Designing Interactive Behaviours Beyond the Desktop

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ABSTRACT
As interactions move beyond the desktop, interactive behaviours (effects of actions as they happen, or once they happen) are becoming increasingly complex. This complexity is due to the variety of forms that objects might take, the different inputs and sensors capturing information, and the ability to create nuanced responses to those inputs. Current interaction design tools do not support much of this rich behaviour authoring. In my work I create prototyping tools that examine ways in which designers can create interactive behaviours. Thus far, I have created two prototyping tools: Pineal and Astral, which examine how to create physical forms based on a smart object's behaviour, and how to reuse existing desktop infrastructures to author different kinds of interactive behaviour. I also contribute conceptual elements, such as how to create smart objects using mobile devices, their sensors and outputs, instead of using custom electronic circuits, as well as devising evaluation strategies used in HCI toolkit research which directly informs my approach to evaluating my tools.

Author Keywords
Prototyping; prototyping tools; design tools; toolkits; interaction design; interactive behaviour; mobile interfaces.

INTRODUCTION
Technological advances have made it so we can interact with everyday devices (e.g. smart phones and watches) and appliances in new and interesting ways. Many of these devices feature interactive behaviours that mediate how outputs take place depending on the inputs. Thus, interactive behaviours are key in creating a continuous dialog between the user and the device: they suggest the effect of the action *as* it happens, as well as *once* it is completed. These live reactions might take place when interacting with *physical input*, such as turning a knob on a coffee grinder to select the grind setting; *sensor input*, such as hitting a guitar string to show its current tuning on a tuner; or *outputs*, such as a digital assistant speaker displaying a light gradient as it communicates with a person.

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Over the last decade, interaction design has become increasingly streamlined. This is partially due to the foundation of standardized practices such as wireframing and prototyping. Furthermore, a wide variety of tools have emerged [9] (e.g. Sketch, InVision) that support designers of multiple backgrounds to lay out and define the flow within a desktop application. These tools excel when it comes to creating interfaces that leverage typical user interface widgets such as buttons and hamburger menus.

However, one area where these tools often are lacking is supporting interactions beyond click-based screen transitions. An action-trigger approach is effective for layout and state transitions, but ignores many nuances such as: animations, continuous interactive responses, context of use and ultimately how the interactions play out given the objects inputs, outputs and physical form. Even everyday mobile interactions such as slide to unlock, pinch to zoom, or Android's quick settings, show higher complexity, as many visual objects are animated in correspondence to the user's actions (e.g. touch and slide).

To explain the nuances behind behaviour authoring, consider the example of a digital assistant speaker which uses light in addition to speech to communicate with people. When the person first calls out to the speaker, the speaker has to acknowledge that it is now listening. Once the question or command is over, the speaker uses another light pattern to indicate that it is looking for an answer. Finally, while verbally responding, the light might flash in accordance to the speaker's sound, to convey that it is speaking. While there are three clear states (listening, loading and responding), there are details in how the speaker's light might be animated to create the user experience, considering aspects of brightness and colour, as well as how those change in the course of the interaction. Moreover, to test these interactions properly, there needs to be an understanding of where the lights are on the speaker and what they might look like. To prototype such a behaviour in a way that could be fine-tuned and tested requires extensive programming knowledge and time, and would require some way of also realizing the physical form.

Figure 1. A 3D printed firetruck toy prototype powered by a mobile phone. Light pipes reroute the colours from the display to the top, while the 3D printed capacitive button touches the screen to start the light animation and play a siren sound.

My goal is to empower interaction designers to rapidly author rich interactive behaviours without undue effort and in a timely manner. This can allow them to test alternatives and variations, and fine-tune the interactions until obtaining the desired result. This means that the designer does not have to wait until a more finished product is created to see if the behaviour works successfully. My research is further motivated by prior studies [6, 7], which show that these behaviours are complex and difficult to convey on sketches and storyboards, and often even require designers to work with video editing tools (e.g. AfterEffects) [6] to effectively communicate these interactions to developers.

