# Metaphors and Technologies for new Tangible User Interfaces

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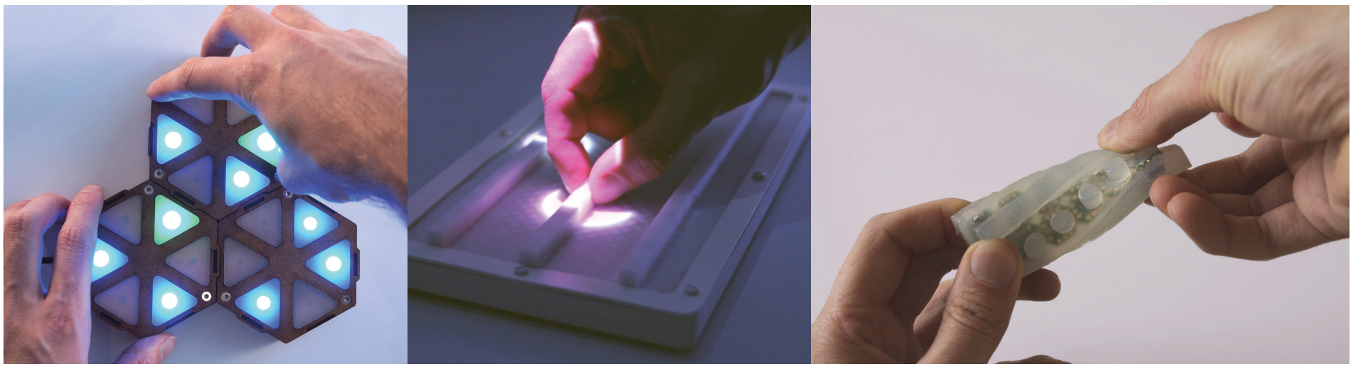

**Figure 1: New technologies and interaction metaphors open up new concepts for interaction. COMB (left) explores the construction of meaningful shapes in the user interface context. StringTouch (middle) explores the metaphor of the string instrument and transfers it to a generic user interface. Therefore, new technologies are developed that motivate new ideas and metaphors.**

## ABSTRACT

Tangible user interfaces create the possibility to provide users with an exploratory, expressive and flexible access to musical interaction. However, new technologies and metaphors can additionally open up further opportunities and mental models for the design of new interaction concepts. In the scope of my thesis I explore new metaphors by designing and building new interfaces which finally explore these ideas and concepts. In addition to the conceptual work, the development of new technologies, which are necessary for the implementation of these concepts, is a central part of the work. In this paper I present the prototypes COMB and StringTouch and discuss potential application areas for the implementation of core ideas regarding both concepts.


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## CCS CONCEPTS

• **Human-centered computing** → **User interface design**; *Interaction design theory, concepts and paradigms.*

## KEYWORDS

TUI; Metaphors; Technologies.

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## 1 INTRODUCTION

With the upcoming ubiquity of computers as postulated by Mark Weiser [24] and the ongoing wave of embedded technologies we as researchers and interaction/interface-designers have to face new challenges. New contexts of use as well as new user groups will create the need for new interface technologies that are adapted to these factors or paradigms for user interaction that motivate new type of interfaces by implication.

Within the scope of my Ph.D. thesis I focus on both the exploration of paradigms and metaphors as well as the development of technologies enabling new conceptual interfaces. Based on my personal interest and my theoretical training as a musician, most of my work focuses on interfaces for the musical interaction or is inspired by interaction principles found in the musical domain. Never the less, these concepts are still transferable to other contexts or domains but music provides many characteristics that are interesting to explore and incorporate in prototype designs, such as: real time usage, collaboration, and performance.

In this research proposal I present the work done so far in the context of my Ph.D. as well as give an outline of the remaining work to come. The current core of my thesis is represented by the two projects COMB [19][1] and StringTouch [21][2] which are discussed in this paper. Further, I present ideas and concepts to expand on these prototypes and to transfer aspects of these to other tangible user interfaces or interaction surfaces. The underlying related work is presented in the context of the specific projects to give additional information dependent on the context.

