MODULAR TOOLKIT OF INTERFACE COMPONENTS
FOR STUDENTS TO EFFICIENTLY AND EASILY TEST DESIGN CONCEPTS

Magnus Feil / Frances Tung
University of Washington / Division of Design
mfeil@uw.edu / francesctung@gmail.com

1. CONTEXT

With the shift from an industrial society towards one that is primarily directed toward the creation and distribution of information over the last decades (Wallschlaeger 1992), the field of design has been directly affected by this shift of paradigms. The challenges for designers have grown exponentially in this period of transformation: While the last generations of designers approached challenges predominantly in a product-centric fashion, the "digitalization" of artifacts for mainstream consumers has changed the paradigm and now calls for a much broader sensitivity of designing concepts to e.g. reflect interactions in the light of increased complexity, stakeholders, and considerations for better sustainability.
The chart "Trajectory of Artificiality" (Krippendorff 2006; Figure 1) illustrates the traditional areas of expertise and highlights the expanded scope for today's design professionals. Designers in the past were trained for specific core areas of skills: Industrial designers predominantly created products under considerations of utility, functionality, and universal aesthetics; Interaction designers' core expertise is centered around interfaces, interactability, understandability, etc… .
Today's challenges of our industrial society therefore call for an expansion of the traditional areas of knowledge to encompass a broader set of skills to encompass form, behavior, and interaction. As the realm of product design is becoming increasingly connected with user experience and software design, teaching developing industrial designers the principles of interaction design in the context of user interfaces is an opportunity that would lead to better prepared students for tackling complex multi-disciplinary problems.

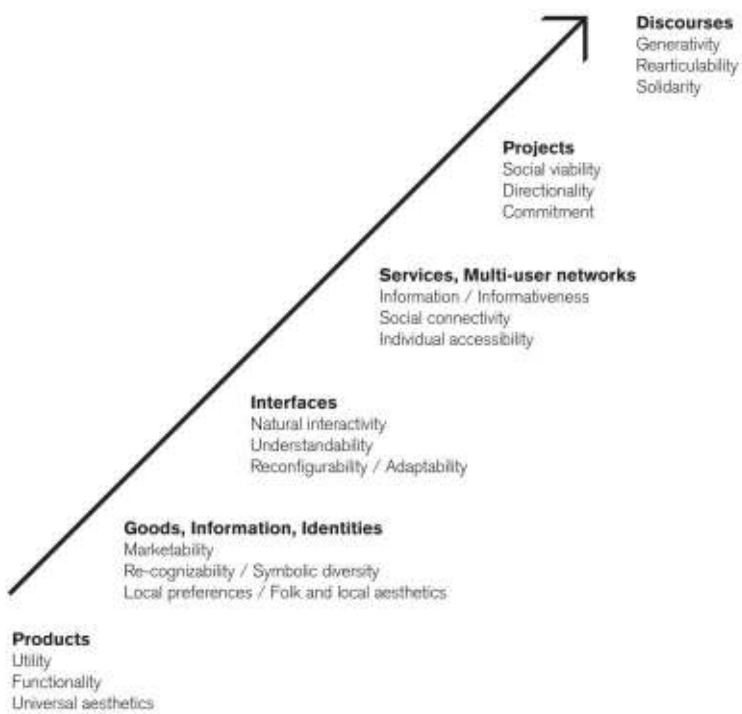

Figure 1. Trajectory of Artificiality (Krippendorff, 2006 - adapted)

