Pervasive Displays in the Wild: Employing End User Programming in Adaption and Re-Purposing

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Abstract. The declining hardware cost has enabled the wide spread of Pervasive Displays anywhere within urban spaces; these systems are composed of displays of various sizes and allow users to interact with the same public screens simultaneously, usually through new and engaging modalities, e.g. Tangible Interaction. Yet the frequent changes in users' needs dictate a continuous adaption and re-purposing of such systems with new and focused features, in order to prevent interest to wear off and overcome people's low expectations of their content value; currently this process has to be done by site managers, and this tedious and necessary task prevented long-term deployments. In this paper we propose to use End User Programming to empower users with the ability to adapt Pervasive Displays to their continuously evolving requirements. We conducted a preliminary study involving university students, gathering scenario's requirements and initial feedback on a prototype we developed.

Keywords: Pervasive displays · End user programming · Natural user interfaces · Tangible user interfaces

1 Introduction

In recent years digital displays have flooded urban areas, providing ubiquitous information hubs to everyone within their reach; lately, thanks to the cheaper hardware's availability and to the recent technology trends, public displays started engaging users through a richer interaction: these systems – called *Pervasive Displays* – are composed of various-sized displays (from hand-held devices to large displays) and support many-to-many interaction, allowing "many people to interact with the same public screens simultaneously" [1].

Because of their ubiquitousity, the interaction modality has to be easily graspable by everyone who comes across a Pervasive Display; this is the main reason why interactions are fostered through a new paradigm, namely Natural User Interfaces (NUIs): these interfaces are based on more innate human interaction paradigms, such as touch, vision and speech.

A fairly recent trend in Pervasive Displays' research studies is to deploy large and long term experiments outside their usual laboratory setting, without the close researchers' supervision, i.e. *in the wild*; this is mostly due to the recent

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definition of new methodologies within the Human Computer Interaction area [2], allowing researchers to evaluate technologies within people's daily usage contexts.

Yet, as pointed out by Hosio et al. [3], such new and long term deployments present two main drawbacks: (1) the expensive maintenance costs in terms of setup and mundane service activities and (2) the gradual loss of interest shown by users and site managers overtime.

The authors also suggested a viable solution: allowing a degree of appropriation when designing Pervasive Displays might enable site managers and users to understand how they could relate to the ordinary activities often taken for granted, leading to a more sustained use. Moreover, because of their public and moderated nature, these displays are usually equipped with just a small set of very specific features, e.g. displaying local points of interests on a map; yet users' interests and needs are heterogeneous and evolving overtime. Thus opening up such systems by empowering users to adapt and re-purpose them into entirely new usage contexts might promote a more serendipitous and prolong usage.

We argue that End User Programming (EUP) could be effective in enabling users to adapt and re-purpose Pervasive Displays without the intervention of site managers.

To test this statement, our main contribution is the design of a simple NUI-based application for Pervasive Display's ecosystems allowing users to collaborate with each other in a group work scenario; we then conducted a preliminary study with users in order to provide an initial validation of our prototype – which will inform the next stage of its design – and investigate practices and problems they face during their meetings, in order to get further insights on the tools they need.

2 Related Works

Employing EUP in Pervasive Displays' adaption dictates a paradigm shift; indeed, ours is not the first attempt of bridging EUP and NUI. The vast majority of studies focused on a subset of NUIs, namely Tangible User Interfaces (TUIs): the main idea is to give digital information a physical counterpart, acting as both its representation and control [4]. This predominance is mainly due to the effectiveness of matching digital constraints and properties with physical ones – and vice-versa; moreover, unlike Graphical User Interface-based EUP systems, with TUIs one can easily and more effectively foster collaboration between users.

The existing literature can be grouped in two main categories, according to the EUP paradigm employed, Programming by Instruction (PbI) or Programming by Demonstration (PbD); the first one – usually referred to as *Tangible Programming* in the TUIs domain – being the more traditional approach to programming, requires learning and using a syntactic construct (e.g. visual languages) in order to impart instructions to the system, while the latter enables users to teach the system new behavior by demonstrating actions on concrete examples [5].

