12 + 1 Questions in the Design of Distributed User Interfaces

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ABSTRACT
Current visual display ecosystems raises new situations and new configurations regarding the way a user interacts with a system through the user interface. In a post-WIMP period, we can find coupled displays, multi-touch devices, and interactive table-tops, tablets, tangible user interfaces, e-Watches and many other devices often interconnected through the same applications. This scenario poses researchers new challenges in the design of distributed user interfaces. In this paper we raise a set of questions as guidelines to consider that may drive designers in their work.

Author Keywords
Distributed User Interfaces; DUI; design; Tangible User Interfaces; Multi-Device Environment.

ACM Classification Keywords
H.5.2 [Information Interfaces and Presentation]: User Interfaces - Graphical user interfaces, Input devices and strategies, Interaction styles, Screen design.

INTRODUCTION
Distributed User Interfaces (DUI) are a novel research field in the Human-Computer Interaction area and plays an important role in the proper design of advanced visual interface display ecosystems when more than one device is used to perform tasks on the same application. This is a common scenario due to the large amount of different devices that users use in their everyday life. Computers have become part and parcel of our daily lives, therefore current applications are also adapted to such situation and provide mechanisms to interact with them from the various devices in multiple ways. New challenges in the design of these applications emerge and they have to be carefully studied by researchers to achieve higher quality applications.

In this paper, we present some guidelines through 12 + 1 questions taken from an in depth study of papers on DUI mainly presented at the DUI workshops held during the last three years. Researches from all over the world presented their ideas, proposals and innovations in the area. Here we synthesize and identify the most important conclusions, agreements and assumptions which may guide a designer thanks to the knowledge of experts in the field. These guidelines will make the designers think on several aspects to explicitly consider many important points when distributing a user interface. There is one final guideline; a question that designers should consider regardless of the kind of application they design; just a must.

The paper is organized as follows. Firstly, a number of advances concerning display technology and interaction are presented in Section 2. Then, a unified and detailed definition of Distributed User Interfaces is given in Section 3. Section 4 provides the twelve plus one questions we propose as guidelines to design DUIs. Lastly, some conclusions and final remarks are presented in Section 5.

ADVANCES IN DISPLAY TECHNOLOGY AND INTERACTION: CURRENT TECHNOLOGICAL ECOSYSTEM
Current technological ecosystem introduces important challenges to developers and researches on display technology as well as on interaction matters. The way a user interacts with the system has evolved in such a manner that new research opportunities arise. In the last decades, we have moved from single end user interfaces to a wide variety of interactions due to the emergence of different devices platforms, architectures, operating systems, space and/or time distribution, etc. We have moved from one user interacting with their own computer in a really simple way, to more complex situations. Moreover, even such complex situations have become further more complicated with the introduction of the wide variety of different devices, platforms, architectures, operating systems, space and/or time distribution, etc. where users may interact despite the complexity of these settings. User interface design and interaction have turned into important research fields plenty of topics to tackle.

There are many interaction techniques such as (a) touching which involves touching an object. Some projects using this technique can be found in [4, 11, 20]; (b) scanning through
the mobile device which is capable of scanning information and interacting with the system to provide a service to the user [21]; (c) approach&remove [16] which allows the user to control distributed user interfaces by approaching the mobile device to an object; and lastly, (d) movement based interaction through motion sensing input-output devices like Kinect and Leap Motion.

New scenarios have appeared such as Multi-Device Environments (MDE) with multiple and heterogeneous devices distributed in the environment along with screens and surfaces where user interfaces are displayed.

We also should mention an increasingly fashionable paradigm, ubiquitous computing, described by Mark Weiser [22] in 1991: “The most profound technologies are those that disappear. They weave themselves into the fabric of everyday life until they are indistinguishable from it”. Its main goal is to provide the user with advanced and implicit computing, capable to carry out a set of services but without being aware of it. In order to interact in these environments, user interfaces are required to allow an intuitive and simple interaction that help remove the barriers so far encountered, such as prior learning of the use of systems.

Another interesting vision lies in doing common objects interactive and perceptible. Tangible User Interfaces (TUI) refers to user interfaces which give physical form to digital information, making the parts directly malleable and perceptible [12].

Current technology offers us a wide variety of possibilities to make interaction richer. RFID (Radio Frequency Identification) is a system for storing and remotely retrieving data which allows the identification of an object from the distance with no contact. In the same way, NFC (Near Field Communication) standardizes the way in which smartphones and other mobile devices establish radio communication with each other by touching them together or bringing them into proximity. Regarding Web communication we could mention Web Services as a set of protocols and standards to exchange data between applications providing interoperability; however, Websocket goes a step further and provides full-duplex communication channels over a single TCP connection. It can be used by any client or server application providing real-time interaction through the Web.

