TUISTER: a Tangible UI for Hierarchical Structures [*]

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ABSTRACT

Tangible user interfaces provide access to virtual information through intuitive physical manipulation. However, feedback is mostly provided by displays in the environment instead of the TUI itself. In this paper we describe the design of Tuister, a tangible user interface with multiple embedded displays and sensors. We explain how Tuister can be used to browse and access hierarchical structures and briefly describe the current state of a prototype we're building.

1. INTRODUCTION

Ubiquitous computing environments pose new challenges to human-computer interaction. The increasing amount of technology embedded in the environment necessitates new interaction metaphors going beyond traditional GUI paradigms. Graspable or tangible user interfaces (TUI) are physical objects, equipped with or tracked by sensing and computing resources. They serve as dedicated physical interface widgets, allowing direct physical manipulation and spatial arrangements. It is most likely that in the next decade TUI will play an important role when interacting with computational processes in the environment. Several multi Purpose TUI designs have been proposed, such as the classical Bricks [2] or the Toolstone [8]. Often these designs focus on haptic input capabilities. Visual feedback is mostly conveyed by other devices in the environment, such as regular screens or projection surfaces. Other approaches use sensor equipped PDAs to construct a TUI providing visual feedback on the device itself [5]. The improvements made towards inexpensive and reliable organic displays will allow for direct visual feedback on a broader range of TUI in the near future. This will lead to TUI which can be used differently in different situations. They will also belong to and remain with the user instead of the environment and will reconfigure themselves according to their situational context [7].

This paper proposes the design of such a TUI named Tuister. We will first describe its basic design (section 2) and the basic modes of operation and then show how these can be mapped to the action of browsing a hierarchical structure (section 3). Finally the current state of a prototype is presented in section 4. Although we think that Tuister is especially good at browsing hierarchical structures, we will propose further applications at the end of the paper in section 5.

2. DESIGN OF THE TUISTER

Originally we were inspired by [1] to design a TUI in the form of a cube with multiple square displays. A discussion with cognitive psychologists made us aware of the fact that a cube could provide too many interdependent degrees of freedom, making it difficult to locate and remember a certain display position. Although from any given position there are only 6 possible operations with a cube (turning clockwise and counterclockwise or tilting north, south, east or west), experiments with dice have shown that people tend to quickly loose overview over the history of movements, i.e. where they came from, and which side moved where in a complex series of motions. This prompted us to choose a design with only one main axis providing just one degree of freedom.

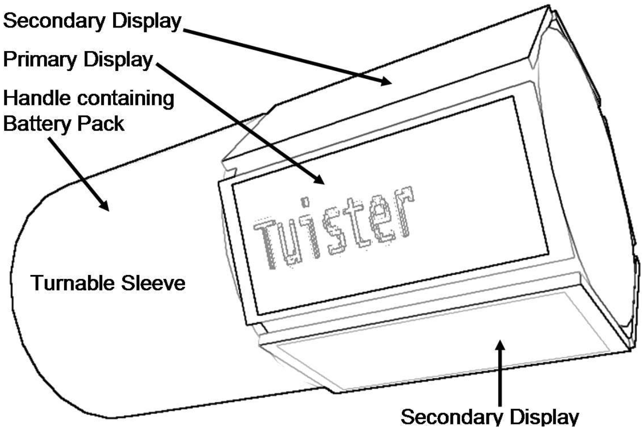

Figure 1: The basic design of Tuister

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As shown in figure 1 the Tuister is a cylindrical device of a size, such that it can be comfortably held in both hands. It consists of two parts, the *display part* and the *handle*. The display part is surrounded by discrete displays or enveloped by a continuous display. It can be twisted against the handle to an unlimited number of turns. The display part has sensors to determine its current absolute orientation in space. Technically, these can be gravitation/acceleration and magnetic sensors, but also a magnetic tracker, ultrasonic tracker, or gyroscope would do. The handle is just a plain cylinder and has no further marks or displays.

The display part can also determine its relative rotation against the handle. Together with the absolute orientation, this allows to track, which part was turned in space, and which was held stable. The picture in figure 1 as well as some of the description in the following section assume a right handed user. The main operation of Tuister is to twist the display part and the handle against each other and to rotate the whole device.