2. ROLE OF PROTOTYPING IN DESIGN EDUCATION

Industrial designers traditionally use prototyping as an effective medium to explore, refine, and share emerging concepts. These physical prototypes succeed an initial phase of two-dimensional form finding on paper, and are usually created out of low-cost materials (paper, cardboard, yellow-foam) that are generally easy to sculpt and manipulate. The benefits of mock-ups are essential in the form-finding process, as they give designers tangible feedback on the validity of the design drawings. In the context of design education, it become especially important for the emerging form-givers to experience hands-on the inherent ambiguity of two-dimensional sketches (analog and digital) once a translation into three-dimensional artifacts has taken place. Mock-ups unmask flaws in scale, proportions, form, transition of surfaces, as well as in the semantic meaning of artifacts. Potential issues on a macro level can be seen by the naked eye, or on a micro level felt through haptic coupling by e.g. running one's hand along surfaces. Mock-ups allow a level of fluidity through alteration, experienced issues can be addressed quickly and ultimately prepare the student to progress towards the next step: The construction of a high-fidelity "final" model that strives to give a realistic impression how the actual product might look like, while offering none of the functional qualities. (Figure 2, Left)
Prototyping by Interaction design students on the other hand strives to create a bridge that enables the dialog between users and a designed product, system, or service. Form explorations address design for affordances and how interaction-oriented design of product form supports product understanding and leads to new behaviors of use. In practice, interaction designers build prototypes to mimic function, while the formal aspects often take a backseat in this exploratory phase. Analog to their counterparts in industrial design, initial ideation usually takes shape on paper, scenarios drawn as storyboards capture the dynamic patterns of interaction between stakeholders, context, and artifacts. In some cases the necessity arises to recreate three-dimensional representations of scenarios to re-create a spatial layout for screen-based interfaces and control physical control-elements (Figure 2, Right)
Once viable concepts have been identified, prototyping of the dynamic interaction patterns continues via non-linear screen-based software tools (e.g. Adobe Flash), in addition to physical components, ranging from off-the-shelf hardware (e.g. Computers, touch-screens, keyboard), to custom build electronic components (e.g. Arduino boards, sensors, and switches).

Figure 2. Left: Upper prosthetic limb evolution: From early prototypes to final model. (Feil, Strum, 2009). Right: Spatial layout for a cockpit interface (Roesler, Minarsch, 2010).

3. CYCLE OF DESIGN PROTOTYPING

While the outcome of the previously described prototyping efforts may differ in tangibility or concept, there is great commonality in the systematic way designers evolve an idea from an initial phase towards a finalized design. A cycle of design prototyping illustrates the dynamic path of ideation that the designers will become heavily engaged in over the course of a project (Figure 3).

- Step 1: Internal Experimentation

This initial phase of the design process reflects the definition of a proposed concept and is concerned about the validity of possible ideas to effectively hone in on viable solutions. The fluidity of this early stage often affords changes that will affect the trajectory of the initial concept. Students are encouraged to amass as much knowledge through research and observation to acquire a sufficient level of domain expertise to understand and scrutinize the status-quo, and be sensitive as well as open-minded towards imposed limitations or opportunities. Prototyping methods in this early stage need to reflect this inherent dynamic of ideation: Typical tools are e.g pencil sketches as an efficient way to quickly capture a vast amount of initial ideas, a collection of (sticky-) notes to form mind-maps to capture, structure and share ideas as a basis for discussions and critiques.

- Step 2: Low-Fidelity Iterations

  If a promising concept has been identified, the designer moves on towards a series of low-fidelity prototypes out of foam, clay, cardboard, or an assembly of existing artifacts. These prototypes are comparatively easy to construct, yet pay a significant role in the evaluation of form, proportions, basic functions of the concept. Identified issues can be addressed swiftly through direct alterations on the model. While early three-dimensional mock-ups commonly lack yet the refinement of a later model, they allow the designer from early on to simulate the projected functionality and interaction, and to assess their validity.

- Step 3: High-Fidelity Iterations

  Once the designer is satisfied with the outcome of the explorations conducted throughout step 2, the concept is elevated to the final stage: the construction of a final, high-fidelity, model that represents a close rendition of how the actual product will look like. Within this phase, the main focus is centered around the refinement of formal details, manufacturability, choice of materials, or the costs of production. The final steps entail surface preparation and paint of the components, assembly of parts, and a detailed programming to simulate interactivity.

