Tangible User Interfaces Seminar 2006 by the DIVA Research Group: *Media and Tangibles*

Dominique Guinard

DIUF – Department of Computer Science
University of Fribourg, Switzerland
dominique.guinard 'at' unifr.ch
http://diuf.unifr.ch/diva

Abstract

This article aims reflect a certain state of the art in TUIs (or Tangible User Interfaces) domain, focusing on the handling and editing of media (e.g. video & sound streams, images, etc.). After a brief introduction to the field of TUIs, it basically provides a review and summary of three projects: mediaBlocks [19], logJam [3] and DataTiles [17]. Eventually, constructive critics as well as an evaluation of the projects will be formulated.

KEYWORDS: tangible user interfaces, TUI, media, user experience, ubiquitous computing, ergonomics, radio frequency identification, RFID.

1. Introduction

May one claim that she never had a frustrating user experience as due to the clumsiness of a Graphical User Interface (or GUI) ?
Reinforced by a growing interest for human-machine ergonomics and the rapid evolution of automatic identification technologies (Auto-IDs) (see [9]), tangible user interfaces have been intensively studied over the last couples of years.
This paper exposes the use of TUIs for media related manipulations by reviewing and summarizing three major articles in the domain: [19, 3, 17]. Finally, it discusses the media TUIs focusing on their future, added-value and ergonomics. To start with, some essential background notions about media, TUIs and the technologies behind them will be provided.

1.1. Background

1.1.1. Tangible User Interfaces

Back in 1991, Mark Weiser[1] argued that the new generation of computers would enable the users to focus on the task itself rather than on the way of commanding a computer to achieve it [20]. Furthermore, Weiser talked about an abundance of task-specific devices enabling this new way of thinking. Since then, these affirmations are the motto of many researchers towards computer systems that will better fit our needs, our ways of thinking, acting and reacting.
In essence, the Tangible User Interfaces (TUIs) offer a new kind of user experience by introducing **physical objects** as interfaces for digital manipulations. One can imagine them as being physical extends of the well known GUIs (Graphical User Interfaces).
According to [17] and [3] the properties of tangible objects enable a broad variety of manipulations which are not possible using graphical objects only. First of all using physical objects as interfaces brings to the digital world the **degrees of freedom** available in the physical world [3]. Additionally, people may use sophisticated skills for manipulating objects [17], leading to an unlimited amount of possible uses and movements. To traditional "pointing and clicking" are added rotating, grasping, attaching, dropping, padding, etc.
Moreover, tangible user interfaces enable people to interact cooperatively and act collectively. This latter fact appears quite often in the TUI related literature and is the essence of [3].
Basically tangible objects can serve as interfaces for any kind of action in the digital world. However, this article focuses on the their use for manipulating media. Thus, before going any further it is certainly worth finding an appropriate definition for the term "media" in this context.

1.1.2. Media

The term media can have various meanings. It is defined in defined in Wikipedia[2] as:
Media (the plural of medium) is a truncation of the term media of communication, referring to those organized

[1] Mark Weiser is often considered as the spiritual father of ubiquitous computing.

[2] `http://www.wikipedia.org`

means of dissemination of fact, opinion, entertainment, and other information[...]

In the case of this article, the best suitable meaning is certainly inspired by the definition above but is more closely related to multimedia. Indeed, this paper and the main articles it is based on (i.e. [19, 3, 17]) focus on the **manipulation and creation of multimedia supports**. As a consequence when referring to "media" in the remaining parts of this paper, one should understand it as **"means for supporting digitalized informative or entertaining contents"**.

1.1.3. TUIs and Media

Amongst the operations requiring intensive manipulations media editing and visualization is certainly in the top ten. As a consequence when working with media the GUI and its related devices (especially the mouse) are highly used. This fact naturally raises issues of optimization and ergonomics[3]: "is the combination $GUI + Mouse + Keyboard$ the right one when talking about media manipulation and visualization ?" According to [17] this may not be the case. Therefore, the three articles summarized in this paper propose new approaches competing with the existing methods.