## 2 RESEARCH QUESTION

**RQ1**: What real world metaphors can provide concepts which are beneficial for tangible user interfaces?

**RQ2**: How can we provide expressive and flexible interaction concepts to the user? What technologies need to be developed to implement such ideas?

## 3 THESIS OUTLINE

In the following section I present the projects which I already finished during my Ph.D. (see sections 3 and 3) and further show how to expand on this basis (see section 3 and 3) to answer the presented research questions.

### Meaningful Shapes

As the starting point for my current research I incorporated new interaction concepts in musical grid controllers. While the incorporation of interactive technologies especially in small, the musician surrounding interfaces [8] has already begun, initial research has shown that almost all concepts in this domain implement shape-wise static devices. Even when rather modular concepts are implemented, the individual modules, of which the interfaces consist of, are static in function, meaning that independent from context they always represent the same functionalities. As an example, the *Reactable* [10] offers the user multiple fundamental musical functions (oscillators, modulators, effects, ...) which then are combined to generate complex music. The blocks/modules which represent these functions can be spatially ordered, altered and reorganized to change/influence the music. Still, the overall music is first and foremost dependent on the individual functions of the employed blocks. This approach is not new in the HCI context and represents the way most physical computing interfaces are designed for children. Modules which represent instructions or control structures can be organized to program robots [25] or complex electronic circuits are split into minimum functional electronic building blocks which already children can rearrange, construct and play with [2].

While this approach perfectly represents and matches the procedural thinking of programmers, one can find a much older "module-based" interface which instead relies on a different approach. **Building blocks**, in their most simplest form, are uniform elements indistinguishable from each other. Further, they contain no specific meaning but rather create meaning by the means of construction. The same building blocks can form a house, a ship, a car, ... in the end, just the constructed shape determines the meaning/function. While new for module-based interfaces, similar ideas have been discussed in the context of Organic User Interfaces (OUI) [7]. Here, the shape of an interface, the perceivable meaning for the user, the manipulation of the shape and the resulting change of meaning are fundamentally interwoven in the concept of the OUI idea.

From this perspective the concept arose to create an interface functionality-wise dependent on its shape, giving the user the ability to simply change the interfaces meaning by reconstruct its physical shape. As the result we created COMB [19] a module based tangible musical interface. The hexagonal blocks offer access to musical patterns, called sequences, via their six back-lit silicone-pads. Such interfaces, called grid controllers, go back to the *Tenori-On* [15] and are nowadays relatively common in music production. Depending on the shape the modules are connected in, different musical instruments can be accessed. Since we built the interface around a playful and familiar interaction which is already known from childhood on, we focused on effects that could be potentially beneficial for children or other groups unfamiliar with electronic music production and create accessibility based on lowering the access threshold to such technologies. During an exhibition in the context of the Ars Electronica Festival 2017 in Linz we presented the prototype of COMB to a large variety of festival visitors. Through the observation of the visitors and the conducted interviews, we found the following aspects which initially confirm our design choices and concepts. After a short introduction the interaction concept was applicable for all participants. While it showed that some participants had a wrong mental model in the beginning (loosing the sequence data after restructuring the interface), all of them were able to identify and revise this conceptual misunderstanding. In addition, it was found that children were not dependent on the introduction but rather learned through observation, imitation and experimentation. We found that the exploration and especially

[1] COMB: https://vimeo.com/231299236
[2] StringTouch: https://vimeo.com/309265370

the experimental interaction was a driving factor for all participating age groups. Almost all participants experimented with (code-wise) unimplemented shapes which were unmentioned during the introduction. Nevertheless, they have tried out these shapes in order to check whether further functionalities are hidden there. Since the interface was simply ignoring such invalid structures the users could proceed their interaction without crashing the system which generated an experimentation-friendly situation.