- Step 4: External Validation

  This step rarely occurs in academic settings, as it reflects the final developmental phase in the industry once a design is destined for production. Prototypes closely resemble the actual product and are often constructed out of early molded components or three-dimensional prints, and usually exhibit full functionality. They serve engineers for functional testing, debugging, marketing needs, and are used during focus group evaluations to prepare successful the launch of the finalized product.

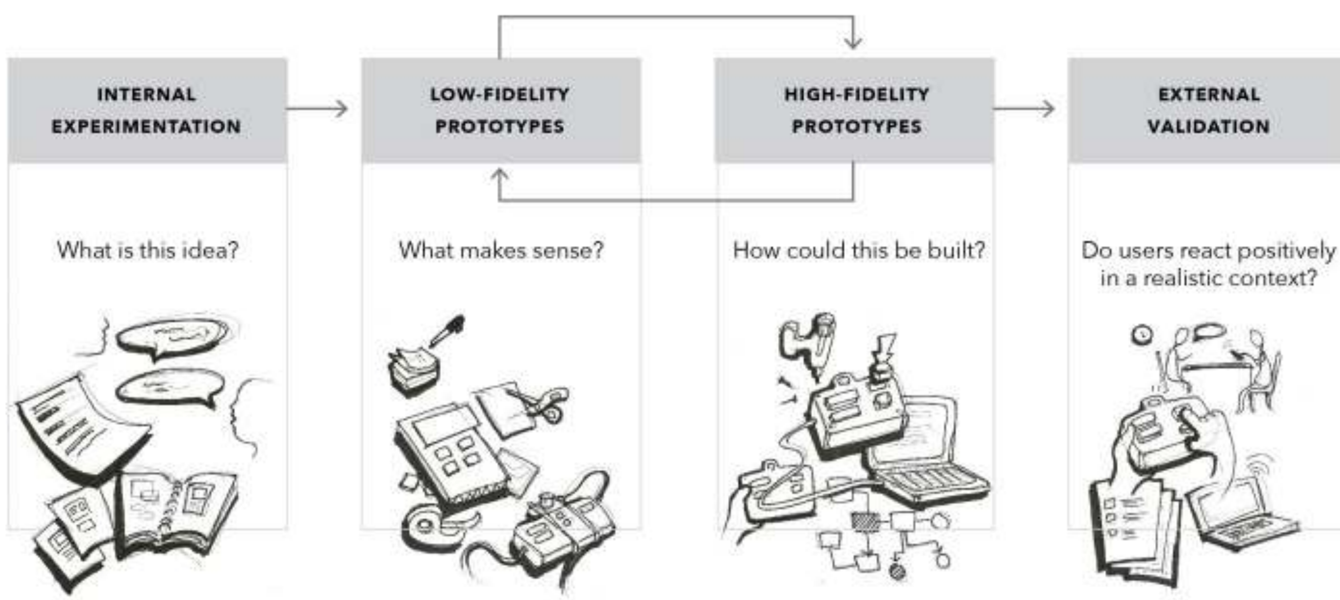

Figure 3. Cycle of Design Prototyping (Tung, Feil 2013)

4. CONTEXT OF PROTOTYPING TOOLKIT

The scale of prototyping often depends on the resources and the timeframe a designer has available until the deliverables are due. Particularly in fast paced educational settings, limited time and finances undermine the potential learning experience of prototyping. While students in design are more successful in disguising shortfalls in functionality by presenting static high-fidelity appearance models, the interactive nature of an interface proves to be a unique prototyping challenge to accomplish. The amount of effort and skills it takes to design, build, and test custom build electronic components often exceeds the given time frames. As a result, students often scale back the scope of a concept and focus predominantly on already existing hardware solutions (e.g. smartphone devices), while neglecting the potential of concepts that encompass a combination of physical/tangible form and screen based modes of interaction. “While the separation of the user interface from the application logic has a long tradition in software engineering, for products with tangible user interfaces there is no equivalent approach that realizes a true separation and flexible combination of interface components, underlying technology, and software parts” (Döring, et al, 2010).