1.1.4. TUIs and Auto-ID Technologies

Literally every physical object may be used as an interface for computerized actions. One may decide to use common (existing) objects as in [15] or may create new ones such as the tokens of [19, 3, 17]. As both approach aim to integrate the physical objects to the human-computer interface, a mechanism enabling the computer to be aware of the object's presence is mandatory. That is, one must be capable of assigning a **unique computer-readable number** (or string) to the object. Alternatively, one may transform the object into an electronic device which can be connected to the computer. While the latter solution offers interesting possibilities it requires strong electronic engineering skills and introduces some unwanted constraints. On the opposite, the former method enables very interesting combinations without much efforts (in terms of electronics engineering).
As a consequence, the tiles of [17] and the blocks of [19] or [3] are physical tokens embedding unique identifiers.
There exist various types of support for such identifiers. These are often referred to as **Auto-IDs** which groups the technologies helping computers to identify objects, animals or people [9]. As an example [19] use iButtons[4] whereas [3] uses "silicon serial number". Eventually [17] use RFID tags on their tiles. It is worth noting that this latter approach is also the most flexible as it enables contact-less identification of the tokens and thus reduces the reliability problems mentioned in [3] (see 4).

[3]See [1] and [6] for studies of ergonomics in terms of human-computer interfaces.

[4]iButtons and the DS2401 "silicon serial numbers" are manufactured by Dallas Semiconductors Inc.

2. Three Media TUIs

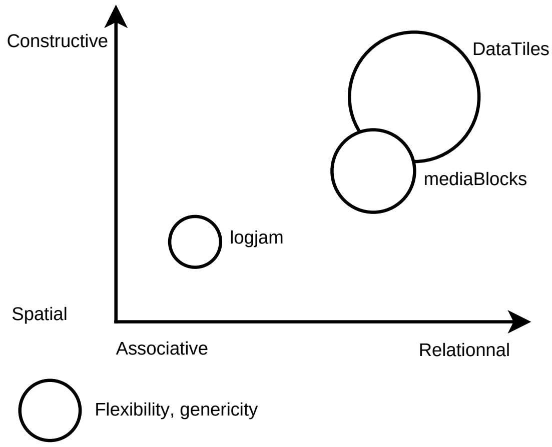

Figure 1: Classifying the three projects

Whereas the previous section discussed the general background of tangible user interfaces for media manipulating and editing (referred to as media TUIs through the rest of this article), this section exposes and summarizes three concrete examples.
For the sake of simplicity, each summary is divided into the same four subsections. The first describes the general goal of the TUI and attempts to classify it amongst the categories defined in [11][5]. Additionaly, Figure 1 provides a visual idea of the projects' classification. Eventually, the "Components Overview" and "System Overview" subsections discusses the intrinsic properties of each tangible user interface. With latter focusing on the interactions of the components exposed in the former.

2.1. MediaBlocks: Physical Containers, Transports, and Controls for Online Media

2.1.1. Aim and Classification

MediaBlocks certainly counts as one of the most well-known examples of media TUIs (not to say of the overall TUIs' examples). Designed by Brygg Ullmer, Hiroshi Ishii and Dylan Glas from the Tangible Media Group at MIT, this interface offers to re-imagine the containment of online media. This could help the user transporting media from one digital device (e.g. a whiteboard) to another (e.g. a printer) in a seamless, natural and ergonomic manner.

[5]It is worth noting that [11] is based on [18] and basically offers four categories for TUIs to fit in: Spatial, Constructive, Relational and Associative.

