Towards a Sensible Integration of Paper-Based Tangible User Interfaces into Creative Work Processes

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Abstract
We live in a hybrid world where standard computers with graphical user interfaces (GUIs) have become an integral part of our daily life. Additionally, novel user interfaces like tangible user interfaces (TUIs) are among emerging interaction styles that offer new potential as tools for supporting creative tasks and weak-structured workflows. In order to meet the users' needs, the most suitable user interface for a task should be chosen and different kinds of user interfaces have to be integrated appropriately. We addressed these topics and applied a generative framework to structure and analyze a creative work process in the domain of Art History. On this basis, we designed the integration of TUI and GUI elements and constructed as well as tested a tabletop TUI to support creative work.

Keywords
Tangible User Interfaces, Reality-Based Interaction, TUI-GUI Integration, Creativity Support Tools, Generative Theories for HCI.

ACM Classification Keywords
H.5.2 [Information interfaces and presentation]: User Interfaces – input devices and strategies, interaction styles, theory and methods.

Living in a Hybrid World

Computing is reaching into all parts of life. People have learned to use computer-based tools and especially the younger generation naturally enjoys integrating the digital world into its daily life. Standard computer systems with graphical user interfaces are well established in all kinds of situations. They are very powerful, as they can handle a variety of different tasks within application domains (also called "expressive power" [6]). Nevertheless, these omnipresent user interfaces do not always meet the users' needs, as we see when people prefer tools of the "analog", real world instead of existing digital tools. For example, in creative tasks and weak-structured workflows, people are inclined to use large surfaces and tangible materials like paper and physical objects. Thus, we should bring these worlds together and design user interfaces that include real items; allow natural, free, and unstructured ways of interaction and creation; and concentrate on supporting creativity. These kinds of interfaces (e.g. tangible user interfaces) that are based on "pre-existing real world knowledge and skills" [6] are part of the framework of reality-based interaction (RBI) [6]. Jacob et al. argue that one should start from the real world and "give up reality only explicitly and only in return for other desired qualities" [6]. In order to combine reality-based interaction and the expressive power of the digital, we have to focus on two central questions: (1) on which basis can we identify the most appropriate kind of user interface for a specific task? And: (2) how can we design a seamless and sensible integration of different kinds of user interfaces?
In this paper, we present an approach for a sensible integration of paper-based tangible user interfaces into creative work processes. We applied a part of Shneiderman's generative framework for creativity support tools [11] in order to structure and analyze subtasks in creative work processes and to find out what kind of interaction meets their requirements best. As a first application context, we chose the domain of Art History research. We conducted a user study of creative work processes within Art History research. Based on the results, we designed a creative work process that integrates reality-based interaction and WIMP interaction ("window, icon, menu, pointing device"). Finally, we developed and tested a novel tabletop user interface with which paper cards were used as tangible input. Our work focuses on a sensitive integration of reality-based interaction and the expressive power of the digital.

Related Work

Tangible user interfaces [6] link physical objects to the digital world and thus provide real handles for virtual data, abstract concepts, or functions. As part of the real world, tangible user interfaces have many advantages. They offer real haptic feedback, are integrated into the environment and provide multiple input devices. Their physical affordances can be used explicitly for interaction. Among the central advantages is the usage of space, e.g. through integrating tabletop surfaces or walls [10]. Nevertheless, TUIs do not suit all situations. The "expressive power" [6] of traditional digital systems is very rich and cannot be easily realized within reality-based interaction. This leads to approaches that combine different tools integrating TUIs and GUIs. Since GUI-based systems are

omnipresent and dominate our work, it is even more important to think about a sensible and seamless integration of TUIs into GUI-based workflows. Hurtienne et al. have discussed the importance of this integration and have introduced an approach using image schemas as a meta-language for analysis and design of tangible interaction [4]. They analyzed advantages of physical and digital user interfaces in order to have a basis for deciding which tasks are best supported by which kind of interface. They applied their models in a user-centered design process, and one of their outcomes was that hybrid solutions are good for users to familiarize themselves with novel TUI-based approaches. Of course, the integration of the physical and the digital parts is an important topic. Ishii regarded the "seamless extension of the physical affordances of the objects into the digital domain" [5] as the major design challenge with TUIs.

In the domain of paper-based TUIs, some prototypes have been developed that integrate GUIs and TUIs. For example, "Palette" [9] employs paper cards with barcodes as physical handles for electronic slide shows and offers an interface to link digital data to the paper cards. Another paper-based prototype is "The designers' outpost" [8], a system for collaborative website design. It supports creative group work on a large surface using post-it notes. In "iCandy" [3], a paper-based interface for iTunes, paper cards represent digital data, i.e. music files.

