Rapid Prototyping of Physical User Interfaces

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In the last few years, researchers have embraced human-computer interface designs that include physical user interfaces augmented by computing power. These began with Weisser's vision of ubiquitous computing and calm technology [8], and continued to notions of pervasive computing [1], tangible user interfaces [6], information appliances [7], ubiquitous media and reactive environments [2], interactive art installations (e.g., see SIGGRAPH Art Galleries), ambient displays [3], and context-aware computing [4]. The area is so new that we are still entranced by breakthrough examples of physical user interfaces. Indeed, many papers and proceedings are speckled with beautiful exhibits illustrating what can be done.

While this is an exciting new area, everyday programmers face considerable hurdles if they wish to create even simple physical user interfaces. Most lack the necessary hardware training. Those willing to learn will find themselves spending most of their time building and debugging circuit boards, firmware and low-level wire protocols rather than building their physical user interface designs.

The problem is that we have not provided programmers with adequate building blocks for rapidly prototyping physical user interfaces. This leaves them in a position similar to early GUI researchers who had to build their widgets from scratch, or to early graphics researchers who had to build their 3D environments by brute force using primitives such as 'DrawPixel' and 'DrawLine'. Given this onerous situation, it is no wonder that papers on physical user interfaces mostly come from top researchers at major university and industrial research laboratories.

Marble Mail by Shannon Goodman is a physical representation of your email box. The top bowl acts as a storage area representing potential email. As email arrives, a marble drops to the middle bowl containing unopened messages. As email is read, a marble drops into the last bowl containing read messages.

Magnetic Desert by Kari Basaraba is an ambient display that moves metal bearings around a dish at a rate that varies with the amount of motion detected in the room. It is constructed from steel ball bearings, sand, a Plexiglas dish, and (behind the scenes) magnets.

As a consequence of these problems, I and my collaborators made a concerted effort to think about how we could package physical devices and their software for easy development of physical user interfaces. Our goals were to create devices:

- simple enough so that developers can concentrate on the overall use, modification and recombination of devices into a physical user interface instead of low-level device construction and implementation;
- easy enough for the average programmer to program and extend.

Our solution was to develop physical widgets, or *phidgets*, whose use is almost directly analogous to how graphical user interface (GUI) widgets are packaged and 'dropped into' software applications [5]. Our primary belief is:

> …just as widgets make GUIs easy to develop, so could phidgets make the new generation of physical user interfaces easy to develop.

Through the phidget hardware and software, it becomes very easy to control various output devices by computer: servo motors, LEDs, 112 volt power bars, variable power to DC components (motors, lights, etc.), solenoids, and so on. It is just as easy to gather input from physical buttons, toggle switches, potentiometers, light sensors, force sensors, heat sensors, motion detectors, accelerometers, and a host of other input components.

I gave phidgets to undergraduate students with no hardware expertise to see what they could do with them. These typically took the form of a short two week assignment. The results were remarkable. While some students replicated examples of physical user interfaces reported by other researchers, most produced their own innovative designs [5]. Several of the more recent student projects are documented on the following pages. I should emphasize that these examples are typical of what students did!

My main message is that packaging devices as physical widgets greatly simplifies their programming and construction, which in turn empowers designers to craft physical user interfaces rather than waste their time on low-level implementation details.

Ele-Phidget by Shivaughan Warwaruk is an ambient notification for an audio chat program. When you receive a message, the elephant turns around and faces you. You push the elephant's stomach to listen to the message. When no messages are left, the elephant turns away. To record a message, you squeeze the elephant's head and speak into the elephant's trunk. A second squeeze sends the message.

Mathletics by Russel Kruger is a game for children to learn their multiplication tables. Multiple-choice questions appear on the screen, and each child enters the answer to their questions using a controller. As one answers a question correctly, a skier skies partway down the mountain. The first child to correctly answer 10 questions wins, at which time their figure reaches the bottom of the mountain, and the lights on their mountain light up.

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Disharmony by Mike Polowick is an abstract conglomeration of loosely-related themes designed for provoking thought in the viewer. All parts were crafted with deliberate intention, but there is no specific meaning; any interpretation is correct. Depending on how one moves a pieces on a chess board (not shown), bubbles disturb real fish in their fish bowl, lights blink, a disk spins, and so on.

Messenger Frame by Michael Hornby-Smith is a physical notification device attached to MSN Instant Messenger. As a person appears online or changes his activity status, that person's photo is lit up and a sound cue is generated. One can send a message directly to that person by touching his photo.

Monster Phidget by Edward Tse greets people as they walk by e.g., "hey, how's it going" or "good day sir". If someone stops in front of Monster, he responds with something like "cool, you're hanging out eh?" and then tells jokes (laughs and drum rolls included). When the person leaves, monster says something like "catch ya later". If someone pulls on Monster's mouth, it responds with a short phrase from the Monsters Inc. movie.