

# A Tabletop System for supporting Paper Prototyping of Mobile Interfaces

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## ABSTRACT

We present a tabletop-based system that supports rapid paper-based prototyping for mobile applications. Our system combines the possibility of manually sketching interface screens on paper with the ability to define dynamic interface behavior through actions on the tabletop. This not only allows designers to digitize interface sketches for paper prototypes, but also enables the generation of prototype applications able to run on target devices. By making physical and virtual interface sketches interchangeable, our system greatly enhances and speeds up the development of mobile applications early in the interface design process.

**ACM Classification:** H5.2 [Information Interfaces and Presentation]: User Interfaces. – Prototyping, User-Centered- Design.

**General terms:** Design, Human Factors

**Keywords:** Paper prototyping, mobile user interface, tabletop, mobile device, participatory design, evaluation

## INTRODUCTION

The growing use of mobile devices and the advances in their technical capabilities have opened up a large potential market for mobile applications. This development is promoted by now well-established, professional and centralized distribution channels realized through specific application stores. These stores create vivid competition, dominated by short development cycles.

The development of mobile applications, in comparison to development for stationary use, bears a number of specific challenges, principally rooted in their interface design. Mobile devices are designed for a myriad of circumstances and usage contexts and thereby have to adapt to unsteady user attention and changing environmental conditions. The additionally limiting hardware constraints of the devices and an insufficient control over these factors can lead to strong usability losses, which can jeopardize the application's overall success and performance. User evaluations of interface prototypes are an important strategy in reducing this risk. The user assessments should be preferably conducted during the early design phases to evaluate the key implica-

tions of the interface layout in a subsequent implementation.

In the following, we describe the implementation of a specific unobtrusive tabletop system [5] that is developed to simplify and accelerate the design of such early-design-stage paper-based prototypes (PBP). Through minimizing the implementation effort, the system enables designers to collaboratively sketch a number of prototype variants, which can be automatically translated into executable prototypes that are executable and examinable on the respective mobile devices. The approach aims to fulfill the following design principle: Of utmost importance is to provide simplicity and speed to the development process, thereby enabling a creative support environment, which promotes collaborative work. This paper discusses the decisions we made in our design approach, shortly describes the required hard- and software components, and finally details a number of specific interaction factors we realized to support and fulfill these factors.

## DESIGN APPROACH

The implemented system offers assistance for the development of prototypes early in the development process, which stands in accordance to the well-established paper-based prototyping approach, in which the evaluation is conducted by test users who interact with paper-sketch representations of the real interface. Our system enables a design team to collaboratively design interface sketches on prepared paper sheets and to virtually add functionality to those, in the form of user interaction elements, for example defining the interrelation of the screens. As a result, the surface system is able to generate a virtual representation of the interface, which can be used by a player installed on a mobile device, to execute and use a functional interface.

Our design approach is based on the concepts of paper prototyping, findings on mobile prototyping, and tabletop-based interaction systems, which we discuss in the following.

### **Use of a Paper Prototyping Approach**

The PBP approach, described in detail in [12], has become an established prototyping paradigm, in which users are asked to fulfill given realistic interaction tasks with paper sketch representations of the real interface. We chose to follow this technique because it promotes our described interaction goals in several ways.

Sketching onto paper is an inherent method to examine and communicate thoughts of any kind and therefore is perceived to be fast, intuitive and uncomplicated, especially if these thoughts are elaborated in a collaborative way. Furthermore, it imposes relatively few constraints on a design and thereby does not impede creativity flow in the way other tools do, aiding project designers to create layouts that are feasible to implement. Part of the design team should have appropriate experience of interface design as well as knowledge of the constraints of the target user interface toolkit, but the PBP method remains very helpful to integrate valuable designers with a less profound technical background into the team through the commonly explored communication base of paper and pen. We adopted this approach to enable fast results from the design process, since every sketch, with an understanding of its functionality, can be used as a testable interface version. Therefore the approach encourages the team to develop a number of further interface alternatives which are then comparatively tested.

It is in a sketch's nature to eliminate details and to take the focus on certain carefully chosen aspects and thereby to create an abstraction of reality. [11] refers to the "less is more" philosophy of many architects to prefer a simple diagram drawing over realistic models to discuss and examine certain aspects rather than to confuse people with complexity and perfection. Generally, a polished interface increases the users' hesitation to critically communicate their experiences. Especially people with limited technical experience generally assess their own personal weaknesses rather than analyzing the interface design in question and therefore are shy to describe their problems and issues with the software. These people will more likely to discuss their opinions, when they are presented with a simple diagram, or even childish looking paper-based sketch interface representation.

### **Mobile Prototyping**

In principal the setup described could be used to prototype any kind of digital interface. We focused our work on mobile applications prototypes, since they are preferable tested on the devices themselves in mobile conditions, rather than in a laboratory surrounding, whereas stationary use applications can be sufficiently tested with the established paper based prototyping scenarios.