In my research *I explore the creation of prototyping tools that can support designers in authoring and testing interactive behaviours beyond the desktop – both mobile and smart objects.* My work focuses on testing the interactions in closer representations of the final products [2], so designers can fine-tune and achieve the desired behaviours [7]. To convey this position, I describe the contributions of my research. I then share future directions for my PhD.

CONTRIBUTIONS TO DATE

I have created prototyping tools to examine both the authoring of behaviours and how to create physical forms based on behaviours. In the process, I also devise conceptual components that help me better understand the role of my research, as well as inform the overall design of these types of tools. I next describe my contributions to date in detail.

Conceptual Contributions

Soul-Body Prototyping

My work in Pineal [3] brings forward the concept of Soul-Body Prototyping. One challenge to prototype behaviours for smart interactive objects is the required expertise to program, create custom circuitry and embed those circuits into a meaningful form. Soul-Body Prototyping proposes using mobile devices in place of custom electronics, and creating fabricated passive 'enclosures' that define the form of the object while exposing the necessary inputs and outputs. As well, designers can repurpose mobile sensors and outputs in new interesting ways. Commercial applications such as Nintendo Labo [10] are already applying some of the principles outlined in Soul-Body Prototyping. Mobile devices are ubiquitous and readily available and make for an excellent temporary stand-in for prototyping different smart objects. Some of the benefits include:

Extensible Geometry. Mobile devices are fairly standardized in their form. Designers can now work with a flat cuboid shape and build more complex forms around it, where the phone or watch becomes the 'soul' of the smart interactive object prototype.

Rich Sensing and Outputs. Mobile devices are self-contained, and house a myriad of sensors and outputs present in many smart objects (e.g. touchscreen, microphone). Designers can use or repurpose sensors in interesting ways. Figure 1 shows how this might be realized in a firetruck prototype, using light pipes to create light sources [3], or using conductive materials to move the location of a touch-point to a point in the new enclosure (e.g. [3, 8]).

Access to Complex Functionality. Mobile devices also feature internet connectivity, which adds further opportunities for Internet of Things (IoT) applications. These include voice recognition, as well as web APIs (e.g. weather and Twitter). This also means it is possible for mobile devices to communicate with other devices within a device ecology.

Low Threshold and Less Technical Hurdles. Replacing custom electronic circuits with mobile devices dramatically lowers the threshold for entry. Working with a mobile device removes the need to solder and embed components onto the form, and mitigates the concurrent and tricky 'circuit vs. code' debugging [1]. Moreover, given the computational power of mobile devices, there is a decreased need for low level constructs, such as memory management.

Evaluation Strategies for Toolkit Research

One recurring question is how the tools I create might be evaluated. My work in [4] shows a survey of evaluation methods in 68 toolkit and prototyping tools. The research examines the different evaluation strategies used in HCI toolkit research, and classifies it into four major categories: demonstration, usage, performance and heuristics. The results inform my own evaluation practice, where I primarily rely on demonstrations to envision new ways of creating prototyping tools using mobile devices.

System Contributions

Astral: Authoring Interactive Behaviours

Astral [5] (Figure 2) is a prototyping tool that uses streaming and input remapping to enable designers to author, test, and fine-tune interactive behaviour in mobile and IoT prototypes using familiar desktop tools. Astral works by (1) streaming visual contents onto a mobile display; (2) streaming mobile sensor data onto the desktop computer; and (3) providing means of interaction by converting the mobile inputs into mouse and keyboard commands. As a result,