### Culturally Widespread Metaphors

After COMB, we focused on the implementation of other widespread metaphors in the user interface context. Research revealed that one of the culturally most common interfaces, namely string instruments, remain mainly unconsidered in HCI research. Musical instruments in general are hardly used as an inspiration for new interface concepts outside the musical domain. There are just a few examples such as *PianoText* by Feit and Oulasvirta [4]. Here, the interface of the piano is used for ordinary text-input. But the common principle of chords, arpeggios and melodies enhance the typical workflow of typing. In the context of string instruments, HCI has so far mainly regarded the string/chord as a useful metaphor for new user interfaces [22]. But string instruments themselves are more than the strings they consist of. More importantly, the musical instrument provides a spatial context for the interaction affording different types of motion patterns and sequences to operate it. The physical quality of the instrument and its dependency on basic principles such as the conservation of energy create a system which functions are based on physical laws and is therefore understandable and predictable based on the users most basic knowledge about the world.

Based on this idea we built StringTouch [21] a tangible user interface using the metaphor of the string as conceptual framework for the design and input space of new tangible user interfaces. We analyzed the possible input gesture space to identify patterns that could potentially be reused to build meaningful interaction metaphors and even whole interaction vocabularies. While we collected interaction techniques from multiple string instruments and clustered them based on their usage, we are just at the beginning of exploring and understanding the whole potential of the metaphor. The current focus lies on the idea of relative interaction regarding the spatial aspects of interaction gestures. Whereas in most interfaces an absolute position marks the area for interaction, in StringTouch the current hand position defines the frame for the upcoming gestures or interactions. Such as playing the guitar is based on the interval structure between the individual strings, which form a musical relationship reflected in the shape of the chords and scales along the instrument's neck, relative movement patterns on StringTouch are independent from the absolute spatial position where the interaction is performed.

In order to enable such interaction and to implement prototypes that make such concepts experience-able, we have developed a sensor technology based on magnets, hall-effect sensors, and capacitive touch sensors which in combination can detect the contact as well as the inward and outward deformation of the silicone interaction surface. This technology allows us on the one hand to prevent the Midas Touch problem [9], typically known from touch screens, and on the other hand to explore the possibilities of continuous touch input in the three dimensional space in form of push and pull interaction typically known from large room-sized interfaces such as the *FlexiWall* [14, 16]. This is possible by providing the user a physical interface element namely a ridge he/she can literally grasp and measuring the deformation and such the spatial manipulation of the in the silicone included magnets in relation to the hall-effect sensors. While the current version of the interface and sensor technology is very precise in measuring the deformation along the z-axis (perpendicular to the interaction surface), other interactions such as bending the ridge (parallel to the interaction surface) are not detectable by the sensor. Therefore, we are currently working on new revised sensor designs to improve the tracking of the performed interactions and enable the detection of more detailed interaction features. Other design opportunities which we currently explore tackle the challenge of providing feedback directly on the interface surface. This includes: vibro-tactile feedback, and shape deformation based on pneumatics or the stimulation of ferro-magnetic fluids included in the interaction surface. Beyond the technical improvement we are currently working on the implementation of the StringTouch interface in different application scenarios. We plan to implement prototypes in the context of discreet interaction [11], collaborative interfaces [13] or in contexts where visual attention is limited [3]. Possible areas of application could therefore be: back-of-device interaction [1], interaction with smart speakers, interfaces in the automotive context.

### Expanding the Grid

Motivated by the insight that many musicians today prefer expressive, exploratory, and flexible ways of making music [20] as well as the current trend of grid controllers [15] entering the consumer market, we investigate the design space of such grid controllers and propose multiple ways of expanding the grid for new user interaction concepts. We define a grid controller as a button matrix with back-lit buttons which are decoupled from the button circuitry itself and can therefore be controlled independently [5]. This results in a low resolution display [6, 17] which is interactive and adaptable to the application context. In contrast to, for example, touch screens, grids additionally offer tactility and passive haptic feedback based on the physical and mechanical characteristics of the buttons.