Applying a Generative Framework to Support Creativity in Art History

In order to support creative work processes with tools, it is helpful to examine their different tasks. Shneiderman introduced a generative framework to support creativity [11]. He identified four stages of activities in creative processes that should be considered separately when designing tools: collect, relate, create, and donate. These general stages of creative work can be found in creative work processes in virtually all domains and can serve as a basis for a structured analysis of an application domain.

We conducted a case study of some Art History research work (see also [2]) and observed and analyzed activities in these four stages. Our aim was to identify the best tools for supporting each task by combining reality-based interaction and digital systems. In the case study, we examined a research project on 220 historical pictures of soldiers that had to be classified according to different motifs. The participating art historians applied the method of iconography, which traditionally uses image cards, card boxes and picture collages on large canvases. Table 1 lists exemplary activities of the four stages as observed in the study. We found that the art historians used traditional GUI-tools within the collect stage (information gathering) and the donate stage (presentation of the results). At the central creative stages (the relate and the collect stages), in which the collected material is analyzed and structured according to their identified central motifs, existing digital tools with graphical user interfaces did not meet the users needs. Instead, the art historians printed all pictures, created image cards, stored them in card boxes, and worked with them on large surfaces. In order to compensate this media disruption, we designed a tangible tabletop user interface prototype and integrated it into the GUI-based workflow.

	Activities
Collect	- Data collection and material browsing in libraries and online - Digitization and storage of collected material
Relate	- Structuring of image material - Discussion with friends and colleagues
Create	- Extraction of groups of motifs through analysis of the images - Usage of additional text sources - Creation of essay and image collages
Donate	- Publication of work - Preparation of slides for a talk

Table 1: Extraction of the activities for each core stage of a creative process, applying the framework from [11]. Analysis of these activities provides a basis to determine which user interfaces are appropriate at each stage.

Integration of the Tangible User Interface into a GUI-based Workflow

Central design considerations for the tabletop TUI were (1) to start from reality-based interaction and at the same time offer the "expressive power" of digital systems, (2) to design a sensitive and seamless integration of the TUI and GUI parts, and (3) to let the user use the system "through the interface" [1] (i.e. to leave the system completely in the background and reduce the mental effort of its user).

Figure 2 gives a schematic overview of the integration of different user interfaces into the creative work process. In the collect stage, the gathering of information and data sources is supported. Since information can be found either in digital resources (e.g., world wide web and databases) or in paper-based material (books and magazines in libraries), both ways of media collection have to be supported and are composed as one set of digital work material. For the relate and create stages, the collected images and metadata are printed onto image cards via a converter program. The resulting paper cards have visual markers on their backs and thus contain links to their digital sources. They can be used as real handles to the collected digital data on the semi-transparent surface of the tabletop system through the relate and create stages. During these stages, the TUI supports group interactions, spatial work, and tactile browsing in big picture collections. The cards can be clustered into motif groups, and this underlying structure can be stored digitally. Finally, during the donate stage, resulting collages can easily be exported and published online, or used for publications and presentations.

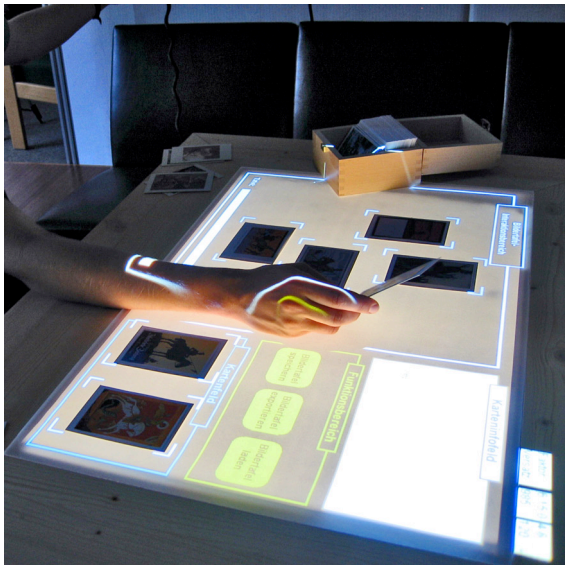

Figure 1: The tabletop tangible user interface with paper cards as physical handles to digital image cards and metadata. The interactive surface is divided into different interaction regions.

We constructed a working prototype (see figure 1) that supports the relate and create stages, as well as export functions for the donate stage. The tabletop TUI was implemented using the reacTiVision framework for marker tracking [7]. It provided visual feedback on the tabletop surface via top projection. The tabletop surface (ca. 40 x 30 inch) was divided into different interaction regions with functions that could be activated either via placing paper cards (ca. 4 x 2.8 inch) on these regions or using traditional interfaces like mouse or keyboard (touch interaction will be added in a future version).

