Paper Computing

Diamantino Ferreira
diamantinorgf@gmail.com

Roberto Dias
rob180@hotmail.com

ABSTRACT
In this work, we will introduce the main features of a paper computing system, their advantages and how they can be used to improve our everyday activities. We will understand the main advantages of paper when compared to digital systems and analyze some examples of paper computing systems. The final part of our work is about future speculations in this area and how it has evolved during the last few years. We will conclude that a vision of a paperless world is far from true and that paper based systems can and will be a part of our future.

Keywords
Paper, interface, digital systems, pervasive computing, papercomp

INTRODUCTION
Before the advent of computers, paper was the prime choice for storing, organizing and transmitting information. Its durability, coupled with the versatility of the printing press, became a factor in the economic and scientific developments [1]. Despite claims that flexible and non-emissive display and input technologies will eventually render paper obsolete overtime, technologies haven't matured enough to fully replace books, newspapers, or notepads, which is why they are still extensively used nowadays.

In this work, we start by underlying the main advantages of using paper as an interaction system instead of the usual computer interfaces. We will address one of the first paper computing systems and understand their results and conclusions. Next, we will analyze the main components of a paper computing system, and describe them in detail where it can be used, and which advantages this technology can offer over the standard computing systems. We will then finalize this paper by speculating how these systems will evolve in the future according to the pioneers in this area.

ADVANTAGES OF PAPER
Various studies confirm paper has inherent advantage over electronic platforms in many forms of activities. Paper sheets can be bent, folded, shredded, recycled, stapled and written on at a very low cost and without the need for software upgrades or everlasting battery supplies. Despite the prediction of a paperless future, paper documents are still widely used in our everyday activities. Paper is not dead [2].

DIGITALDESK
The first clear vision of paper computing potential remotes to the DigitalDesk, by Pierre Wellner. The system's aim was to combine both advantages of a virtual desk and paper documents on a real desk. This was done by adding the computer to the real world and creating a computer augmented environment for paper [3].

The DigitalDesk has the following three important characteristics: it projects electronic images down onto the desk and onto paper documents, it responds to interaction with pens or bare fingers, and it can read paper documents placed on the desk. Some basic applications were supported, such as the Paper Calculator. It allows people to place ordinary paper documents on the desk and simply point at a printed number to enter it into the calculator. Paper Paint, one of the supported applications, however, makes it possible to select and paste paper documents in the same way that we select and paste electronic documents. In Paper Paint, a sketch on paper can be electronically selected by sweeping out an area of the paper with a stylus; displays a rectangle on the paper to indicate what is selected, and the user can manipulate each area wherever he wants to.

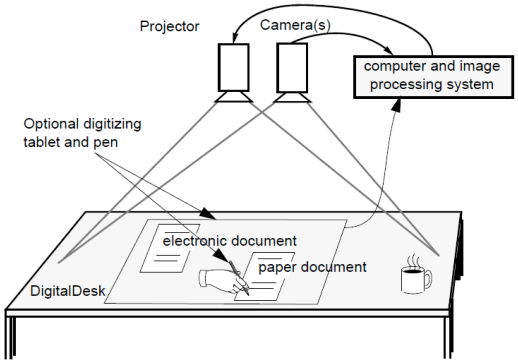

Figure 1 – Schematic diagram of the DigiDesk platform.

This work can be seen as a step towards better integration of paper documents into the electronic world of personal workstations, making paper-based information more accessible to computers.

BASIC COMPONENTS

From our research over several devices, we concluded there are 3 major parts in any paper computing system. These are the recognition system (that can be done by either a camera or a sensor), the decoding mechanism (that varies a lot depending on the system, for example it can be an image recognizing algorithm, like data bit-strings, [7] or pattern recognition, and the projection system (which may be a monitor, or paper itself trough a camera projection).
However, these are not the fundamental structure for every paper computing system; there may be some differences in certain systems that adopt a different architecture and purpose.

