Interaction with Electronic Paper: Defining Properties and Affordances

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Abstract

Electronic paper has not reached a final stage but different approaches were already tried, in order to simulate possible interactions fostered by this technology in the future. Independently of the approach taken we believe that it is possible to define a set of properties, affordances and interactions of future electronic paper, as discussed in this paper. In addition, we present the current main challenges for electronic paper interactions.

Author Keywords

Electronic Paper

ACM Classification Keywords

H.5.m. Information interfaces and presentation (e.g., HCI): Miscellaneous.

General Terms

Human Factors

Introduction

Electronic paper is still an under development technology [13, 17] and there is not a clear definition of this technology [13]. Signer and Norrie [27], start to distinguish between *electronic paper* and *augmented* or *interactive paper*. The first approach makes existing devices similar to paper, whereas the second augments

paper with digital information or services. Like Signer and Norrie, we also consider that this division of concepts will be valid until a final stage of electronic paper will be achieved. This final stage will combine digital technology with paper so deeply that will be hard distinguish between *electronic paper* and *augmented* or *interactive paper*.

Different approaches were tried [27] in order to simulate interactions that will be possible with electronic paper. These approaches can be divided in three main categories: projections in physical paper with human gestures detected by cameras, multitouch tables and the already commercialized tablets or slates. Independently of the approach taken it is possible to define a set of properties, affordances and interactions of future electronic paper.

Most of the research and discussion about this topic has been focused on reading tasks and on electronic books [24, 26]. Only recently, some research work uses regular paper interactions for multimedia tasks [5, 20]. In this paper, we hope to contribute to a more broad discussion about this future technology, its future interactions and the current challenges to achieve them.

Properties of Electronic Paper

In order to electronic paper be so useful and popular as paper, it needs to have some important properties:
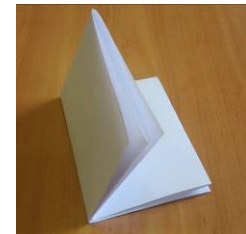
Mobility
One of the most properties powerful about paper is being weightless. This physical property fosters the portability of paper where ever one wants to go. Therefore, being mobile it an essential property of

electronic paper. The mobility property should not be limited to a physical property. As digital device paper should be also mobile in issues like energy or Internet and document access.

a)   b)

Figure 1. Reducing paper size: a) original paper sheet size and b) paper sheet folded

Stiffness
Being flexible or not is an intriguing issue for electronic paper. Flexibility is well known property of paper but is a real advantage of paper? Usually, paper folding and bending tasks is more used for reducing size (Figure 1), adaptation for non flat surfaces (Figure 2 a)) or for construction of figures, like in origami (Figures 1 b) and c)).

a)

b)   c)

Figure 2. Folding paper: a) adapting to non-flat surfaces, b) and c) paper figures

In the case of paper content, flexibility can work as an advantage for search tasks, like flipping pages [26], but can also be disadvantage, as reading a folded newspaper, as shown in Figure 3.

Figure 3. Reading a newspaper.

Although, there is some interesting research about interacting with flexible digital devices [18], we believe that in some cases this not represent the most familiar interaction and in others can be meaningless, e.g., why should one folder a device to see a document below if one device can display more than one document? On other side, works like Xpaaand [16], which change the display size by folding it, correspond to a more familiar interaction (Figure 1). This ability to reduce size of devices just by folding them is also an important issue for mobility.

Extensibility
One interesting feature of digital technology is the ability to attach other devices or sensors, e.g, keyboards, cameras, storage devices (Figure 4). Electronic paper should also have this ability, in order to enhance the future device with other devices or additional sensors.

Figure 4. External devices: a keyboard, a webcam and pen drive.

Storage
The ability to store data should an essential property of electronic paper. In contrast to regular in which the quantity of data is proportional to physical quantity of paper, digital devices allow the storage of huge amounts of data in small physical space. Although, storage capacity can be extended using external devices like external harddrives or cloud services, it is crucial to keep some storage capacity in electronic paper. This internal storage will help to maintain the mobility property of electronic paper. A constant dependence of external storage devices or Internet access will reduce the number of places and situations where the future device can be used.

Affordances of Electronic Paper

The affordances of electronic paper can be discussed from the affordances of digital technology and paper. The affordances of each are described in the book "The Myth of the Paperless Office" [26], as described in Table 1. Even though, the presented affordances were initial described for "reading", the ability of digital technologies to display and process different media, like video, they can easily be transpose for "watching".

Quick, flexible navigation through and around documents
The use of bookmarks, touch displays and additional side buttons are essential to replicate document navigation based on paper.

Reading/watching across more than one document at once
Different approaches can be used on digital technology, in order to allow the display more than one document at once. The most direct solution is the display of two or more documents in a same screen. However, this approach presents the disadvantage of reducing the size of window document, making harder do read or watch, particularly if more than two documents are being displayed. Dual-screen devices [8] as well as the use of multiple devices [9] can also be used for access or display of a set of documents. The use of multiples devices is highly depended of the cost of each and the usage of a computer network, particularly for accessing the same set of documents in different displays or devices.

Marking up a document while reading/watching
Since the XLibris [25], different attempts were made in order to allow free-forms of annotations. Current tablet software supports efficient methods for annotations, although, there is always space for improvements [11]. Considering, the ability of digital technology to play different media, like video or audio, annotations can be

	Quick, flexible navigation through and around documents	
	Reading (watching) across more than one document at once	
Affordances of Paper	Marking up a document while reading (watching)	
	Interweaving reading (watching) and writing	Affordances of Electronic Paper
	Storing and accessing large amounts of information	
	Displaying multimedia documents	
Affordances of Digital Technologies	Fast full-text searching	
	Quick links to related materials	
	Dynamically modifying or updating content	

Table 1. Affordances of Paper and of Digital Technology for Reading [26] transposed for *electronic paper*.

made in time-based documents [4, 28] or even using different modalities [5].