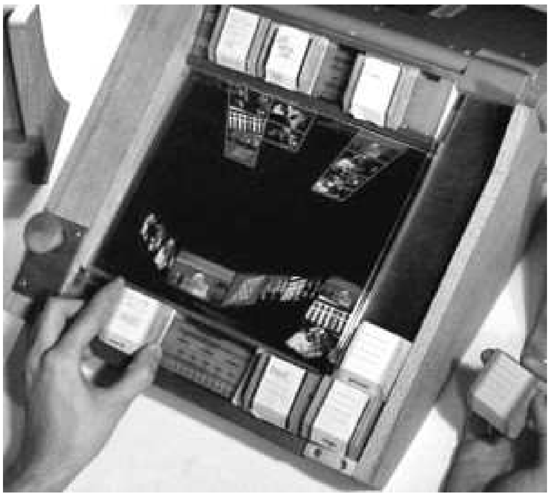

Figure 2: The media sequencer (from: [13])

To achieve this goal, the authors propose the use of small wooden blocks (i.e. the mediaBlocks) serving as physical icons (or "phicons") for online media. The basic idea is for the token to **represent** the media, **not to store it**. In short, a mediaBlock embedded an URL pointing to the actual media it stands for.
This forerunner project is a good example of a **relational** TUI, in which the tokens associate digital information.

2.1.2. Components Overview

The mediaBlock physical framework is composed of four main groups:

Containers are the already mentioned wooden blocks. In order for them to be identified by computers, they were equipped with an electronic device storing either an URL to the actual media or a numeric unique identifier.

Sources physical devices accepting mediaBlocks (e.g. whiteboards, computers, video recorders, etc.). The Sources are used to **bind** a Container to the media.

Displays are used to visualize the "content" of the blocks.

Manipulators such as the media sequencer (see Figure 2), are tangible user interfaces which enable the sequencing of media elements.

2.1.3. System Overview

As mentioned before, the mediablocks do not act as a medium of storage, but rather as a **mechanism for physical references and exchanges**. Thus, the entire system can be thought of as a physical version of the well-known **copy/paste** mechanism. Indeed, one can use a Source, say a video camera to copy data to the token and a Display, say a laser printer, to paste it. As a result, after inserting the token into the slot of the printer, the previously captured picture will be printed.
It is crucial to understand that the picture is never actually recorded on the block instead, the system will identify the token as standing for a file recorded somewhere within the networks. Thus, when the block is inserted into the printer's slot, the software will download the media from where it is actually stored and print it.
Furthermore, the mediaBlock system provides a so called "media sequencer" as an instance of the Manipulators. It allows the user to actively manipulate (primarily sequence and position) the blocks' content. Using this device, Ullmer, Ishii and Glas explore the new possibilities introduced by the physical tokens.
In essence, physically moving the tokens (chute, stacking, racking, padding) on the media sequencer triggers actions on the contained media. For instance, making a token chute will delete (or **unbind**, to be more precise) its content.

2.2. Logjam: a Tangible Multi-Person Interface for Video Logging

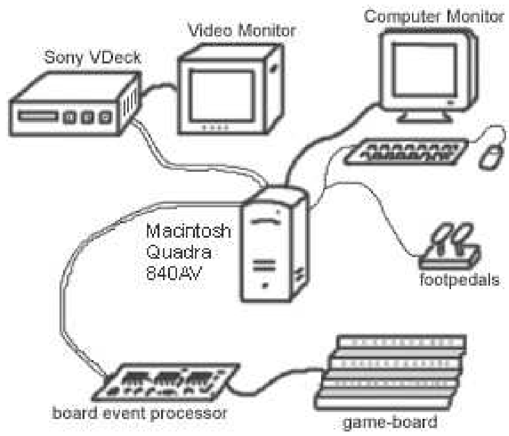

Figure 3: Logjam system diagram (from: [12])

2.2.1. Aim and Classification

Imagined by Jonathan Cohen and Meg Withgott and Philippe Piernot, Logjam is a system for **video logging**. The source of inspiration for the authors to design such a system is to find back in 1994. During this summer a group of video ethnographers accompanied a band on a US tour and shot several hundred of hours of interviews and interesting segments of society. Back to their research lab, the ethnographers had to categorize and comments this huge amount of video fragments.