HTML5, Android OS, Windows Phone, iOS as well as many other technologies, and research fields around them provide amazing challenges and design opportunities. User interface distribution is becoming a really interesting research topic because of the nature of such advances. Even more, we could talk about real necessity more than mere opportunities.

**DISTRIBUTED USER INTERFACES**

GUI (Graphical User Interfaces) formerly thought to be used for PC-based software applications and controlled by a mouse and a keyboard are no longer enough in the new scenarios where we have multiple devices and displays. In these cases, other kinds of interfaces are necessary. DUIS (Distributed User Interfaces) have been conscious or unconsciously used and defined in many different ways in the near past.

As Niklas Elmqvist [7], Jean Vanderdonckt [19] and other researchers state, the specialized literature is plenty of references highly related to distributing the user interface, as in [9, 2], among others. We can find Migratory and Migratable Interfaces [3] to describe applications capable of roaming freely on the network instead of being confined to a particular computer. Plasticity [18] is a concept defined as the capacity of a UI to withstand variations in both the device and its physical environment while preserving usability. The aforementioned Multi-Device Environment (MDE) consists of multiple, heterogeneous and distributed devices, displays and surfaces. Also Ubiquitous Computing was previously introduced; it integrates data and computation into everyday objects and activities. Other connected terms are Multi-Device Interaction Techniques, Application and Content Redirection. Lastly, Niklas highlighted CAMELEON-RT as a middleware software infrastructure for distributed, migratable, and plastic interfaces 1.

Some approaches to a definition of DUI may be found in recent past years [6, 15 19]. However, after several workshops on Distributed User Interfaces where researchers have deeply discussed about this novel research field, we have found the definition given by Niklas [7] as the most appropriate, also assumed by many other authors subsequently. DUI was then described as “a user interface whose components are distributed across one or more of the dimensions input [so called input redirection], output [so called display or content redirection], platform [i.e., architectures, operating systems, networks, etc.], space [i.e., co-located or remote interactive spaces], and time [synchronous or asynchronous]”. The wording in square brackets corresponds to some comments he made after the definition.

In order to get an in-depth understanding of the need of distributing user interfaces, Donatien Grouiaux, Jean Vardendonckt and Peter Van Roy illustrated us with a really appropriated metaphor: a painter painting a scene [10]. In such scenario, the painting is the main focus of attention, while the rest of tools remain secondary. If we consider a software tool for painting, the colour palette, the pencil, the painting tools, etc. are allocated on the screen in different positions. Although they are well-grouped, the user interface collapse with so many information altogether, and it is not considered natural [13]. It is true that many possible configurations are available so that the user can
modify the layout of toolbars when needed, but still no natural and uncomfortable. We could design a more natural interface making use of different displays. Each display allocated in a similar way as it would be allocated in a real scenario. The main objective would be the same: painting. There would be still only one application. But several user interfaces in different devices could make it more natural. This is just a small example to show the power of distributing the user interface. Applying this minor example into our daily reality is much more complicated. That is the reason why researching on DUIs is more and more trendy. If we put together the complexity of nowadays applications and the aforementioned dimensions of DUIs (input, output, platform, space and time), it is not only a matter of quality, but a matter of necessity. We also depicted the distribution of user interfaces according to the users’ mental models, splitting the interface of collaborative games on a projector to be displayed more clearly. Mobile device interface were used as interaction devices between the main interface and several tangible user interfaces.

Up to this point, the concept of DUI has been adequately explained. However, if we would like to go further on, we also could consider how to dynamically deal with such user interfaces in the developed applications. To do so, Grolaux [10] defines a set of properties as the basis of what they call a detachable user interface: “detachability [any UI component of the interactive application of interest can be detached from its host UI], migratability [the detached UI component is migrated from the source computing platform […] to another target platform], plastifiability [the migrated UI component is adapted according to the new constraints posed by the new target computing platform], attachability [the plastified UI component is attached to any UI running on the target computing platform, if needed].”

The wording in square brackets corresponds to some comments he made.

