DESIGNING MOBILE MULTIMODAL ARTEFACTS

Tiago Reis, Marco de Sá and Luís Carriço

HCIM, LaSIGE, DI, FCUL, University of Lisbon, Campo Grande, Lisbon, Portugal

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Abstract: Users' characteristics and their different mobility stages sometimes reduce or eliminate their capability to perform paper-based activities. The support of such activities and their extension through the utilization of non paper-based modalities introduces new perspectives on their accomplishment. We introduce mobile multimodal artefacts and an artefact framework as a solution to this problem. We briefly explain the main tools of this framework and detail two versions of the multimodal artefact manipulation tool: a visual centred and eye-free version. The design and evaluation process of the tool is presented including several usability tests.

1 INTRODUCTION

Multimodal interaction provides users with interaction modes, beyond the usual keyboard/mouse for input and visual display for output. Usually, multimodal systems combine different modalities according to the user's characteristics or/and surrounding environments, enabling them to interact with the system adequately according to their situation at a given time (Gibbon, 2000). These systems have only started to be used and seriously researched in the past 15 to 20 years (Oviatt, 2003), as they became more feasible from a technological point of view.

The additional interaction modes included on a multimodal system can be used either in a complementary way (to supplement the other modalities), in a redundant manner (to provide the same information through more than one modality), or as an alternative to the other modalities (to provide the same information through a different modality) (Oviatt, 1999).

Multimodalities are particularly well suited for mobile systems given the varying constraints placed on both the user and the surrounding environment (Hurtig, 2006). Adaptability is a key issue on these systems, as users can, in some circumstances, take advantage of a single modality (or a group of modalities) according to their needs (Gibbon, 2000). The use of non-conventional interaction modalities becomes crucial when concerning human-machine interaction for users with special needs (e.g.,

visually impaired users). In these cases the objective is not to complement the existing modalities of a system with new ones but to replace them with adequate ones (Blenkhom, 1998; Burger, 1993; Bloyd, 1990).

In this paper, we present a mobile multimodal framework developed to support/extend paper-based procedures and activities. This framework enables users to create, distribute, manipulate and analyse the utilization of artefacts based on several kinds of media: text, audio, video and combinations of these. Users can easily produce, distribute and use multimodal: questionnaires, exams, role play games, books, tutorials, guides, prototypes, simple applications, etc. Furthermore, they are able to study the utilization of the created artefacts, which provides them with valuable usability and usage information.

As we describe our framework, we focus on the modalities included as an alternative or complement of the previously existing ones. The following section describes the related work on mobile multimodal systems developed for many different purposes. After, we introduce our multimodal artefact-based framework, we describe the design and evaluation of its multimodal characteristics and, finally, we present our conclusions and future work.

2 RELATED WORK

Current paper-based activities and practices are highly disseminated and intrinsic to our daily lives. Particular cases such as therapeutic and educational procedures, which rely strongly on paper-based activities, assume special importance due to their critical content. However, given the underlying medium, some of the activities fall short of their goals. Moreover, the ability to introduce digital data and multimodalities can enhance the activities and facilitate users' lives. Mobile multimodal applications have been emerging more as the technology evolution starts to enable their support. Several systems, which combine different interaction modalities on mobile devices, have already been developed. The approaches vary in the combination of modalities that, generally, suit different but specific purposes, which address the users' needs and surrounding environments.

Studies on multimodal mobile systems have shown improvements when compared to their unimodal versions (Lai, 2004) and several multimodal systems have been introduced on different domains. For instance, mobile systems that combine different interaction modalities in order to support and extend specific paper-based activities have been used with success in art festivals (Signer, 2006) and museums (Santoro, 2007). The latter also supports visually impaired user interaction. Still, both are extremely specific, targeting activities that occur in particular, and controlled, environments.

Other approaches focus mainly on the combination of interaction modalities in order to eliminate ambiguities inherent to a specific modality: speech recognition (Hurtig, 2006) (Lambros, 2003). However, once again, they focus specific domains and use the different modalities only as a complement to each other.