This is where Cohen, Withgott and Piernot, first came out with the idea of logging aided by a tangible user interface empowering **group interactions**. Their TUI aims not to replace but to augment conversation using a set of physical tools permitting to focus on the dialog rather than on the computer artifacts.
To achieve this goal the three scientists imagined an interface comprising of a computer-enabled game-board and a set of footpedals. The former is equipped with small tokens representing the various possible categories of video extracts whereas the latter serves for video speed control. Additionally, a classical GUI offers some further (and more classical) media manipulating functionalities.
Because the tokens are associated with digital information (video) one could imagine this system as being a relational TUI. However, since the tokens have no relation to each other, classifying it a an **associative** user interface is probably a better approach.

2.2.2. Components Overview

Logjam basically comprises three tangible components:

The Game Board was initially designed for another project. It is a surface which can detect the position and identity of domino-like tokens: the "blocks" (see below). The wooden board offers 48 possible locations. The architecture of the game board is similar to the classical smart card system. Indeed, whereas RFID for instance, does not require contact or even line-of-sight to identify objects, the game board needs galvanic contact to locate the tokens[6]. For this purpose, a Motorola 6811 processor is in charge of polling, up to ten times per seconds, all 48 locations of the surface.

The Blocks are wooden tokens which are very similar to the media blocks mentioned in 2.1. Each block embedded a "silicon serial number" holding a 48-bits identifier. Furthermore, a copper strip on the bottom of the block is connected to the ground line of the identifier chip. When disposed on the game board, this strip initiates a galvanic contact with the board's main bus.

The Footpedals are connected to the a Sony Video Deck controlling the speed of the video play. Both pedals have two positions "down" and "way down".

2.2.3. System Overview

As introduced before, all the components cited above aim to empower group logging. Thus, when using the logjam system the group can use its various elements (see Figure 3) to efficiently log the video.
The game board is the central element of the infrastructure. Indeed, the ethnographers can use it for various tasks. First of all by placing a block on a special location on the board, one can assign it a category (e.g. interviewing, observing, dancing, group, crowd, couple, etc.). It is worth noting that the description of the category has still to be entered using a classical keyboard and GUI fields.
Furthermore, the game board can be used for actual logging: dropping a block b on the surface creates an annotation at current time t in the category represented by b. Similarly, picking up b after n seconds ends the annotation at current time $t + n$.
Finally, the game board also serves for video speed control. Dropping any block on the back raw of the board controls the display velocity of the video.
The footpedals are also meant for this purpose. By pushing and releasing them one can control the video speed.
Eventually, the classical GUI permits everything the TUI offers plus prompts for (textual) input when required (e.g. when creating a new category).

[6] Refer to [8, 9] for comparisons of the contactful/less automatic identification systems.

2.3. DataTiles: A Modular Platform for Mixed Physical and Graphical Interactions

Figure 4: The Datatiles system (from: [4])

2.3.1. Aim and Classification

Amongst the vast world of TUIs, the DataTiles project from Sony CSL (Computer Science Laboratory) is certainly one of the most impressive. The TUI imagined by Rekimoto, Ullmer and Oba pushes the border between the graphical and physical interfaces one step beyond. The basic idea behind DataTiles is to mix both interfaces in order to enable more complex configurations. The added value of the project lies in the flexibility of the system. Hence, where many TUIs are dedicated to a particular use-case (like the logjam TUI), the DataTiles are not

bound to a single purpose.
The tokens of the system, called tiles, are somehow like physical widgets[7]. Indeed, each tile has a number of features decoupled from its genuinly meant application. Thus, the DataTiles system can be thought of as a **physical framework** for media related manipulations.
In particular it proposes to solve the increasing complexity of managing digital devices by providing a generic control interface integrating the functionalities of a number of digital appliances. It is worth noting at this point how similar this latter goal is to the aim of the mediaBlocks project.
Because of its flexibility, the DataTiles project can not be classified in a well defined category of TUI. The communication capabilities of the tiles makes it a good candidate for an **relational** TUI whereas the possible combination of various tiles makes it more a **constructive** system.