The display part has one primary display, which is the one facing the user in a comfortable reading position. In the case of a continuous display, there will still be a primary display region. If the Tuister is held at a comfortable reading distance, it will mostly be looked at from above at an angle of about 45 degrees from horizontal. By analyzing the input from the orientation sensors, the primary display can be determined, assuming that a right handed user will hold the display part in her dominant right hand.

The two displays above and below the primary display provide a visual context, since they are still partially readable. The effect of this is comparable to the perspective wall, firstly described in [6]. The form factor of a display head with six discrete displays (six-sided polyhedron with caps at both ends) has already been shown to be useful in [10]. There, a 3D-widget is described which can be used for interaction with text blocks related to anatomical 3D-models presented in the same scene.

Left handed users might prefer to hold the display part in their left hand, and operating the handle with their non-dominant right hand. This can be achieved by electronically switching the display direction by 180 degrees and by physically turning the device around accordingly. When text is displayed, the display direction also ensures that the whole device is held in the right direction, since otherwise all text would appear upside down. The direction is important for determining the primary display.

3. BROWSING A HIERARCHICAL MENU

One application we had in mind when designing the Tuister, is the browsing of hierarchical structures, such as nested menus. For the following description, we assume a right handed user. It is also helpful here, to think of the representation of the nested menu as a horizontal cone tree [9], with its root on the left and its leaves on the right side. The following interaction scheme is somewhat related to the manipulation of a cone tree. Another example of a 3D widget with a similar working principle can be found at [3] and is shown in figure 3.

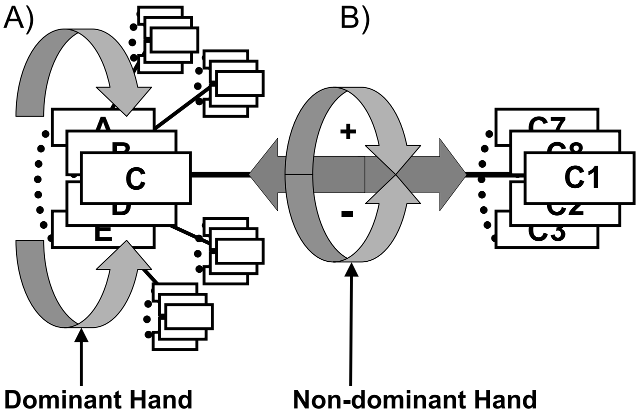

Figure 2: Browsing a hierarchical menu with two hands

The Tuister is held in both hands and the primary display initially displays the first entry of the first level of the nested menu. By holding the handle fixed in the left hand and turning the display part with the right hand, the user scrolls the first level of the menu (figure 2A). The direct metaphor for this is a selection dial. When the desired menu entry appears on the primary display, the display part is held fixed in the right hand, and the handle is turned clockwise. This selects the entry and moves to the corresponding submenu. Turning the handle counterclockwise will move the user one step up in the menu hierarchy (figure 2B). The metaphor for this motion is turning a screw.

The interaction thus uses two metaphors related to the act of turning something. Turning the display part corresponds to turning a knob that chooses between things, such as the tuning knob on an analog radio receiver or the program dial on an old washing machine. Turning the handle part uses the metaphor of a screw which is fastened clockwise and unfastened counterclockwise. Digging deeper into the hierarchy thus corresponds to fastening the handle, while going back up in the hierarchy corresponds to unfastening. We expect these metaphors to be intuitive and and understandable to a general audience after short explanation, although the second might not be obvious entirely without explanation. It will be interesting to study learning times for novice users, given no explanation at all, just a functional explanation, or the analogy of fastening a screw.

One side effect of the physical construction of the Tuister is that one part can be set in rotation and then let run freely. For the display part, this means that a menu level with very many entries, such as an alphabetical list of names, can be comfortably scrolled. For the handle, this means that we can unwind very quickly from very deep levels of the menu.

Another property we hope to verify in user studies is the fact that specific menu selections can be remembered as their corresponding sequence of turns and can eventually migrate from the cognitive memory to the much faster motor memory, just as the complex operations for solving Rubik's cube have entered the motor memory of some of us eventually.