Closer to our goals ACICARE (Serrano, 2006) provides a good example of a framework that was created to enable the development of multimodal mobile phone applications. These rely on: command based speech recognition, keypad (for input) and visual display (for output). The framework allows rapid and easy development of multimodal interfaces, providing automatic usage capture that is used on the evaluation of the multimodal interface. However, the creation and analysis of these interfaces cannot be done in a graphical way, thus not enabling users with no programming experience to take profit of this tool. Moreover, modalities relying on video are not considered and the definition of behaviour that responds either to the user interaction, navigation or to external events falls out of their purposes.

Finally, none of the work found in the available bibliography enables users, without programming experience, to create, distribute, analyse and manipulate multimodal artefacts that suit different purposes, users and environments. Furthermore, most of the existing multimodal mobile applications rely on a server connection to perform their tasks, limiting their mobility and pervasive use.

3 MOBILE MULTIMODAL ARTEFACT FRAMEWORK

The original framework was developed to enable the creation and manipulation of mobile artefacts that support and extend paper-based procedures and activities. As the framework utilization evolved, we faced new challenges that clearly pointed to its extension through the inclusion of multimodalities.

Four main tools compose the framework: the Creation Tool allows users to create multimodal interactive/proactive artefacts (e.g., role play games, dynamic questionnaires and activity guides); the Manipulation Tool enables the instantiation and manipulation of the artefacts (e.g. playing the games, filling the questionnaires and registering activities); the Analysis Tool, actually a set of tools, provides mechanisms to analyse and annotate artefact manipulation and results (e.g. see how and when the game was played, the questionnaires were filled); and the Synchronization Tool, handles the transfer of artefacts and results between devices. All tools are available for Microsoft's OS in Desktop/TabletPCs and PDAs/Smartphones and were developed in C#. A simpler J2ME version, tested in PalmOS Garnet 5.4, is also available.

In this paper, we focus on the creation and the manipulation tool, since those were the main targets of the multimodal extensions and the analysis and synchronization tools required only minor modifications.

3.1 Mobile Multimodal Artefacts

Artefacts are an abstract entity composed by an ordered set of pages and a set of rules. Pages contain one or more elements. These are the interaction building blocks of artefacts (e.g., labels, selectors) and are arranged in space and time within a page.

Rules can alter the sequence of pages (e.g., <skip to page X>) or determine their characteristics (e.g.,

<hide element Y>). Rules are triggered by user responses (e.g., <if answer is "yes">, interaction (e.g., <on 3 answer modifications>), navigation (e.g., <on 4 visits to this page>), or by external events (e.g., <when elapsed time is 10s>) defining the artefacts' behaviour.

3.1.1 Basic Output Elements

These elements present content and put forward size (e.g., fixed-size), time (e.g. reproduction speed limits) and audio-related (e.g. recommended volume) characteristics; they may also include interaction (e.g., scrolling, play/pause buttons) that, however, does not correspond to user responses. The following variant is provided:

- **Text/image/audio/video labels** present textual, image, audio or video content or a combination of audio with image or text.

Simple artefacts, such as tutorials, guides and digital books can be built with these elements.

3.1.2 Full Interactive Elements

These elements expect user responses which can be optional or compulsory and may have default values. The elements may have content (e.g., options of a choice element), thus inheriting the characteristics of basic ones, or gather it from user responses (e.g. inputted text). The following elements are available:

- **Audible text entries** allow users to enter text and optionally ear their own entered text when the device is able to support a text-to-speech (TTS) package available on the manipulation tool.
- **Audio/video entries** enable users to record an audio/video stream – quality and dimension attributes may be defined.
- **Audible Track bars** allow users to choose one value from a numeric scale – scale, initial value and user selection are conveyed visually and/or audibly.
- **Text/image/audio choices** permit users to select one or more items from an array of possible options – items may be text, images, audio or a combination of audio streams with text or images; presentation characteristics such as the number of visible/audible options (e.g., drop down/manual play) may be defined.
- **Audible 2D selectors** allow users to interact with images or drawings by picking one screen point or a predefined region (like a 2D choice) – audible output is available for point (coordinates) selection and regions (recorded audio) selection and navigation.