EXAMPLES OF PAPER COMPUTING APPLICATIONS

Direct Latitude/Longitude Identification of Paper Maps Using a Camera Phone

This system adopts a new technique to embed geographical coordinates into paper maps and directly identify them using a camera phone, which is particularly useful for travelling. Through a simple photo from the camera, the system can easily trace back the map coordinates for that region, which can be exchanged with GPS devices to find the way around. This provides real-time recognition via print maps on most commercial mobile phones. Unlike other map recognition systems, this new technology does not match camera images with map images which usually leads to failed matching; instead, it uses methods that embed geographic coordinates into paper maps invisibly, and recognize the coordinates directly by patterns instead of comparing them with matched data.

The decoder works on camera phones and provides direct recognition of embedded latitude/longitude geographic coordinates from a camera preview image. The following show the decoding steps: detecting the map grid (by line detection and corners), determining bit-strings by comparing blue levels (The decoder computes the screen positions of all embedded blocks from the grid corners and makes a list of blue levels for the same. The next part is determining data bit-strings by a majority (The decoder divides the bit-strings specified in the previous step into N parts and a majority vote of the same for each bit decides the data bit-strings in the third step) followed by the error detection and correlation of the data-bit strings (Errors in the data bit-strings are detected and corrected by decoding the BCH codes included in the data bit-strings). If the error correction succeeds, the original data, namely the latitudes and longitudes of the top-left corner, the latitude range from top-left to bottom-left corner, and the longitude range from the top-left corner to the top-right corner are decoded. Where the error correcting fails, the decoder reverts to the second step and tries to acquire data from another direction).

Searchable Books

Representation of information is increasingly becoming digital. Yet, paper books remain popular, as many readers prefer the reading experience that paper books provide, which digital interfaces cannot. In this example, the goal is to improve users' reading experience by enhancing books with digital functionalities [6].
This application can be used on a mobile phone to scan trough a book with a camera, recognize the information, and ultimately be able to search any contents within the text. In essence, we are virtualizing books, keeping both the physical and virtual paper advantages.
Historically, paper has been the preferred option because of its availability, lightweight, as well as its low-cost economic value and other benefits. If paper books could adapt digital books' characteristics, the main functionalities to include would be searching, interactive information and input recognition for faster browsing.

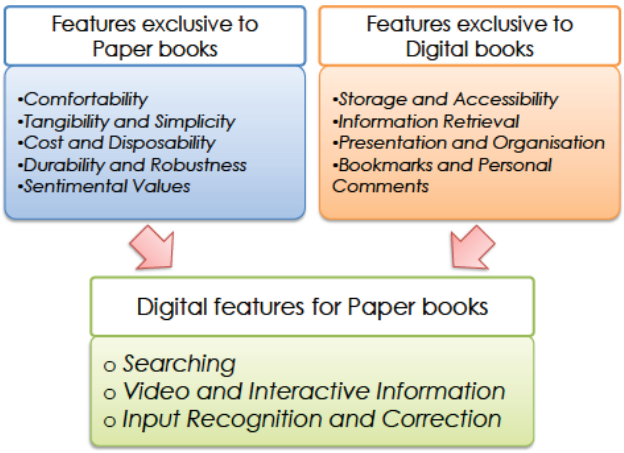

Figure 2 – Advantages of both systems.