Interweaving reading/watching and writing
The ability to use different layer for annotation [4, 11] in digital devices, enables to separate notes from original documents. However, the use of a single and small device cannot be sufficient for a paper-like interweaving between reading, or watching, and

writing. The use of multiple displays [8] or devices [9] can help on this task.

Storing and accessing large amounts of information
Digital devices are well known for the capacity of storage of large amounts of information. As Lynch [21] referred "Think of portable libraries, not portable electronic book…". Electronic paper will work as portable libraries not only of books but of musics and

videos. Even tough, storing in a single device can be a limitation, the usage of external storage, by other physical devices or a network, can easily expand the capacity of storage of one single device.

Displaying multimedia documents
The ability to display any type of media in a paper-like device is one of the most powerful affordance of electronic paper when compared with regular paper. Watching a video or a TV show in a light and portable device can deeply change how we face media.

Fast full-text searching
Image you could search for a keyword in all your paper documents or notebooks. Great, no? However, the usage of digital technologies allow more than that, searching images by sketching [7] or by similarity [googleimages] can improve the options and interactions of searching tasks.

Quick links to related materials
Having access to the Web in a paper-like device can be very interesting, particularly using search engines, like Google or Bing. However, annotations can also lead to hypermedia [23] or be used to search related content [15].

Dynamically modifying or updating content
Editing a document or a note on-the-fly can reduce the waste of paper drafts usually made on working processes. As a digital technology, we should not restrict editing activities to text documents but think that can also include audio or video editing.

Interacting with Electronic Paper

Tangibility is a main property of paper [26]. Therefore, electronic paper should also be tangible and take advantage of touch interfaces. It is common to use both hands, i.e., multitouch interaction, when interacting with paper. However, the usage of pen-based technology is essential for writing notes and sketching activities [2, 22]. This bimanual, pen and touch interaction, emulates paper interactions (Figure 5) [14, 26], which its familiarity was already proven by user studies [3, 19], and should also be adapted to electronic paper.
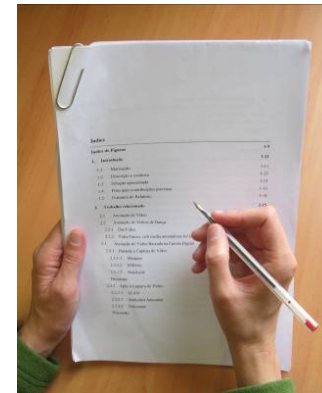

Figure 5. Pen and touch interaction on paper.

The development of pen-based and touch interfaces can transpose already known paper tasks, like paper cut [14], but can also be adapted to other activities, like video manipulation and editing (Figure 6) [5, 20].

Figure 6. A pen-based approach to video editing using a tablet computer [5]

Nonetheless, as Backon [1] pointed out that the keyboard fosters productivity, whereas the pen fosters creativity ``as an extension of human hand and several regions of the brain''. Therefore, being able to use a keyboard on electronic paper, in the same that paper what used in old typewriters (Figure 7) can be essential for long text production activities like book or report writing [24].

a)

b)

Figure 7. Keyboard usage for long text documents: a) Old typewriter b) Tablet with attachable keyboard.

Since electronic paper will be mainly a digital technology, it should be possible to take advantage of additional sensors like cameras or microphones. The usage of such sensors can improve interactions and tasks, which can be hard to accomplished using regular input interfaces, e.g. audio or face recognition for logging in into services [12].

Paper is quite used in collaborative work situations [26]. Electronic paper should also follow this rule. If the future device presents can be portable and presents all the affordances described above, we believe that collaborative interactions using electronic paper will only depend on particular software features, e.g., different annotation layers for different users [11].

Ongoing challenges

Because electronic paper is still an under development technology, as already referred, a set of challenges still to need to be faced until a final stage is achieved.

Optics and light

One critical aspect of electronic paper is the optics of the display. Most of the current developments [13] and e-readers do not present internal light in order to facilitate text-based document reading. How this technology issue can be compatible with the display of images and videos still needs an answer. However, being able to display text, images and video is crucial for the usefulness and sucess of electronic paper.

Cost

The cost can influence to usage of more than one device at the same time. A high cost of the device can limit an user to have one device without taking advantage of the benefits of multiple devices at the same time, like accessing two documents with using two devices as two sheets of paper [9].

Pen-based Technology

As Marshall [22], pointed out, pen-based technology is a familiar input for writing notes but in order to take full advantage of this technology, interfaces have to be better designed for these pen interactions [24]. Advances on recognition of handwritten notes can also help on text search operations.

Batteries and Electric Supply

Batteries that can provide sufficient energy for at least one working day but without increasing much of the weight of the device will be crucial of the success of electronic paper. No one will rely on a technology, which is supposed to be similar to paper, if it will fail in a middle of a working meeting or a lecture due to the lack of energy.

Multimedia Interfaces

One of the key advantages of electronic paper is the ability to work and display different, like audio or video, when compared to regular paper. Even though, there is some recent research [5, 20] about the usage of pen and paper interactions for multimedia browsing or editing, we believe that there is still a lot of space of improvement on this topic.

Conclusions

In this paper we have discussed a set of properties, affordances and interactions that should possible in future, using electronic paper. We also presented the current challenges, in order to achieve the interactions fostered by this technology.

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