Topobo [6] (proposed by Parkes et al.) falls under the second category, comprising a set of modular components that can be assembled and animated by pushing, pulling and twisting, then observing the system repeatedly play those motions back. Employing PbD to teach different movements to the system directly on the actuated physical object proved to be very effective and intuitive, therefore it forms the basis for Robot Programming by Demonstration [7].

Moving on to the PbI-based systems, Mugellini et al. [8] proposed the tangible shortcuts: they've used physical objects to improve information retrieval, enabling users to develop new shortcuts using a puzzle-based visual language.

To the best of our knowledge, ours is one the the first attempts at employing an EUP approach within the Pervasive Display domain. Due to their effectiveness and ease of use, we decided to build all the interactions with our application around a TUI, which will allow end users to easily customize and assemble – in a PbI fashion – the services provided through a puzzle-like metaphor.

3 Prototype Design

Our prototype is an application enabling users to develop simple workflows by assembling several functions together, thus falling under the PbI-based systems category; it runs on a horizontal display, offering a tangible interaction through the movements of the users' smartphones on the main display's surface.

Employing smartphones allows us to adapt the system to each different user, because they hold all users' personal information and can be used to display a wide range of widgets that can be presented to end users depending on the specific service (e.g. a virtual keyboard to input text).

To make the system easily graspable by every user, we based the interaction metaphor on a puzzle [9]: each available function is mapped to a piece, which will (possibly) require inputs and produce some outputs, as depicted in figure 1; constraints on inputs and outputs are afforded using different shapes. The smartphone itself is associated with the main puzzle piece (a circle representing the smartphone halo), which will move alongside the smartphone on the main display's surface; moving the main piece towards another one will add the latter's related function to the workflow – if the two shapes are matching, that is to say the latest output is compatible with the required input. If a single piece requires some additional inputs from the user, such as selecting an option between several ones or typing in some text, a dynamic widget will appear on the smartphone screen, allowing the user to do so.

We developed the first set of features keeping in mind the targeted scenario, thus the available puzzle pieces were: (1) fetch a file from Dropbox, (2) display a PDF or an image on the main screen, (3) search for a book in the library and get an image depicting its location, and (4) send a text document via email.

4 Preliminary Study

To get a better understanding of the scenarios where Pervasive Displays might be used, we carried out a study involving users in the university setting, where many public interactive displays are already being deployed and used. This particular study involved Computer Science undergrad students during their second year:

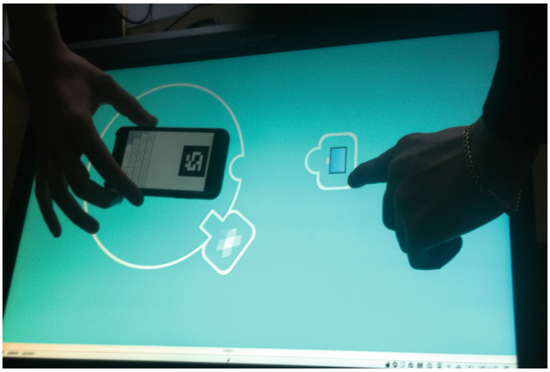

Fig. 1. An example of a workflow that can be assembled using our prototype; widgets are displayed on the smartphone once a new piece requiring some user input is assembled

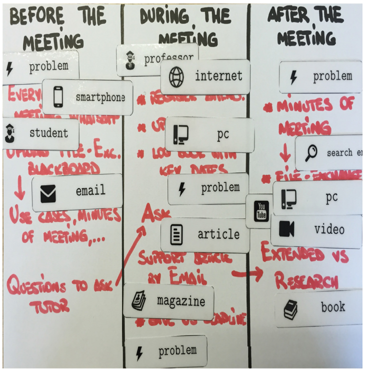

Fig. 2. The rich picture generated by one of the groups participating in our study

as part of their degree, students have been clustered into groups of 4-6 people and assigned with an Android application to be developed during the course of the year, with the supervision of a teaching staff member, whom they usually meet all together once a week. Students have to work collaboratively and meet on a weekly basis, usually in a college's meeting room: our study took place in the same environment to simulate "in the wild" settings.