A Paper Interface for Code Exploration

Paper Code Explorer, a paper based tangible interface for code exploration. This augmented reality system is designed to offer active exploration tools for programmers confronted with the problem of getting familiar with a large codebase.
Programmers are often challenged with the problem of getting familiar with large amounts of code, methods, classes and relations. In a typical scenario, new programmers coming to an institution have to learn about a project in order to start their own contribution.
Paper interfaces intend to provide computing abilities to paper, while trying to keep its simplicity and advantages over electronic devices; in this case the simplicity is achieved by a simple tangible class diagram.
Each class was represented by a box containing three boxes: one for the name of the class, one for the list of the name of the fields of the class, and the list of the name of the methods of the class. Paper Code Explorer is a software meant to be used with an augmented lamp, i.e. a projector and a camera above a desk. We print flash cards containing

the name of the class, the list of its members, and a tag allowing Paper Code. This way, programmers can easily browse through classes, edit methods trough simple steps, and preview their changes on a large class diagram display. One of the main advantages of this application is the quick and intuitive code editing; the user only needs to select a class to edit its contents, and by selecting a method or variable will automatically highlight it. He can thereafter apply the changes he wants in the computer and update them in less than a second. Another solid advantage is that it allows users to quickly detect any design issue by taking a look at the global class diagram.
Paper Code Explorer is integrated in the Eclipse environment, which provides a very mature framework to handle code, and is easily extensible and customizable [5].

In this example the interaction zone is limited to the area covered by the lamp, which is comparable to the one of a screen (or in this case, the table). However, the advantage of a paper interface is that the menu can exist outside of this area. The user does not have to find a compromise between accessibility of various actions in menu and the space allocated to objects. Moreover, the same manipulability advantage of paper applies to actions: they can be organized and grabbed easily. Command results being linked spatially to them can be moved in an equally easy manner. This also gets rid of the annoying cross-referencing activities between classes by simply highlighting a method, and it also makes it easier to check both the source code and documentation (which are the 2 options that pop up every time we click on a class).

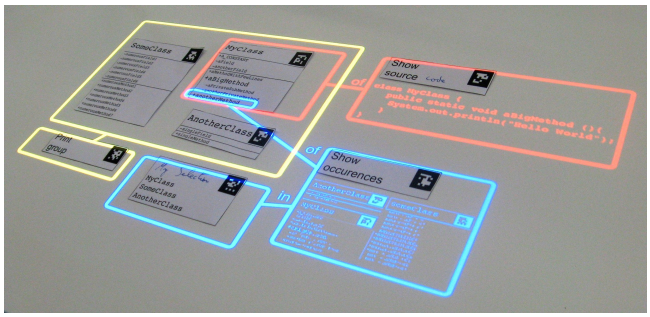

Figure 3 - **Three classes (**MyClass, SomeClass and AnotherClass) are used for this illustration. The paper command **show source** is applied on MyClass, and projects its result in red. The paper command **print group** has been used to produce the paper object representing the three classes circled by the yellow box. The surface taken into account is delimited by a yellow projection. The paper command **show occurrences** is applied on one of the methods of MyClass, and the resulting set of class is restricted to the previously mentioned group. The results are projected in blue.

INTEGRATION WITH OTHER AREAS

There are a variety of interactive paper applications covering different domains. In addition to different hardware solutions, there exist a number of software frameworks for the digital pen and paper technology. In the remaining part of this paper, we would like to outline some future technical as well as non-technical challenges to stimulate a discussion between interactive paper application and framework developers [4] as well as which areas of knowledge can take use of this technology.

Education

Paper computing has a prominent future in the education area; its appealing features in the augmented reality area generate a lot of possibilities that can help younger children interact with books in situations they would normally not.

The augmented reality vision also creates a more interactive environment that has been proven to be very popular between children and can be used effectively for both pre-education students (with either story books or augmented drawings) to even college students and workers (with advanced note taking systems). Engaged by both physical and digital dimensions, users are no longer constrained by traditional story writing means, but instead, are encouraged to explore stories as multisensorial experiences [7].

Entertainment

Entertainment is also a big part of the paper computing industry. There are endless possibilities in games or entertainment applications that can be brought to life with paper computing technology. From all kinds of virtual reality systems, we can create strategy, real time or even turn based games that rely on interactions with paper. Augmented reality also opens many possibilities in this area, and the rich interaction offered by these systems is something that will not go unnoticed in future.