The heterogeneity of mobile applications use contexts is pointed out in the work of [9], which introduces a design space including factors such as Locations and Settings of

use, as well as the Movement and Posture of the users. Further dimensions are described in specific schemes about the Devices and their Usages, the degree of Workloads, Distractions and Activities and Users and Personas.

To take these specific variables into account, [9] and [13] follow a consequent continuation of the paper prototyping approach in carrying it over to a mobile surrounding. They used dummy versions of the devices in question and built reproductions in accordance to the original's size, weight, and buttons, substituting the screen with interchangeable paper interface representations, letting the dummy device react to the user's behavior. However, some problems of such low-fidelity prototypes are obvious. The reproduced device will lack some properties, which might be important to the evaluation, such as the brightness, reflections or shadings on the screen. In addition, a high extent of Wizard-of-Oz supervision is necessary to react according to the users' behavior and monitor their interactions for the later review.

For these reasons our approach uses mixed-fidelity prototypes, which directly display the designer's sketches, but in a virtual way, running on the specific device. This gives the test users the opportunity to integrate the application use in their regular habits. Thereby the experiments do not only clarify the picture of how users interact with the application in specific use contexts, but are moreover able to identify these fields.

### **Tabletop-Supported Prototyping**

Setting up a tabletop environment in combination with paper sheets as the core interaction element in our system differs from approaches followed in [7] or [10] who use computers and other digital devices to directly sketch prototypes. This is motivated on the one hand by the native use of paper and pen to create sketches, on the other hand by a better support of collaborative design. Gathering around a table to work on and discuss ideas of any kind is an accustomed attitude. This is especially true for design tasks since they demand a high level of communication. A detailed examination on how tabletop interface systems are able to support collaborative work and to mediate group dynamics is done by [6]. These thoughts are followed by [2] in a tabletop application that supports users in collaborative brainstorming sessions. A collaborative design-specific examination of a setup which uses an overhead projector is done by [1], implying the use of paper as a combined input and output channel.

Following a tabletop approach additionally creates the possibility to carefully retain the appearance of the system within the development process. A standard (obtrusive) tabletop system behavior risks limiting the creativity flow of the design team through over-exposure of its hardware [3]. Therefore our technical setup is embedded into a usual working desk environment, allowing its appearance and interaction level to be largely controlled by its users.

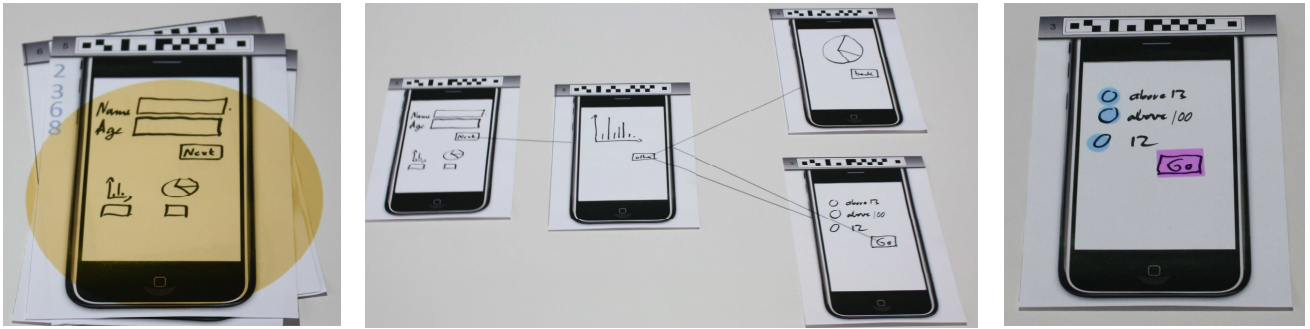


Figure 1: Heap Building Tool(left); Display of Screen Interrelation(middle); Adding Functionality to the physical content(right)

## HARDWARE AND SOFTWARE IMPLEMENTATION

We used an unobtrusive tabletop setup, which is composed of video projector, located in a central position above a regular meeting table and three cameras, two firewire CS-Mount digital cameras and a DSLR, which are used to implement the user's input channel for interaction. A Java application running on a PC controls all cameras. One firewire camera is used for infrared finger tracking [8], another for barcode marker recognition [4]. The DSLR is used to take high resolution images of the tabletop surface. Additionally, a printer is included in the setup, which is used to print out physical representations of the user interface sketches.