This study proposes a concept of modular components representing the basic spectrum of interface elements encountered in devices and control panels to assist designers in the prototyping phase of both tangible as well as interactive concepts. This toolkit will enable designers to quickly assemble and test an interface. Elements of this basic set will include universal functions such as buttons and knobs that have been distilled into their neutral and unadorned forms. By providing a blank canvas for exploring interactivity, the modular UI prototyping toolkit will also enable students to design their own components to work with the existing library and thus expand the learning opportunities even further. The resulting designs will elevate the creative output by enabling designers to draw upon unobtrusive functional modules to enable both high visual polish and functionality for their design concepts. Depending on the phase of prototyping, the modules of the UI Toolkit can be individually arranged in a spatial layout on a flat surface, attached to volumetric objects, or discreetly integrated into a three-dimensional design concept.

5. ANALYSIS OF CURRENT GADGET BUILDING KITS

An analysis of already existing solutions on today’s market has yielded a variety of components that can partially cover the proposed UI toolkit, yet neither solution encompasses the envisioned full scope of possible applications nor ease of use (Figure 4). Most products require intensive and time-consuming soldering and wiring. Once assembled, the designer is facing the challenging task of giving the construct functionality through programming on complex code-based software solutions that require a high degree of knowledge. At the end, the results are time-intensive to build, difficult to program or alter, plagued with incompatibilities, and fall short of the aesthetic qualities one would expect from a design concept. While the existing solutions by themselves represent a right step towards prototyping for interaction, the lack of a broader vision is creating complexity that is severely affecting usefulness for creating mock-ups along the cycle of prototyping.