Distance collaboration

Another point of interest in paper computing is the ability to create virtual work stations around the world with virtual organizations. This enables workers to complete their work anywhere, anytime and there can be a myriad of applications to allow collaborative work based on a shared paper interface, similar to the early stage DigiDesk.

There have been many applications following this model, and in future we can only expect these to grow and perhaps change our working standards.

Portable utilities

There are a lot of things to be said about this area in regards of possible portable applications. We have analyzed some examples earlier in this article in the examples section, and can only conclude that these industries will grow larger every year. There are countless new applications of this kind, from Anoto pens [8], Note taking systems, writing and even map recognition can all be a part of our future. With the latest trend of mobile technologies and the development of new and improved mobile platforms, we are able to integrate a larger number of modern features into these devices.

PAPER COMPUTING: THE FUTURE?

Over the last few years, there has been a significant increase in the number of researchers dealing with the integration of paper and digital information or services [9]. In the early 1990s, the visionary Mark Weiser described a scenario of how intelligent paper might be integrated into future working environments. This has opened new ways of thinking and application development. However, one might think how these will evolve in a near future. As we have seen previously, there is a rich domain variety on which paper application can be built around, which require different hardware solutions. These can often create technical and non-technical challenges around the following areas:

Device Independence - The interaction with the application logic of an interactive paper solution should be decoupled from any device-specific details. This enables an easy migration of applications in the case that new devices become available by just implementing the necessary device drivers [9].

Digital ink abstraction - Open and standardized data formats might help to not only exchange information across frameworks but also enable the integration of pen and paper data with other types of media to realize generic mixed-reality environments.

Application deployment - Currently, most interactive paper applications are isolated solutions without any potential cross-application interaction. In general, a user has to ensure that they have installed the right application before they start to interact with a document. In the future, it might be worth investigating a service-oriented architecture where interactive paper applications can be automatically downloaded and installed on demand based on specific pen and paper interactions. This will ultimately contribute to a faster and more portable application Framework.

Interaction design - Similar to the lack of visual guidelines, there are no rules on how to design the interaction with an application and it might be worth investigating digital pen and paper interaction strategies. There are many design differences that produce completely different scenarios with different user needs and priorities. This must be taken into account in order to use a better user experience.

DISCUSSION

The development of interactive paper solutions has become a very active research area. While different interactive paper frameworks support the application development, the question is whether these frameworks are missing a common abstraction layer [4]. It might be the right time to reflect and share some wisdom. The definition of common data formats and design guidelines could be a first step towards real cross-application and cross-framework interoperability. There is also the need to debate whether these applications, despise being useful in practice, can be an economically viable source of investment.

One of the most challenging obstacles to overcome would also be the need of precise cross-application operability, as well as more advanced data recognition, data processing and rendering algorithms that fit a useable device on our everyday use. Afteral, that is the main premise of Weiser's vision.

REFERENCES

[1] Coelho, M. et al. "Pulp-Based Computing: A Framework for Building Computers Out of Paper." Proc. Ubicomp 2007, ACM Press ed.

[2] Káplan, F et al. " First International Workshop on Paper." PaperComp 2010.

[3] Wellner, P. "Interacting with Paper on the DigitalDesk." 1993, ACM Press ed.

[4] Singer, B et all "Interactive paper: Past, Present and Future", 2010 Paper Comp

[5] Bonnard, Q et all, "A Paper interface for code exploration", 2010 Paper Comp

[6] Chong, M et all, "Improving paper books: Searchable books", 2010 Paper Comp

[7] Follmer, E et all, "The Never Ending Story telling Machine: A Platform For Creative Collaboration Using a Sketchbook and Everyday Objects", 2010 Paper Comp

[8] Olberding, S et all, "Towards Understanding Erasing-based Interactions: Adding Erasing Capabilities to Anoto Pens", 2010 Paper Comp

[9] Signer, B et all, "Interactive Paper: Past, Present and Future", 2010 Paper Comp