- **Visible Time selectors** allow users to select an excerpt (a time interval) within an audio or video stream - predefined excerpts can be defined and correspondence to values may be set (corresponds to the 2D selector, but on a time dimension).

The user's responses entered in elements may be used within rules to control artefact behaviour. As such, the entire set of elements and rules can be used to compose fairly elaborated adaptive artefacts.

3.1.3 Materialization

Artefacts, in their persistent form, are represented in a XML or in a relational database format. XML is used in mobile and desktop versions whereas databases are restricted to desktop/tablet platforms.

3.2 Creation Tool

The artefact creation wizard is the application that allows users to create, arrange and refine artefacts. Overall, the process of creating artefacts is driven by a simple to use interface that comprises three steps: creating elements by defining their content and interaction characteristics; organizing the sequence of elements/pages; and defining behaviours. Each element type can be edited by its own dedicated editor. A preview of the resulting page is always available and constantly updated. Rules also have its own editor that can be invoked in the context of its trigger (element, page, artefact or external element).

The whole editing process incorporates and enforces usability guidelines (e.g., type and amount of content, location of elements and adjustment to the device's screen), preventing users from creating poor artefacts regarding their interactivity and usability. Besides generic guidelines, domain specific ones can be added to the tool. As such, the tool enables the creation of sophisticated applications by non expert programmers

3.3 Manipulation Tool

The Manipulation Tool (in Figure 1) materializes artefacts. It provides mechanisms to load artefacts, instantiate pages and elements and arrange elements as needed, navigate through pages (as defined by the corresponding rules) and to collect and keep user responses. The tool permits artefact locking (disable modification of responses), through timeout or user command (e.g. at the end of the artefact), auto-save of responses and navigation status and on-request summaries. This tool also includes a logging mechanism that, if enabled, gathers information

about artefact usage for subsequent analysis. The gathered data is composed by time-stamped entries including clicks with location, (re)chosen options, typed characters, etc. Logs and users responses are stored in XML files or in a database depending on the platform and database availability.
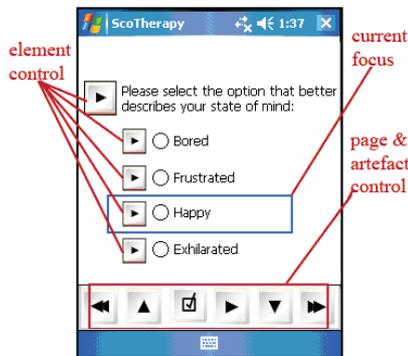

Figure 1: Manipulation Tool (visual version).

Navigation and interaction were kept simple and were substantially changed with the introduction of the multimodal dimension. We assumed devices without physical keys, in view of specific usage contexts (e.g. the user is already holding a stylus) and aligned with current trends of some emerging mobile devices. If keys/joystick are available in the device, mapping is straightforward for most of the interaction and the user can combine visual and physical solutions as desired.

Two versions of the tool are available. Both are the result of a user centred design approach that included several evaluation steps.

3.3.1 Visual Version

The visual version of the tool takes primarily a direct manipulation strand. Users' responses are directly entered on elements. For text/speech/video entries, once directly selected, a specific input gadget can be used (virtual keyboard, microphone and camera). For audio/video playback an element control was added near the element/item (in Figure 1) allowing simple play/pause options. Navigation through pages is achieved with the arrow buttons at the extremes of the page & artefact control bar (in Figure 1).

An alternative localized interaction approach is also available as a consequence of the requirements gathered during user evaluation. For that, a focus mechanism was added to all elements and items - expecting or not user responses. Focus feedback is visual (see Figure 1) and audible. Four new buttons were included in the page & artefact control bar. The arrow-up and arrow-down buttons allow focus

changing within a page. The two central buttons permit selection/answering (left) and audio/video playback (right) on the element/item with the focus. As such, all the interactions, except the text entry, can be done through the bar.

Both alternatives are configurable. The central buttons of the page & artefact control bar or the element controls can disappear as required. The bar can be moved to one of the four boundaries.

