects with digital tooltips in-place (e.g. introduction to components, data sheets, visualization of electrical currents). We want to present our initial explorations of using interactive surfaces for tutorials that let users explore physical computing and its underlying electrical principles. The next section will explain this concept and will be followed by an exemplary tutorial to better illustrate the idea.

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[1] http://mindstorms.lego.com

[2] http://www.arduino.cc

PHYSICAL COMPUTING ON INTERACTIVE SURFACES

Interactive surfaces offer various benefits which we can utilize for learning environments. *(1) Support multiple users*: Tabletops allow not only one single person to use the application but invite groups of users to collaboratively explore and discuss their mental models of electrical principles. *(2) Enrich work environment:* Hardware components are usually arranged and connected on a regular desktop. An interactive surface can augment the usual work environment with digital information. *(3) Transition from digital to physical:* Novice users gradually advance from single digitally augmented components to a working physical prototype under digital guidance, thus transitioning from a digital to a physical setup.

General Setup

We are currently validating our ideas with interactive high-fidelity mockups: A set of basic electrical components (Arduino board, sensors and a breadboard) are tracked via fiducial markers on an interactive surface. Users begin their learning experience by placing devices, discovering their use, functions and data in-place. Depending on the components situated on the surface, digital tutorials impart the necessary skills to connect them physically. A major help for novices would also be to track and validate the completed physical setup, which bears a challenge due to insufficient means of tracking tiny components (e.g. cables, resistors, etc.). Nevertheless, our prototype is currently able to make assumptions about correct wirings via the Firmata protocol[3], which allows circuit evaluation through voltage metering on microcontroller platforms.

Example Scenario: Arduino & Analog Input

After novice users have completed a basic tutorial about the general setup of a sophisticated IO board (e.g. Arduino) they are suggested a tutorial, covering the basics about analog pins, electrical circuits and a simple analog device, like a potentiometer. By placing the potentiometer on the surface, basic information about it is displayed (see Fig. 1 (left)). Subsequently the user can explore digitally how to correctly connect the components and receive feedback on the performed actions (see Fig. 1 (middle)). To indicate a successful connection, the augmented physical potentiometer will be "flooded" with electrons. The functioning of the device can be further discovered by turning a virtual slider, thus influencing the visualized current flow. As soon as the user got acquainted with the basic connection process, the digital circuit can be rebuilt physically. A digital version of the real hardware setup, including breadboard etc. (see Fig. 1 (right)), supports the user in accomplishing this task. When completed, the user can control the virtual electrons also by turning the real potentiometer. This tangible interaction technique could also be applied for visually programming corresponding code, thus serving as entry point for tutorials on developing software for microcontrollers.

By mixing explanations, simulations and guided exploration phases, the system enables a transition from digitally augmented single hardware components to a working physical prototype.

SUMMARY & OUTLOOK

While prototyping toolkits simplify the creation of physical interfaces by providing the means to quickly implement simple setups, they also entail limitations when dealing with more complex projects. Thus we want to teach users the required skills to tackle this problem by understanding the underlying basic electrical principles and components.

Letting users explore physical components in step-by-step guided tutorials on an interactive surface offers the following advantages: (1) *Collaborative learning experience,* through the support of multiple users: by inviting additional users, one is able to benefit from group learning environments. (2) *Augmentation of physical components* for in-place knowledge mediation: explanations or visualizations next to their physical equivalents, support users within their learning process. (3) *Continuous guidance from digital draft to physical prototype* for novice users: this provides a *fluent transition* from a rather *virtual and explorative* learning environment to a real *physical* representation. Whereas the digital tutorials with simulations (like electrical currents) help the users to understand the underlying principles, the virtual connections serve as guidance for building the actual physical setup.

After testing our initial assumptions on an adequate first tutorial with high-fidelity prototypes, we plan to implement the first described exercise in near future. In further tutorials, users can be interactively guided in learning about breadboards, resistors and Ohm's law, analog output, etc.

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