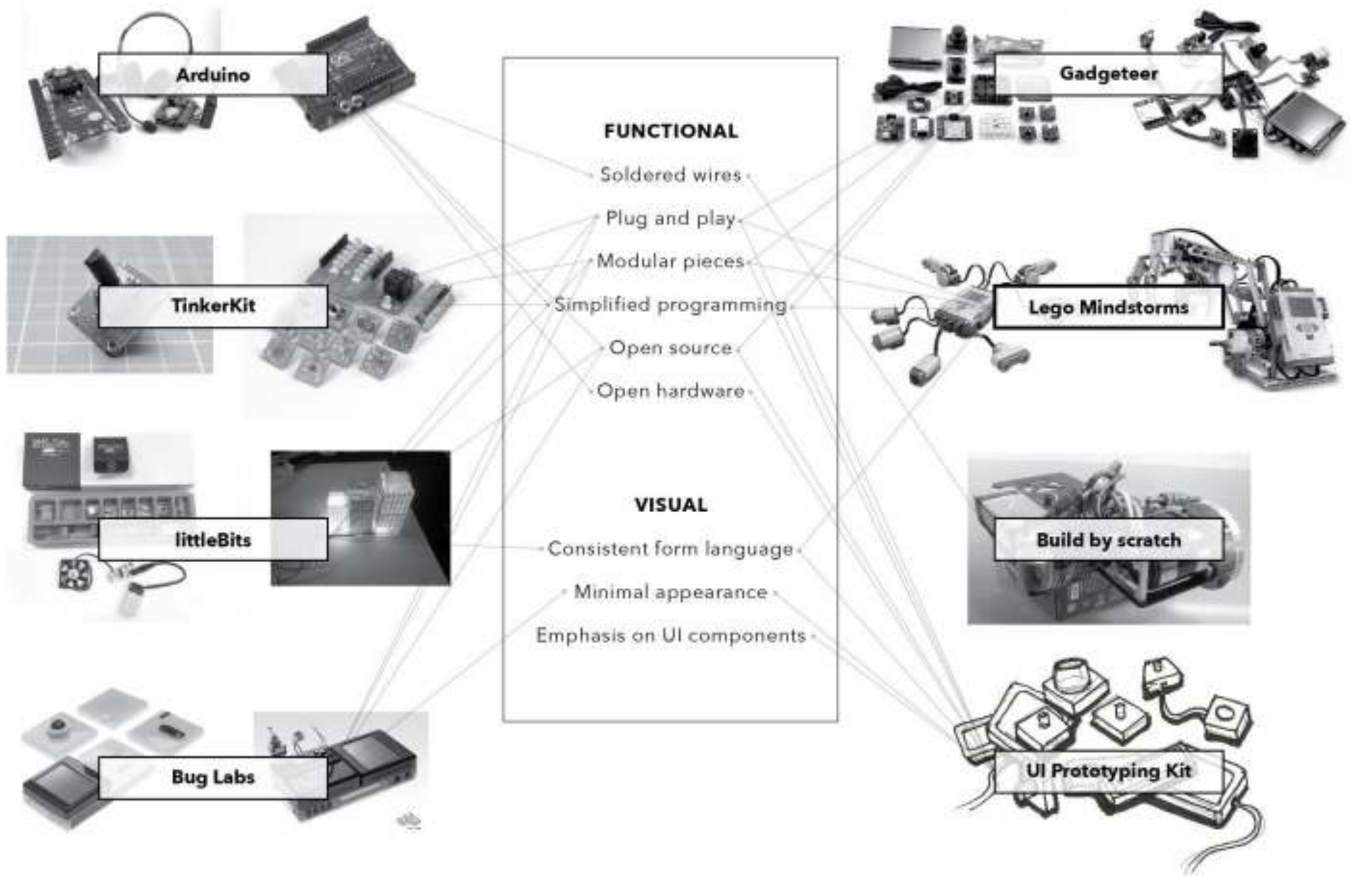

Figure 4. Analysis of current gadget building kits (Tung, Feil 2013)

6. EXPLANATION OF FEATURES

Analog to the simplicity of Lego bricks, the UI Toolkit will provide a vast functional scope to the user: Plug and play connectors will provide ease of use by eliminating the static constraints of soldered wiring, the modularity and variety of components will enable the designer to custom assemble the backbone of the envisioned concept. Programming will be object-based on a graphic user interface to mimic the physical layout and logic of the components in use, and should be easy to comprehend and apply. Inspired by the concept of crowd-sourcing, the proposed concept intends to be both open-source and open-hardware to enable and encourage the development of additional components by an avid community of users.

The identified key-objectives for the proposed UI Toolkit are:

- *Neutral form language:* Simple yet aesthetic; Retain the focus on functionality, but not let raw components become distracting.
- *Modular components:* All modules can connect together and create a clean assembly with minimal effort.
- *Plug and play:* Lower technical knowledge barrier to empower designers and students.
- Wide variety of modules: Starter-kit will allow users to prototype a wide variety of common devices and interactions.
- *Open Hardware:* Enable the community to alter/adapt the technology to better suit their needs.

- *Simplified programming:* Speed up the process for integrating interactivity into the prototype and record test data.
- *Inexpensive:* Accessible for small design studios and schools.
- *"Blank canvas"**:*** An adaptable and free-form system for exploration and experimentation for design.