3.3.2 Eyes Free Version

The Eyes-free tool (Figure 2) is a configuration that eliminates the need for a visual output, provided that an audible presentation is defined for all elements of the artefact. User action modes are restricted to haptics and voice. A haptic card (Figure 2, on the centre), placed on top of the mobile device's touch screen, enables the interaction mapping.

Figure 2: Eyes-free Manipulation Tool.

To simplify navigation, only two navigation buttons are available. These run through all the elements of an artefact without considering the page (an essentially visual concept). The remaining screen is used as a T9 keyboard for text/number input and the haptic card holes map into these components (virtual T9 keys and toolbar virtual buttons).

The feedback on the users' input and the navigation information within the artefact/elements reproduce only the audio output. Users are aware of their own text/audio/video responses, because the input was either recorded or it can be synthesized through a TTS package.

4 DESIGN AND EVALUATION

During the design of the multimodal elements and the redesign of the artefacts, we followed a user centred approach specifically directed to mobile interaction design (Sá, 2007).

Requirements were gathered from a wide set of paper-based activities that could benefit from the introduction of new modalities. These considered different environments (e.g., class rooms,

gymnasiums), users (e.g., visually impaired users) and behaviours (e.g., walking, running). Tasks were elicited from psychotherapy (e.g., scheduling, registering activities and thoughts), education (e.g., performing exams and homework, reading and annotating books), personal training (e.g., using guides and exercise lists), etc. These were modelled into use cases and diagrams that were employed to define multiple scenarios. The scenarios contemplate different usage contexts throughout distinct dimensions (e.g., users, devices, settings, locations).

As these scenarios gained form, several low-fidelity prototypes were created. On an initial phase, they were evaluated and refined by the development team. Afterwards, potential users tested the prototypes within some of the previously defined scenarios. The newly identified requirements were then considered on the implementation of high fidelity prototypes, which were subsequently used in a similar evaluation cycle, with a larger group of users. Users' procedures were filmed in order to provide us with usage and usability information that was crucial to our conclusions. After the test, the users answered a usability questionnaire where they pointed the experienced difficulties.

The developed low and high fidelity prototypes addressed both versions of the manipulation tool (visual and eye-free), focussing the usability tests in the visual and audible aspects respectively. In both cases, the prototype was a form composed of seven pages, each with a question (basic output element) and an answer holder. For the latter different types of interactive elements were used (e.g. choices, entries).

In all tests users had to accomplish two tasks: (1) fill the form and (2) change their answers on some specific questions. Results were rated as follows: one point was credited if the user was able to successfully fill/change the answer at the first attempt; half a point was credited if the user was able to successfully answer at the second attempt; no points were attributed in any other case. The time spent on the overall test was registered.

4.1 Low-Fidelity Prototypes

The tests involved 11 persons, all students (7 male, 4 female), none visually impaired, between 18 and 30 years old. They were familiar with computers, mp3 players and mobile phones but not with PDA's, listenable or multimodal interfaces. Approximately half of the users tested the prototype walking on a noisy environment. The rest of them made the test sitting down in a silent environment. The researchers

simulated the application behaviour and audio reproduction (Wizard of Oz approach).

4.1.1 Visual Version

We used a rigid card prototyping frame that mimics a real PDA in size and weight characteristics (see Figure 3). For each test, seven replaceable cards, each representing one page, were drawn to imitate the application. Two major audio/video control variants were assessed: one based on the element controls (two tests) and another on the single page & artefact control bar (one test). All users performed all tests, but the order of tests was defined to minimize the learn factor.

Figure 3: PDA prototype.

Element Control. one control is inserted for each media element/item. Two design alternatives were tried: one relies on the media element controls only ("El. Ctrl" - see Figure 4) and the other includes additional text ("El. Ctrl + Text" - see Figure 5).
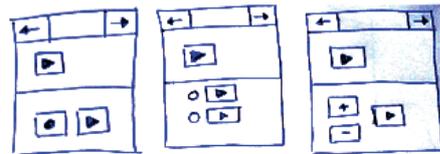

Figure 4: All contain a page navigation bar (top), an audio label (middle) and an interaction element (bottom) – the latter is (from left to right) an audio entry, an audio choice and an audible track bar.
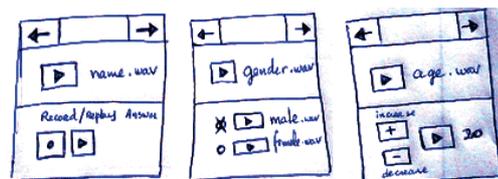

Figure 5: Same as for Figure 4 but with text.