On the one hand we are working on the incorporation of the StringTouch technology into musical grid controllers which enables new interactions such as pulling grid buttons. This could, for example, be used for accessing secondary modes (c.f. right click) or delete contained values. On the other hand we currently transfer common interaction principles, which are already known from the touch screen context, to grid controllers. This encounters the problem of limited real-estate on such low resolution displays. In the context of touch screens users are already used to the concept that content or UI elements can be placed outside of the visible screen area (notification bars, menu bars, ...) and that these can then be accessed via the help of familiar methods such as dragging the notification bar from the outside into the screen [12]. On the grid, many buttons are used for static content such as menu functions, shortcut or shift buttons. Our idea is to give the users access to static content or to provide access to different functionalities just on demand by providing touch gestures in addition to the typical interaction with the grid's buttons. Possible implementations could be swipe gestures to switch in between modes or to drag down menu items such as mentioned previously. Further interaction possibilities are: mid-air gestures based on sensor technologies such as the Soli sensor [23], static hand postures scanned on the device surface (open/closed hand), and interaction with the device itself [18].

Currently, we are working on a comprehensive overview of the history of the grid controller in anticipation of its 15th anniversary next year. In addition, we investigate in detail the design space, which opens up design opportunities, such as the touch-inspired interaction principles or the integration of mid-air gestures.

### Extrapolating to new Domains

Beside the implementation of the developed technologies in the context of tangible user interfaces and interaction surfaces we are keen to explore the possibilities arising especially from the StringTouch sensor technology in other research areas such as the robotics. We see a huge potential that our technology could provide a universal high resolution surface to track touch and deformation which could provide robotic systems access to real world information in self executed interactions or in interactions performed to instruct the robot. Sensitive – technologically enhanced – skins could lead to more human-like types of interactions in the HRI context. We see especially benefits in the possibility of our interaction surface to not only sense perpendicular pressure towards the surface but also shear stress which means the impact of forces in parallel to the skin. As humans we use this information to understand a variety of subtle interactions. Especially in the context of inter-human interaction a lot of gestures such as stroking are based on this types of sensations.

## 4 TIMELINE

The following list gives a short overview over the already finished projects (**bold**) as well as the upcoming agenda (*italic*). For the rest of my Ph.D. (including write up time) I calculate one and a half up to two years. In the remaining time I want to finish a deeper examination of the already presented technologies and concepts but also want to continue to explore new ideas and concepts in the context of tangible user interfaces and musical controllers/instruments.

- **COMB** [19]: Exploring shape as a new input method for tangible interaction.
- **StringTouch** [21]: Transferring the metaphor of string instruments to generic user interfaces.
- **Modular Synths** [20]: Understanding needs of modern electronic musicians.
- *Definition of the grid controller design space and conceptual studies for new interaction possibilities.*
- *Refinement of the StringTouch technology (input and feedback).*
- *Implementation of StringTouch technology in discreet use cases such as back of device interaction.*
- *Exploration of COMB in co-laborative user scenarios.*

## 5 CONCLUSION

At the moment I am halfway through my Ph.D. and the concrete outline of my thesis is beginning to reveal itself. While I have new ideas, concepts and prototypes that I want to realize and implement during the reaming time, I see the advantage of participating in the graduate student consortium in the fact that I have the opportunity to discus my work, and the overall narrative of the thesis with experts and other doctoral students from the tangible and embodied interaction community. Especially with regard to the context of the conference, in which I see a large thematic overlap between my work and the work of other researchers versus other more general HCI conferences. The TEI community and the topics, ideas, and concepts presented there are in general a great inspiration for my own work. Hence, I am looking forward to share my work with researcher from the community and discuss with colleagues at TEI 2020.

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