7. MODULE CATALOGUE / SCOPE OF MODULES

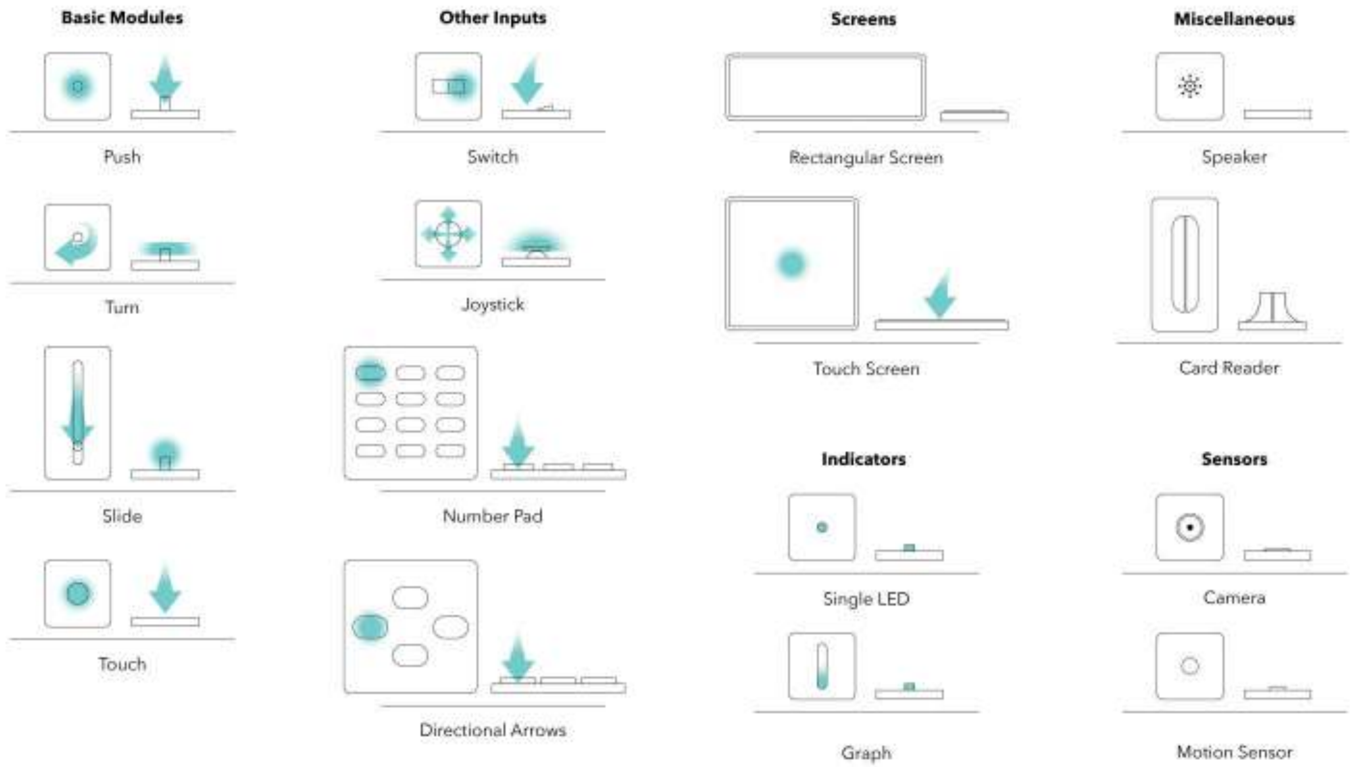

Figure 5. Module Catalogue of UI Toolkit (Tung, Feil 2013)

The modular based nature of the UI Toolkit allows the designer to choose from a catalog of pre-defined artifacts to construct interactive prototypes of the envisioned concepts. Relative to the scope and complexity of the design, the designer can draw upon a variety of input modules ranging from basic interactions (push, turn, slide, touch), to complex multimodal operations (joystick, directional arrow-keys, keypad, touchpad). In addition, the toolkit gives the designer various options to indicate visual feedback (single LED, an array of LEDs to display graphs, TFT-screens, or touch screens), modules for audible feedback, as well as a variety of sensors (card-reader, cameras, etc.). All modules are sized to fit together via connectors within a grid-like array for a close coupling to recreate a realistic narrow spacing between the individual elements. The elements hereby serve as hubs and can be joined together in a simple plug-and-play fashion. If necessary, the designer has a further option of interlinking the individual modules via simple USB cables to bridge longer distances between the components, and to facilitate the integration within a three-dimensional mock-up. The form factor is held deliberately simple to serve as an unobtrusive canvas for the envisioned design, rather than drawing attention the individual parts of the system. The bases of each module feature dedicated holes to afford mounting the elements in different positions and on a variety of surfaces. In addition, the designer is given the possibility to install the modules behind a thinly layered surface to fully emerge and integrate the components for a maximum amount of realism.
Additionally, the UI Toolkit offers the designers to prototype interactivity beyond simulated functionality and integration within a three-dimensional model by providing the option to design control elements such as knobs, buttons, and levers to incorporate tangible forms of interaction.