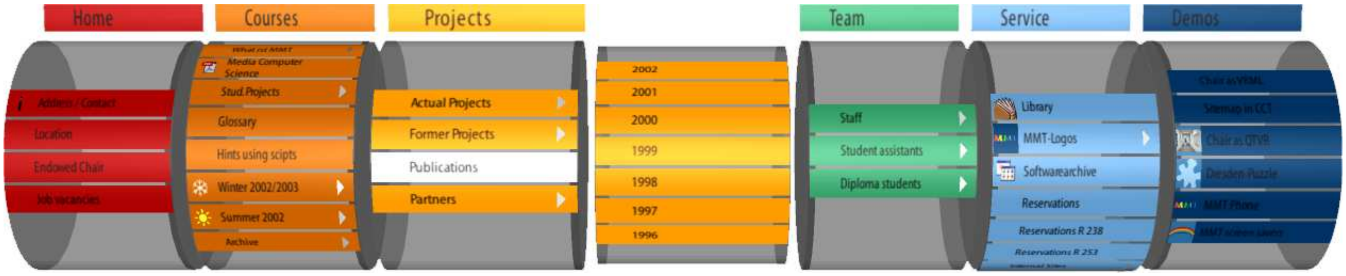

Figure 3: Browsing a hierarchical 3D menu with the mouse

4. PROTOTYPE

In this section we will describe the physical components of Tuister at the time of writing. Some of the electrical and physical design issues are still open, but most of them have already been solved and only need further refinement.

The current prototype will have a length of about $12cm$ and a diameter of about $6cm$, defined by the size of the displays in use. The display part consists of six organic displays with low power consumption and high brightness (see also figure 5). Each of those displays has a resolution of 64 by 16 pixels and is capable of displaying a short line of text, a few symbols or a small graphics. The handle part is firmly mounted to the display part and contains a battery pack with four AAA standard batteries. It is covered by a turnable sleeve that allows the battery pack and the attached displays to be rotated freely and without limitation with one hand, while the sleeve itself is held by the other hand (and of course vice-versa).