The study involved three different groups of students and was composed by two different activities, both carried out in the same session with the group as a whole: the first activity consisted of gathering the specific scenario's requirements from participants; we asked students to tell us about the tasks and tools they use during their meetings, trying to keep the discussion going with a semi-structured interview; we gave them a set of non-exhaustive sample icons representing some of the resources and tools they might be using, such as books, papers, search engines, smartphones, and so on. We asked them to place the icons on a sheet of paper, which had three different sections: before, during and after the meeting. As a result, we obtained an accurate picture of what is happening during a meeting, which tasks require some preparation and which ones trigger some other activities to be performed after the actual meeting (figure 2).

During the second activity we carried out a preliminary evaluation on the proposed interaction modality by explaining them how the system works and we let them play with it until they were satisfied, carrying out a semi-structured interview (mainly focused on the interaction modality).

Results of both the interviews are reported in the following.

4.1 Results

The first interview's results were structured with regard to the focused aspect, obtaining three ex-post generated categories.

Scheduling. Students use instant messaging tools to schedule meetings with each other and discuss urgent matters together; this happens before a meeting, thus they also can all agree on what should be discussed with their supervisor and build an agenda for the next meeting.

Reporting. Because the groups usually get together with their tutors once a week, one of the objective of their meeting is put together a report on what has been done so far; students describe how they've handled previously assigned tasks and report the problems they've encountered with the development.

Discussing. The discussion happens in all of the three phases: before the meeting, students discuss with each other (using instant messaging tools for pressing issues, emails for tasks requiring additional details) the tasks they were assigned and how they're addressing them, getting suggestions from the other members.

As for the results emerging from the second activity of the study, it seems that participants quite liked the idea we've pitched them through our prototype; feedback was mostly pointing towards the missing features and the interaction with the smartphone. Firstly, for the system to be really useful in the targeted scenario, it should have included a deeper integration with the online content manager used within the university and the ability to send several types of files via email. Secondly, it became clear how a TUI is an effective way of interacting with the system while composing the workflow, but it's not really effective when it comes to operating on their results: indeed, all of the groups attempted to drag the images displayed on the main screen with their fingers.

5 Discussion

Based on the results of our study, we noticed a clear distinction – in terms of the most suitable interaction modality – between the composition and the execution environment: while they are composing a workflow, users have to deal with abstract concepts – such as functions and type constraints – thus we argue that the puzzle metaphor coupled with a tangible interaction modality could help them building an effective mental model, allowing them to easily deal with such intangible concepts; when the system prompts users with the result of an application, the natural need of directly manipulating content takes over, thus users automatically shift interaction paradigm and try to operate directly on the resource, rather than keep on relying on an indirect control mechanism (i.e. the smartphone). This shift stems also from the literature on the difference between the PbD and PbI paradigms: there's a clear overlapping between the editing and the execution environment within the first paradigm – i.e. users operate on an artifact to impart instructions *and* to interact with the results, as in Robot Programming by Demonstration – while these two perspectives are definitely separated within PbI-based systems. We intend to study this problem more deeply in future, since PbI appears to be a more adequate paradigm to be employed in our scenario, being inherently less domain-specific.

One final remark follows directly from our research question: all the existing attempts of bridging EUP with TUIs (and more generally NUIs) deeply rely on Visual Languages. It's worth pointing out how employing such construct, which was developed back when Graphical User Interfaces were the widespread interaction modality, in a NUI environment might violate the latter's premises and act more as a barrier to an effective communication with the end user rather than easing it. It might be worth investigating new forms of communication with end users – highly coupled with NUIs principles – in order to exploit the real value of this modality, which already proved to be really effective in lowering technology's barriers and are heavily employed in public displays.

6 Conclusion

In this paper we outlined how EUP might be a suitable methodology in helping users adapt and re-purpose Pervasive Displays; adaption and re-purposing of Pervasive Displays, as proposed by Hosio et al. [3], might help overcome the progressive loss of users' interest in actively using such systems overtime.

We carried out a preliminary study with second year university students, whose aim was to gather scenario's requirements and feedback on our proposal. Finally, the study offered us new and interesting insights, as well as new and unforeseen issues, which will be highly relevant during the next design phases.

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