2.3.2. Components Overview

As shown on Figure 4. The DataTiles system is composed of two main kinds of elements.

The Tray is a flat panel screen. Placed horizontally, it offers both an information display and a support surface for the tokens (tiles). The board is split into 12 regions of the size of a tile. Each of the square area is equipped with an RFID sensor coil (antenna). Additionally, the tray is enhanced with an electromagnetic pen tablet. Furthermore, the system can be composed of various trays. Indeed, solutions for inter-trays communication were also developed by Rekimoto, Ullmer and Oba.

The Tiles are (partially) transparent acrylic tokens. Each tile embedded an RFID tag. Similarly to the "silicon serial numbers" of the logjam system or the "iButtons" or the mediaBlocks project, the tag enclose a unique identifier. This latter fact permits the RFID sensors placed on the tray to identify the tiles. However, in contrary to [3, 19] the identification scheme is **contact-less**. We shall later (see 4) emphasize how this fact is important in regards to ergonomics and ease of use.

2.3.3. System Overview

As mentioned before, the DataTiles project could be qualified as a physical framework. This makes it difficult to describe the possibilities of the system within a few lines. As a consequence, this section gives an overview of the architecture, focusing on the capabilities of some existing tiles.
At a basic level the system integrates three interaction concepts:

1. Tagged objects (tiles) as graspable module to represent digital media and to trigger specific actions. This is the **relational** part of the TUI.
2. **Mixed** visual and physical interactions.
3. Physical combinations of tokens to create complex behaviors and actions.
   This is the **constructive** part of the interface.

To enable these interactions five categories of tiles are proposed:

1. **Application Tiles** have predefined behaviors. When such a tile is disposed on the tray, the system starts the corresponding application and displays it through the token. These tiles are basically graspable representations of digital information or media. The wheather forecast server or the scribble tool are example of such tiles.
2. **Portal Tiles** represent physical objects or places as well as digital entities. A printer or a webcam are two examples of portal tiles.
3. **Parameter Tiles** are used to manipulate and control other tiles. For instance one could use a "wheel" tile[8] to control the time point of an application tile displaying a movie.
4. **Container Tiles** are used to store data extracted from other tiles. Such a token can then be transported on another tray or to any appliance supporting tiles. This concept is similar the "blocks" developed by Ullmer, Ishii and Glas (see 2.1.).
5. **Remote Tiles** are used to connect different trays. When such a tile t_0 is placed next to another, t_1 the content of t_1 is continuously sent by t_0 to a twin of t_1, $t_{1remote}$, on a remote tray.

Moreover, to better understand the way tiles can be used for complex interaction a use-case example is of great value.
To begin with one can drag a Weather tile (application tile) and place in on the tray. It is worth noting that the tile may be transparent or may have some patterns printed on it. Indeed, remember the tiles are a mixture of digital and physical information. The Weather tile for instance has a map of the location printed on it. When the system (through the RFID sensor) recognizes the tile it displays the temperatures of the corresponding area through the partially transparent tile.
We now drag a Webcam tile t_{web} (portal tile) and dispose it on the tray. The system recognizes it and displays the corresponding (live) webcam through it. We also place

[7] A widget is basically a graphical component (e.g. a scroll-bar, a text field) the user employs for interacting with a computer.

[8] Such a tile is similar to the well known iPod's scroll wheel designed by Synaptic Inc. Refer to [2] for a full cover of the story behind this mythical wheel

a container tile t_{cont} next to the webcam tile. Using the electromagnetic pen we can now copy (by making a special gesture) the image currently displayed by t_{web} to t_{cont}. As a result the system displays a static image of t_{web} through t_{cont}.
Again by making a special gesture, one can now use t_{cont} to paste the image onto another tile of the local tray or of a remote tray.
Far more complex interactions and use-cases are enabled by the DataTile system, however these two samples already provide an overview.