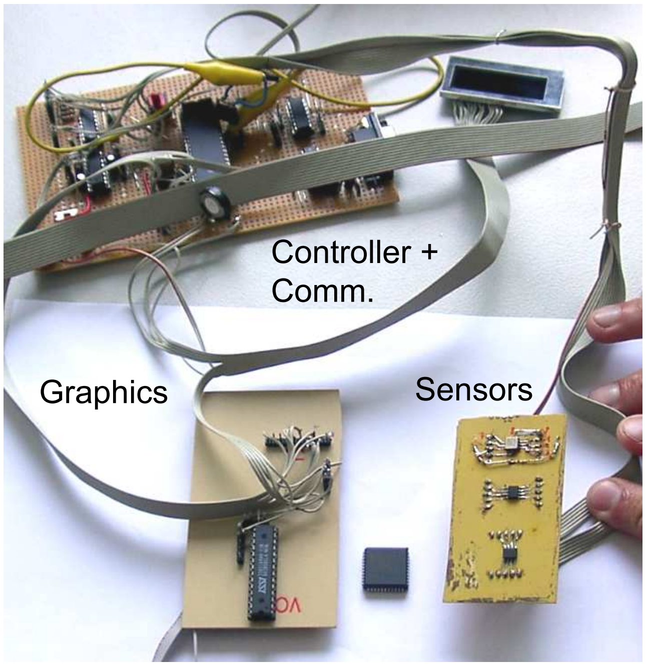

Figure 4: The hardware components of Tuister

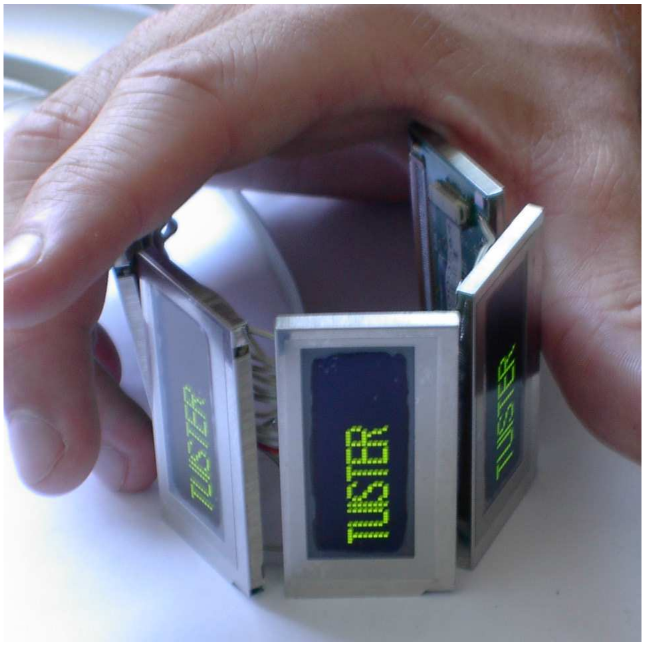

Figure 5: The display part consists of six organic displays in a hexagonal arrangement

Several sensors help to detect the absolute motions of the Tuister. 3D-acceleration and 3D-magnetic sensors will be embedded in the display part. At the moment these are working outside of the display part on an experimental circuit board (see figure 4), but embedding them should be straight forward. Both sensor types track the absolute orientation in space and movements of the whole device, such as twisting, turning and shaking of the Tuister. An additional optical sensor will track the movement of the sleeve relative to the rest of the device. Together with the absolute orientation, it is possible to distinguish, whether the sleeve or the inner part is rotated. As we will see in the next section this will allow the use of different metaphors for rotating both parts of Tuister. The functional diagram in figure 6 presents the main electrical components of Tuister. A custom-made graphics card, consisting of RAM and a graphics chip, provides the six OLED displays with the bitmaps stored in the RAM. All communication is managed by a Microcontroller, which also stays in contact with a host computer over a serial line. At the moment this connection is cable-based, but we plan to replace the cable with a wire-

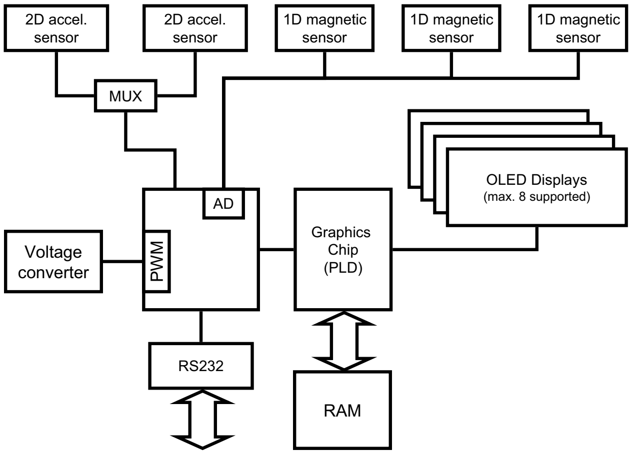

Figure 6: Functional diagram of the electric components

less link (probably with Bluetooth). The Microcontroller preprocesses the raw sensor data and hands it over to the host PC. In turn it receives bitmaps addressed to any of the six displays. Similarly to conventional input facilities, this implies that the interface logic runs in the environment (e.g. on a PC) and not on the device itself. Since Tuister is designed to remain with the user, it will reconfigure itself and eventually also integrate its interface into all instrumented environments the user visits.

5. OUTLOOK

At the moment the Tuister has materialized to the extent shown in figure 4 and as a virtual design study, but we hope to finish the engineering task in a few months. Some issues have still to be solved, e.g. how to design the sleeve in order to have enough haptical feedback and to be able to easily twist the Tuister at the same time. Further steps require to establish a wireless link between the device and the host computer. This will enable us to implement the menu browsing example and to start user studies.

Other interaction scenarios await further investigation. One idea is to use the Tuister to browse graphical material (e.g. maps) or tables (e.g. bus schedules). The device could also be used as pointing device in multi-modal system dialogues. This will enable usage pattern similar to those of the bluewand [4] with the advantage that visual feedback is available directly on the device.

The current physical dimensions are only determined by the size of electronic parts. With time, Tuisters might assume the form factors of pens or jewellery. They only need to remain big enough to be comfortably read.

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