The standard set of basic control-elements that will be included with the toolkit can be easily removed and exchanged with designs to meet the designer's vision for the final concept by incorporating form, scale, as well as semantic meaning.
These custom elements can either custom build in the model-shop, or 3D printed to match the expectations of the designer. In the spirit of crowd-sourcing, we envision a growing catalog of shapes and designs to emerge over time from a group of avid UI Toolkit users. A forum to publish and exchange either CAD models for the control elements, or pre-printed knobs, would greatly expand the possibilities of the modules, inspire designers, and greatly reduce the workload of prototyping.

8. SOFTWARE / VISUAL PROGRAMMING

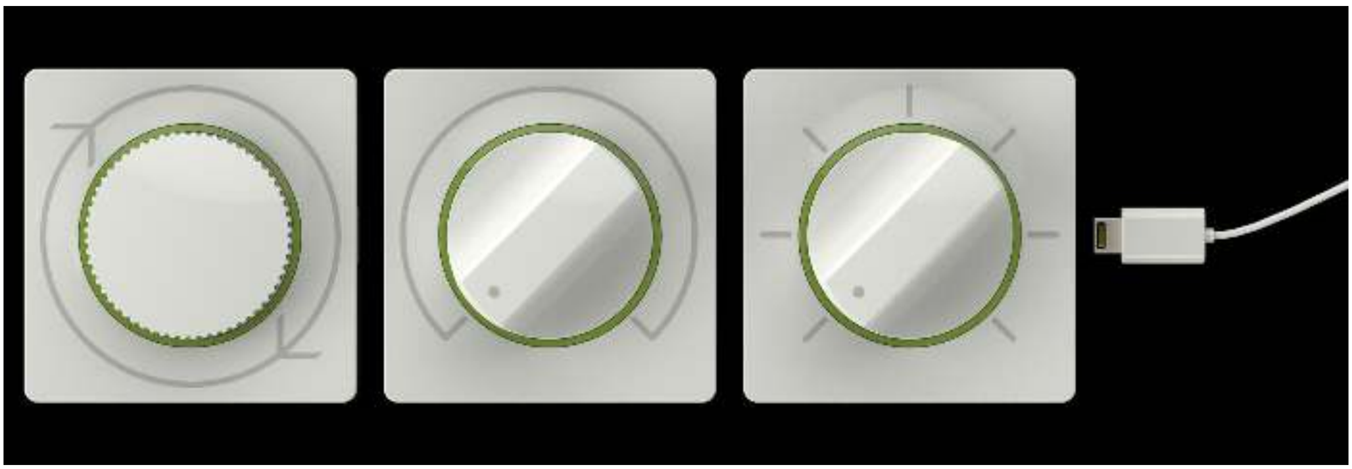

Figure 6. Defining button actions: Spin, End Stops, & Stepped (Tung, Feil 2013)