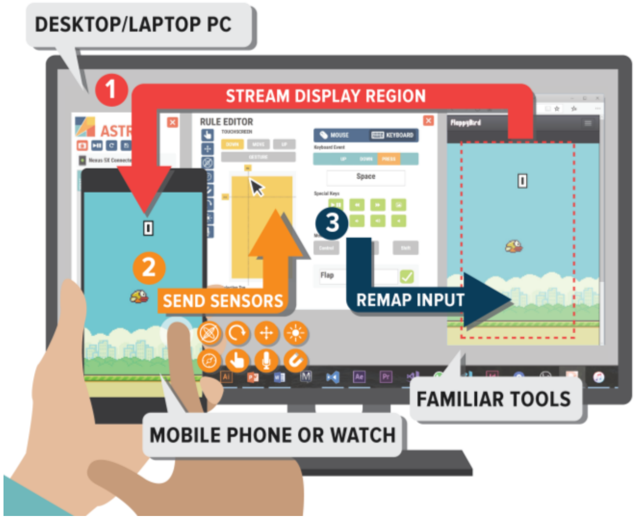

Figure 2. Astral allows designers to prototype interactive behaviours by (1) streaming contents of a desktop display to a mobile device, (2) sending mobile sensor data to the desktop, and (3) remapping the sensor data into desktop input as mouse and keyboard events.

designers can use Astral to author interactive mobile behaviours to support many interaction design applications.

In the current version in preparation for CHI 2019, Astral supports the following interaction design tasks: behaviour exploration and fine-tuning, creating prototype alternatives, iterative design of multiple fidelities, and interactive video-based prototyping. The functionality can be further applied to IoT applications, and can also extend desktop usage by adding controls to mobile devices. For example, sensor values of the microphone amplitude can be used to scrub through a video and create a prototype that changes light intensity as the person speaks. Thus, it is very easy to design and test behaviours such as continuous light patterns of a digital assistant prototype, created using a mug housing a smartwatch with a 3D printed light diffuser (See Figure 3).

Figure 3. "Smart Home Speaker" prototype consisting of a mug, a smartwatch with a custom holder and a light diffuser. The watch display can show different light patterns when prototyping behaviours for a smart speaker.

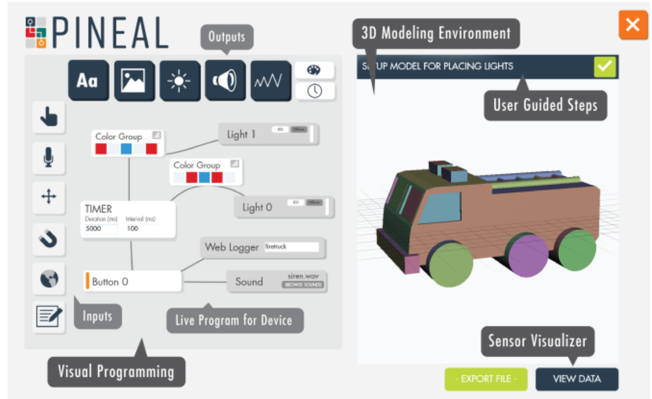

Figure 4. Pineal, showing a visual programming environment (left) which automatically modifiers 3D models (right) for Soul-Body Prototyping.

Pineal: Automatic Form Generation from Behaviours

Pineal [3], shown in Figure 4, is a prototyping tool that enables designers to author interactive behaviours using visual programming to automatically modify 3D models to fit a mobile device, and expose the necessary inputs and outputs. For instance, the program in Figure 4 will send instructions to modify the 3D model, as depicted in Figure 5, which can then be 3D printed. The result is an interactive firetruck toy, shown in Figure 1. Furthermore, changes in the visual program are rendered live in the mobile device. Pineal demonstrates one way to realize Soul-Body Prototyping, and shows a range of prototyping possibilities as explored in our design space through different prototypes. The prototypes include: a magic 8 ball that responds to shaking, a firetruck toy that flashes lights and plays siren sounds, a voice activated lightbulb that changes colours based on voice commands, a level that shows a visual indicator and vibrates when leveled, and an ambient planter that changes colours based on Twitter activity.