## KEY INTERACTION FACTORS

Due to space constraints there is not enough room to describe the whole paper prototyping tabletop system and all aspects of its usage process in detail. To give an overview, we summarize the design process. The tabletop system supports designers in the early stages of the design process, by allowing them to draw sketches on paper and to specify links between widgets, such as buttons, on paper to other paper sketches. The tabletop system automatically captures sketches as they evolve. It identifies screens by scanning a barcode marker that is located on the top of each sheet (Fig. 1). The borders of the device display are pre-printed on the sheet. There is some white-space around this border to allow writing down notes – either for the designers themselves or for communication with developers in later stages of the design process. All additional semantics, such as links between paper sheets, are projected onto the table. The complete interface can thus be laid out onto the tabletop with the virtual semantics projected on top. From the paper sheets captured at high resolution and the additional semantics specified by the designer, the system then creates a virtualized paper prototype, in which each paper sheet is shown on the mobile device display and user actions on the virtualized prototype can be activated immediately by the test users. The paper sketches are thus useful for designers as well as test users. The prototype can be used on actual mobile devices out in the field and it is thus possible to evaluate the prototype in realistic usage contexts.

The following subsections highlight the key interaction factors, which are all focused on achieving the design principle stated in the introduction.

### Focus on physical paper sheets as the interaction center

The center of development consists of ready-made paper sheets in the slightly enlarged shape of the display, on which the paper-sketch representations of the interface can be drawn and edited. Every paper sheet is equipped with a barcode-marker, which allows the system to steadily determine the sheet's current position and rotation on the table. This allows the system to project virtual information onto the paper which is aligned relatively with the paper sheet.

As most prototyping projects will embrace a substantial number of interface screens, design teams will often face limitations of tabletop space. Designers can intuitively handle this problem by arranging spontaneous groups of screens which are then aggregated to heaps. Here the system supplies a navigation aid in monitoring the arrangement of groups and projection their constituent parts, as shown in Figure 1.

### Adding functionality to paper

To be able to actually run and test the interface prototype in a later project phase, the single screens have to be equipped with certain user-controls and other forms of functionality.

Controls which trigger the activation of a different screen are of central interest to the development process. Designers are able to define these relations, such that the system optionally marks the connection as a projected visual representation on the table. The projection is updated in real time as the designer moves the paper sheets containing the interface sketches. This permits all the interaction paths to be shown on the table's surface, keeping the interface's storyboard traceable throughout the design process.

### Merging physical and virtual interface representations

The content of the individual interface screens is displayed using two methods. Virtually, through the projection of virtual contents on paper and physically, as a result of the treatment of the paper by pen. The two media, pen drawing and projection, are integrated and overlaid to facilitate an unobtrusive and liberated design process. The contents can

be merged with each other. A high resolution digital SLR (DSLR) camera photographs the physical interface. This high resolution image is subsequently translated into virtual space. This allows the virtual representation (after potential modifications by the designer) to be retranslated to a physical form by printing it out onto a new sheet of paper. In order to carry out such a virtualization of the interface sketch; the DSLR captures one or more frames. Using the 2D barcode marker as a reference, the image frames are perspective corrected and cropped to contain only the interface elements. After an interface sketches have been virtualized, the system prompts the user to swap the photographed versions with an according blank paper canvas, on which the virtual representations remain as projections.

The created virtual representations can still be physically edited by pen sketches, which can be layered and integrated into the virtual version. If the system receives a capturing command for a frame which already comes with a digital representation, it blends out this digital content for the image capturing instant, so that an addition of the existing and new frame of the interface can be added to the merged version without quality losses. As already stated, the system can convert the virtual interface back to a physical paper format using printouts. The printed interface representations can then be immediately reintegrated into the design process.

#### Easy editing through virtualization

The interface's virtualization is not just oriented towards later export onto mobile devices; it additionally creates a number of advantages for the design team, which lie within the digital editing of the content. In a way similar to the operations available in most computer graphics applications, the system allows virtual content to be marked, copied, moved, and pasted.

Thereby highly annoying editing-procedures of can be avoided, such as the subsequent reallocation of interface elements, or the drawing of structures that occur time and again.

#### FUTURE WORK

Current Mobile Applications increasingly take use of interaction paradigms which reach beyond the use of standard UI- controls such as checkboxes or buttons. The recognition of gestural input via multitouch screens has especially developed to a standard control principle. We plan to apply functionality to the described tabletop system with its infrared finger tracking, allowing the developers to practically define finger gestures on the table surface, which can then be introduced as controls within the running prototype.

#### CONCLUSION

We have described a tabletop-based system that focuses primarily on paper sheets as an input medium for sketching interface prototypes for paper prototyping. The system can digitize the contents of the paper sheets and permits designers to specify dynamic behavior in their paper prototypes. The system therefore helps interface designers in the

process of creating paper prototypes, for instance by making it possible to track changes and recall earlier versions of sketched paper prototypes or to reproduce physical versions of previous instances of sketched paper prototypes. Furthermore, our system enables designers to generate software prototypes for on-device evaluation of interfaces previously sketched as paper prototypes at a very early stage of the interface design cycle. By following a paradigm of unobtrusiveness, our tabletop system is designed such that it does not restrain the creative flow of the designer and consequently the productivity of the interface design process in general.

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