3. Other Media TUIs

Even if probably amongst the most popular the mediaBlocks, logJam and DataTiles projects do not have the monopoly in the domain of media TUIs. In fact this research subject is one of the most prolific in the field of tangible user interfaces. Thus, the analysis of [19, 3, 17] only provides an entry point.
Plenty of other interesting works exists. These projects are often the achievements of media laboratories (like the Tangible Media Lab [14] or the DIVA group [5]) or of ubiquitous computing laboratories (like the Embedded Interactive Systems group at Lancaster University [7][9]).

4. Evaluation and Final Thoughts

According to [19, 3, 17] exchanging, editing or visualizing media using a traditional GUI approach is not always as easy as it may appear. The variety of media, the complexity of exchanging it amongst the various devices, the size of the data (in terms of duration, volume or dimension) are some key factors for the clumsiness of purely graphical approach towards media manipulating. As a consequence, inquiring for new ways of achieving these tasks does not seem void.
Interstingly enough, while all three articles present concepts for new solutions their empirical results emphasize how impressive approaches can be reduced to useless just by failing to solve some (apparently) minor issues.
Hence, while the idea of the game board in [3] seems of great interest, the technical limitations introducing unreliability and variable latency reduces the user acceptance by an important factor. Thus, by their work on logJam Cohen, Withgott and Piernot do not only show the benefits of tangible artifacts but also emphasize two keys for a usable TUI: **reliability and responsiveness**. Towards the seeking of a valuable metrics for TUI evaluation these two terms seem to be amongst the most important.
Logjam failed to fulfill them because the identification system was lacking in flexibility. Indeed, the user was supposed to place the blocks on the board in a specific manner in order to initiate a galvanic contact between the token and the main bus. This approach is in contradiction with the real physical world where placing things usually do not require for us to place them in an exact manner.
Technology advances are helping worthy ideas to meet the requirements. Going in the direction of real world ergonomics, the contact less identification scheme (using RFID) for the tiles in [17] seems to be more reliable and responsive.
Flexibility is not only important in terms of ease-of-use but also in terms of use-cases. A modern TUI should not be bound to a single use but ought to offer an interface for various manipulations. The DataTiles and mediaBlocks projects represent a step towards this aim. However, for such generically projects to get out of the laboratory some so called "**killer app**"[10] are required. Hence, while mediaBlocks and DataTiles provide an impressive framework for media manipulation and interchange, both projects somehow fail to reveal totally convincing applications.
Nevertheless, all three projects exhibit many benefits from using tangible objects as interfaces. First of all logJam emphasizes some **idiosyncratic uses** of the interfaces such as the way each user places the tokens to fit his own perception of organization. This fact is the direct consequence of a great benefit of TUIs over GUIs as exposed in [19]:
[...] the GUI metaphor appeared unable to generalize across the potential design space of tangible user interfaces
or in [3]:
[...] TUIs allow people to take advantage of all the degrees of freedom available in the physical world.
TUIs **introduce the malleability** of real world objects to control the digital world. This malleability coupled with flexible composition schemes enabled the guinea-pigs of the DataTiles project to create non-anticipated combinations close to real world ergonomics.
Moreover, the undeniable benefit from **physical contact** is emphasized by the three projects as in [3]:
[...] there was an unmistakable sense of physical contact [...]. Such physical sensations do not exist on the screen.
Besides physical contact, **physical exercise** introduced by tangible user interfaces is also of great value. As an example its benefits in the learning process are distinct (see [10]).
These facts alone are enough to justify the TUI researches in the media domain. However, the technologies still need to evolve towards reliability, flexibility and responsiveness. On their side, users have to overcome the "de facto" ergonomics introduced by years of GUIs monopoly in order to appreciate the real benefits of tangible user interfaces for manipulating media content.

[9] Some of their impressive works on media TUIs are not published yet but videos of the projects are available on the web (see [16]).

[10] A "killer app" is basically a use-case showing a positive ROI (Return On Investment) or meeting a real need that has enough powers to initiate a buying decision.

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