During the test, we have noticed that all the users were manipulating the prototype with both hands (one holding the device and the other interacting with the cards). The test results (in table 1) show that the additional text information improved the time and success rate significantly. In the final questionnaire users confirmed the difficulties of interacting without the textual information.

Page/artefact Control. a control bar is available for the interaction with all the media elements/items, within a page/artefact (Pg. Bar - see Figure 6).
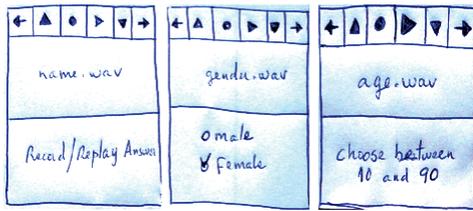

Figure 6: Same as for Figure 5, but navigation bar was replaced by the full page & artefact control bar (top).

During the test, we have noticed that the users manipulating this type of control used only one hand (holding the device and interacting with it using the same hand). We have also noticed that the bar's position made users cover the artefact while manipulating it. The test results (in table 1) show that page control bar alternative suits movement situations better than the element control variant.

Table 1: Average evaluation/time of the visual version.

	El. Ctrl	El. Ctrl + Text	Pg. Ctrl
STOPPED	71.4% 3.5 min	100% 3 min	100% 3 min
WALKING	71.4% 5.5 min	100% 4.5 min	100% 3 min

Considering both quantitative and qualitative results, we have decided to create high fidelity prototypes with a configurable solution, allowing both element control and page &artefact control. The decision was based in the fact that, although the latter performs better or equally to the former (with text), two handed interaction is often used in a sitting situation. Besides, with the current diversity of devices, this design option will allow us to evaluate both alternatives for different screen sizes, which we expect to have some impact on results. In any case, we also decided to locate the bar on the bottom of the screen device instead of the top.

4.1.2 Eye-free Version

We used the same prototyping frame, but with a single card only. The card contained only the page & artefact control bar. Sounds were defined to notify a new working page, the required/possible interaction (dependent on the elements' type) and the interaction feedback. Two alternatives were evaluated: one relies on earcons and the other on voice prompts. Again, all users performed all tests with an appropriate order. Since the bar usage was not an issue in these tests, the knowledge acquired on the visual version was not a problem. Nevertheless, the virtual application page sequence was modified (the researcher issued sounds corresponding to a different page order).

Earcons. "*abstract, synthetic tones*" were defined and repeated for each notification (see above). The meaning of the sounds was carefully explained before the test.

The results (in table 2) show that the users failed some operations. We believe some of these problems could be overcome with training or/and with a better choice of sounds. The comments reported on the post-tests questionnaire corroborate these findings.

Voice Prompts. succinct phrases were defined and repeated for each notification. The user could skip the information by pressing forward. The test results (last column of table 2) show that this approach assured the correct filling of the questionnaire, but also increased the time to accomplish it. This is because voice prompts are a lot longer than the earcons, and the users did not realize that they could skip them.

Table 2: Average evaluation/time for eye-free version.

	Ercons	Voice prompts
STOPPED	85.7% 4.5min	100% 6min
WALKING	87.8% 4.3min	100% 6.5min

Considering the evaluation results voice prompts seemed a preferable solution. Moreover, from the video analysis and the users' final comments, the 4 navigation buttons (two for pages and two for elements) were found superfluous. The high-fidelity prototypes adopted 2 buttons and voice prompts.

4.2 High-Fidelity Prototypes

These tests involved: 20 persons, all students (10 male, 10 female), none visually impaired, between 17 and 38 years old, familiar with computers, mp3 players and mobile phones, but not with PDA's, listenable or multimodal interfaces.