FUTURE DIRECTIONS

I have one more project left in my PhD, for which I hope to get feedback during the UIST Doctoral Symposium. I next list some of the possible options. I also hope to reach a point where there is a better understanding of interactive behaviour, as current definitions are vague, and look forward to suggestions as to how I can help bridge this gap.

Making Everyday Objects into Smart Prototypes

One potential avenue for my work is to explore how we can attach mobile devices to existing objects to make them smart. A prototyping tool can examine how designers might author these types of behaviours and interfaces based on the mobile sensor data. This would provide designers with a way of creating sophisticated Soul-Body prototypes while working with existing physical forms.

Multi-Sensor Behaviour Authoring

An interesting direction to examine is to create a prototyping tool that allows designers to create animations based on sensor data. It should allow designers to create nuanced behaviours based on sensor data and also support animating using multiple sensors. In contrast to Astral, this tool would

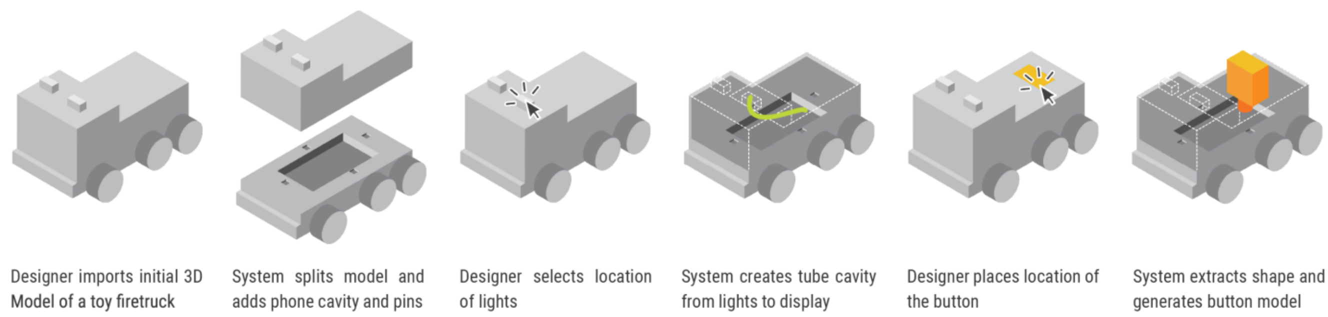

Figure 5. Pineal's steps to generate a toy firetruck which combines designer input with automated system modifications.

(1) focus on the nuances to animating behaviours, and (2) support more than sensor animation at a given time.

Multi-Device Authoring

To further extend the scalability of Soul-Body Prototyping, one might consider how multiple devices can come together within one prototype. For example, devices can act as individual widgets, or provide more than one display point within the prototype, or depict a micro ecology of IoT devices. Thus, the mobile device becomes a universal module that can be combined with others to create that prototype.

Live Mobile Coding Toolkit

I find value in creating a toolkit to support the development of authoring tools for designing and exploring interactive behaviours within mobile devices. In doing so, the software toolkit can provide researchers with the ability to author PC applications that: (1) connect mobile devices to the PC application; (2) access mobile sensor data from the PC application; and (3) modify the contents of the mobile device from the PC application in a live manner. As in my current tools, mobile devices (i.e. phones and watches) run a blank application that executes the commands or renders contents given by the PC application. This would enable other researchers to join the area of interactive behaviour authoring.

CONCLUSIONS

My research explores how prototyping tools might aid designers in authoring interactive behaviours beyond the desktop in contrast to typical trigger-action approaches. My hope is that my work will lead to designers being able to create rich prototypes without needing to code and in a timely manner, and that they can fine-tune behaviours until they find their desired result. This can improve existing practices, and ultimately lead to more interesting designs. I hope the UIST Doctoral Symposium can provide me with a sense of how my thesis fits as a whole, as well as the potential behind some of my proposed future directions.

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