Although it is practically not considered [7] in the definition of DUI, collaboration is still a highly important concept to take into account. It was not included since users were not considered as a distribution dimension; nevertheless, space/time dimensions of CSCW are specifically mentioned in the definition. Besides, due to the nature of nowadays applications, technology and the use of devices by users, we also consider collaboration as a key issue to keep in mind. Empirical studies [14] indicate that the distribution of shared and private workspaces to support balanced participation in face-to-face collaboration is very important in collaborative settings.

GUIDELINES TO DESIGN DUIS

As stated above and according to the visions presented in previous editions of the workshop on DUIs and our own expertise in this area, we may summarize a number of key points to be considered as important subjects to cope with in the development of DUIs. It is important to notice that the main perspective we consider regards Human-Computer Interaction research field. As can be imagined, the distribution of the user interface implies many other fields which are also well appreciated. Interaction techniques such as touching, scanning, approach&remove and movement based interaction through motion sensing input-output devices, among others, determine the success of these systems. Traditional interaction techniques could be also good ones; however, analyzing the most adequate interaction in such a specific system becomes a key factor.

Q1: What are the most appropriate interaction techniques?

Tangible User Interfaces (TUI) is also closely linked to interaction as implies a new way of interacting with software applications. Everyday objects take part in the distribution of user interfaces and interactions, which makes the development of systems more difficult, but makes the interaction and participation easier for many users. TUIs and the big amount of new devices that invade our everyday life drive us to consider the principles of Multi-Device Environments (MDE) as well as the idea of Ubiquitous computing: anytime, anywhere, anywhere, if possible. Q2: What are the devices working in the whole system? Q3: How do they communicate with each other? Q4: Where are they allocated?

In accordance with the assumed definition, we should consider the mentioned dimensions: “a user interface whose components are distributed across one or more of the dimensions input, output, platform, space, and time”. Some of these basics are partially included in the previous questions; however, we may still wonder about substantial points. Q5: What parts of the user interfaces should we distribute? Q6: What are the main features of the different platforms, mainly according to compatibility, interoperability, etc.? Q7: What tasks are thought to be performed synchronously and what asynchronously? Q8: Are all de UIs thought to be co-located in the near space or in different spaces?

For a more in-depth consideration, Grolaux et al. [10] defined a set of properties as the basis of what they called a “detachable user interface”: detachability, migratability, plastifiability, attachability. If considered, we also may pose another question. Q9: What components of a UI may we compose and decompose?

Sangiorgi et al. describe a set of challenges for distributing the user interface [17]. They finish the discussion with an interesting message: “The list of challenges presented on this paper is intended to bring the discussion of “old” problems of collaborative systems to the contemporary context”. That is what, beyond the collaboration concept, we propose with this paper. Anyhow, once more we should realize about the importance of considering what users do in the whole system: collaboration as well as awareness. The four challenges they introduce for a distributed sketching system take into account user awareness as a first issue: “make users aware of each other’s activities […]”. Furthermore, by having such a large number of possible
devices and an “infinite” workspace to work on, it is hard to keep track of which devices are observing specific parts of the wall.” Then the problem of pointing remotely: “how to “point” at something remotely?” Other important factors are concurrency and conflicts. Lastly, what they introduce as a novel subject is considering “the right tool for the job: Not all the devices have the same resolution or performance […] which devices are suitable for the […] activities”. Q10: In what way users collaborate, coordinate and communicate? Q11: How can the user be aware of what the other users of the system do? Q12: Where may we find concurrency problems and other conflicts? The problem of “pointing remotely” and “the right tool for the job” are somehow included in previous questions, mainly regarding interaction techniques.

Lastly, keeping always in mind that technology evolves quickly, the state of current technology should also be considered as a fundamental issue. Technology such as RFID (Radio Frequency Identification), NFC (Near Field Communication), HTML5, Android OS, Windows Phone, iOS enriches interaction and provides new ways in the distribution of the user interface. Designers and researchers need to keep abreast of new developments in the field. The last question is Q13: Are we using technology properly or is there any other that could solve the problem more accurately? This last question is a really generic one, which could be used in the design of any kind of system; however, how not mention it?

CONCLUSIONS
In this paper we have presented twelve questions as guidelines that designers might consider when addressing the design of applications based on Distributed User Interfaces. These questions pose a set of problems or situations that designers should take into account in these environments. In this way, key aspects regarding would be explicitly addressed. Another last guideline just highlights the importance of using the appropriate and cutting-edge technology. These 12 + 1 questions are a synthesis which comes from the expertise of a number of researchers who are experts on DUIS. These guidelines do not intend to be a must, but just another piece of the puzzle that may be helpful in this research field.

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REFERENCES


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