4.2.1 Visual Version

The evaluation of the visual version (Figure 7) was done by 10 of the 20 persons involved on the high-fidelity prototypes' testing.
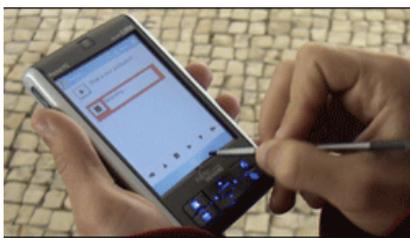

Figure 7: Evaluation of the high-fidelity prototype.

Half of this population has performed the test using the element control (EC + Text) and the other half did it through page/artefact control bar (Pg. Bar), both in stationary situations. The purpose of this particular evaluation was not to choose the best interaction option according to the user's mobility stage, but to understand if people: (1) were capable of using our interfaces correctly; (2) felt comfortable interacting with them; and (3) thought they could perform school exams on it.

The results (in table 3) clearly indicate some interaction issues, on the first attempt. Namely, people were not sure on how to manipulate audio/video entries, time selectors and audible track bars. Nevertheless, on a second utilization the results have improved substantially, suggesting a very short learning curve (in table 3, last row).

Table 3: Comparing average success and speed for element/item control VS page/artefact control on the 1st and 2nd attempts.

	EC + Text	Pg. Bar
1st try	88.5% in 2.5 min	80% in 2.6 min
2nd try	100% in 2,7 min	100% in 2.6 min

During the video analysis of these tests, we were able to identify some other problems. The most significant were: (1) button feedback (audio and visual) was not enough - some people were not sure whether if they pressed some buttons or not; (2) in

some situations, regarding the page/artefact control bar, people were not sure which button to use in order to perform specific actions - here again, graphical feedback was not enough.

The users' answers, expressed in the post-test questionnaire (in table 4) revealed good acceptance.

Table 4: Users' evaluation of the high-fidelity prototype.

	EC + Text	Pg. Bar
It was easy for me to accomplish the purposed activities.	80%	70%
I think this application is easy to use.	80%	70%
I would use this application to perform an exam	80%	60%

The overall results of this evaluation suggested some minor modifications on our final prototype. These were considered and implemented during the integration of the new modalities on the Manipulation Tool as described above.

4.2.2 Eye-free Version

The evaluation of the eye-free version was done by the 10 remainder persons. We developed a prototype without any graphical information, besides 4 buttons (back, record, play and forward) in the place of the control bar. On the other hand, this version provides audio content, voice prompts for navigation and interaction requests, and audio feedback. The prototype simulated, as much as possible, usage scenarios found by a blind person.

Table 5: Average evaluation/time on the voice prompt eye-free version of the high-fidelity prototype.

	Voice prompt
STOPPED	100% in 7 min

The test results (table 5) have proven that people were able to use the application. However, task accomplishment time (when compared to the visual version) and the users' comments, suggested some changes. Although the users were informed that they could skip navigation/interaction information in order accelerate their task's accomplishment, all of them reported an excessive use of the voice prompts.

In view of that and of the previous tests, we adopted a configurable solution for the final prototype: users can choose whether to use voice prompts, earcons or a combination of both.

5 CONCLUSIONS AND FUTURE WORK

In this paper, we have presented a framework that supports the creation, distribution, manipulation and analysis of mobile multimodal artefacts. We have focused the design and evaluation of a manipulation tool that enables users to manipulate such artefacts. Our evaluation results have shown that these artefacts can extend paper-based activities through non paper-based modalities. Moreover, these results have also proven the ability to support an eyes-free mode directed for visually impaired users.

Our future work plans involve making a new, wider, set of tests addressing the evaluation of the whole framework. The integration of the existing analyses components within the multimodal artefacts enables us to perform tests on real life scenarios, gathering useful usability information that will lead us to new challenges. We intend to test the eyes-free version of the manipulation tool on visual impaired persons aiming school activities such as homework and exams. We also envision the test of this framework on non paper based activities such as physiotherapy homework, that can be filmed in order to provide the therapist with information on how well his/her patients perform their given tasks.

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