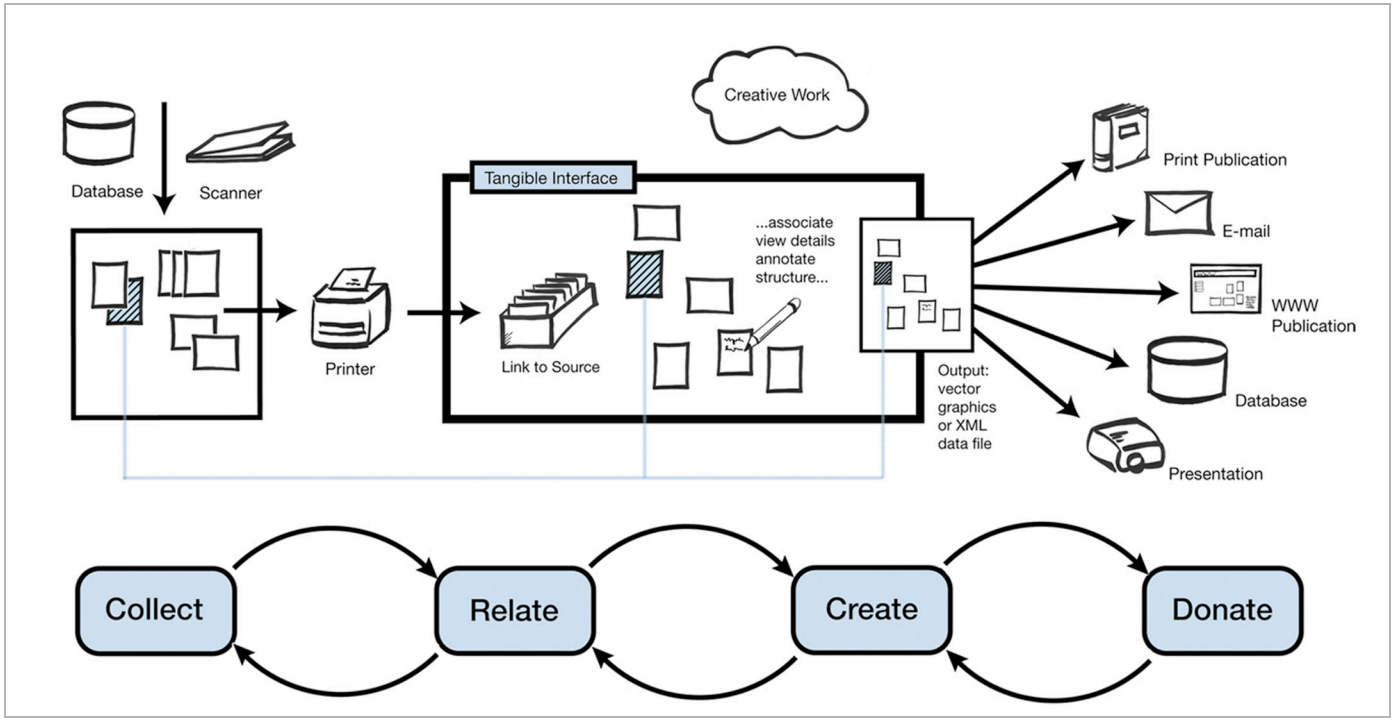

Figure 2: Integration of the TUI into the creative work process.

Observations

In a first expert evaluation with an art historian, we addressed the quality of the interaction and the benefit of the implemented functions. The expert user obtained a card box with a set of image cards to work with the table. After a short period of free usage of the tabletop prototype, she had to solve a number of interaction tasks, e.g. "zoom into picture x" or "construct a collage out of a specific set of cards and publish the poster as webpage". We applied the think-aloud technique and observed her during the tasks. Afterwards we discussed the interaction elements and functions. Overall, the expert liked working with the real paper cards that were linked to their digital sources. She was able to handle all tasks without a problem and remarked that the TUI suited her needs very well during the free work with image cards. Our results indicated that TUIs fit the relate and create stages better than GUIs due to the direct interaction with paper cards on a large surface and the disappearing computer that supports the user in the background. GUIs match the collect and donate stages best, as they offer the comprehensive amount of materials and tools, which are needed to accomplish the related tasks.

Conclusions and Future Work

Our paper-based tangible user interface has been designed to support creative research work in Art History and focuses on combining reality-based interaction and the expressive power of the digital. By connecting real paper cards to digital image data, our TUI provides a seamless connection between the digital and the physical world and allows users to choose between a GUI and a TUI for a given task. Feedback from the first tests with this TUI was encouraging. In future work, we aim to make a real deployment in an Art History research environment. Furthermore, we would like to apply the collect–relate–create–donate framework to other domains of creative work and learning environments, in order to work towards design methods for interaction techniques that combine reality-based interactions and the power of digital systems where appropriate.

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