The software component plays one of the most critical roles of the UI Toolkit concept. Without the software back-end, the individual modules would remain just empty shells. The software gives each of the elements meaning, and virtually ties the components of the system together into an interactive system. Analog to the philosophy of the UI Toolkit, it is uppermost important for the effectiveness of the concept that the programming remains intuitive and easy to understand for a broad range of users, while offering a full range of functionality. Instead of compiling lines of code, the software is envisioned to follow a visual, object based logic similar to programs to the like of Max/MSP Max or Lego Mindstorms. Each of the physical components of the toolkit will have a virtual representation on the computer screen that can be positioned analog to the physical counterpart on virtual work-space. While the modules are connected via USB cables, the virtual modules are tied together with strings; a simple click on the "module" opens up a dialog box that allows the designer to define the parameters for interaction. A module with a knob for turning, could e.g. be specified to be freely spinning (shuttle wheel), rotate within a defined degree with stops on each end, or can be set to be stepped. The designer has the option of swapping out the control element to increase ergonomics and semantic meaning. Once the parameters have been set, the user can print out a scale and attach the graphic to the corresponding physical module component. (Figure 6)
Upon accomplishing the programming and establishing the desired interactivity, it is envisioned that the UI Toolkit will feature a logging system to capture quantitative data during user behavior testing to enable the designer to directly draw conclusions and to quickly implement changes to the concept.

9. CASE STUDY: RE-DESIGN OF AN ALARM CLOCK

This example illustrates a typical use-case scenario of a designing an alarm clock with the help of UI Toolkit components. The designer will follow the previously described cycle of prototyping by starting off with an initial phase of *internal ideation*, resulting in research on form and patterns of interaction. A series of sketches is generated to capture ideas and define the scope of the project. Once a promising path has been identified, the student proceeds with creating *tangible low-fidelity* iterations of the envisioned concept. While explorations in form would follow the traditional path of building simple models (foam/CAD), the UI Toolkit components will serve the

designer as an efficient tool to quickly assemble the functional components of the concept to prototype interactivity. In this phase, the modules (push-buttons, sliding button, and a screen) would be tethered together on a work-surface to recreate a rough layout that would represent the envisioned concept. The programming is accomplished via a connected computer by arranging the virtual representations of the connected modules on the software's work-area to match the physical counterparts and by setting the parameters and rules for the envisioned interaction concept for setting the time, alarm-time, enable/disable alarm, and snooze button. The UI Toolkit software gives the designer an option to print out labels for the individual modules that will match the programmed definition for the individual switches. The completed system enables the user to quickly test and refine the programming until it meets the designer's expectations. Upon completion of this low-fidelity prototype, the UI Toolkit allows the designer not only to evaluate the merits of the proposed system, but also to share and communicate a complex concept that encompasses both tangible and screen based patterns of interaction.
Once the concept is thoroughly tested, the derived conclusions allow the designer to progress towards the final step of the model-building process: the construction of a *high-fidelity iteration* of the envisioned alarm-clock design. In this final phase, great attention is given to accurately build the final physical design model. The flexibility of the UI Toolkit will allow the designer to fully integrate the control elements and the display into the final model iteration to create the illusion of a fully functional and refined product.

10. CONCLUSION

In this paper, we introduced an approach for a didactic User-Interface Toolkit that would present students and designers an efficient way towards prototyping concepts that encompass both physical form and interactive functions. The modular nature of the proposed UI Toolkit would allow designers to implement and evaluate screen-based and tangible interactivity along the cycle of prototyping. The proposed modular toolkit would include all components representing the basic spectrum of interface elements that can be interconnected without deep technical knowledge. An object-based software suite would allow the designer to program the connected modules to simulate and test the envisioned concept. As an empty canvas for interaction, the proposed system will inspire designers to project their concepts beyond the limiting boundaries of a screen.
At the end, the system enables the designer to apply principles of interaction design to physical appearance models and represents an opportunity that would lead to better prepared students for tackling today's complex multi-disciplinary problems.

REFERENCES:

Döring, T., et al (2010). Design by Physical Composition for Complex Tangible User Interfaces: CHI 2010, April 10–15, 2010, Atlanta, Georgia, USA. ACM 978-1-60558-930-5/10/04.

Krippendorff, K. (2006). The Semantic Turn: A New Foundation for Design: Boca Raton: CRC Press, Taylor and Francis Group

Wallschlaeger, C. & Busic-Snyder, C. (1992): Basic Visual Concepts and Principles for Artists, Architects, and Designers: Boston: McGraw-Hill