Dedicated E-reading Devices: the State of the Art and the Challenges
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Abstract
Dedicated electronic text reading (e-reading) devices hold the potential to drastically improve e-reading experiences. Nevertheless, up to now they remain in a niche market. This paper surveys existing dedicated e-reading devices and related research to examine the state of the art and the challenges. Firstly, it briefly recounts the evolution of e-reading devices; secondly, it examines the development and issues regarding several critical aspects of this type of device, including form factor, display, interaction methods, connectivity, and e-text distribution methods; finally, it analyzes the reasons why these devices have not become mainstream, and speculates on their future.

Keywords: electronic text, reading, human factors, e-paper

Introduction
With the explosive growth of textual information in electronic form, finding the right tool for reading electronic text (e-text) is becoming increasingly important. There are many ways to read e-text. People can read e-text on the screen of their desktop computer, but in doing so become restricted in front of their workstation; laptop computers free people from the location restriction, but the customary landscape screen layout and the mouse-keyboard interaction paradigm make it sub-optimal for reading and interacting with e-text; tablet computers improve the form factor of reading devices, and support pen-based interactions, but still suffer from issues such as heaviness, short battery life, and eyestrain associated with computer screens; highly portable devices such as PDAs and smart phones are prized for their compactness and light weight, but their small screens make them unsuited for reading lengthy text. Ironically, while the primary source of many of today's work-related documents is e-text, a lot of people still prefer to print out these documents for reading, rather than reading them on screen. This practice does give users some of the benefits of both the paper and electronic media. Nevertheless it involves the extra step of printing out the documents, which is inconvenient and sometimes impossible for travelling readers. Moreover, once printed, the paper version becomes static and disconnected from the electronic version, and cannot reflect changes made to the electronic original; vice versa, annotations made on paper are not reflected on the electronic original and become difficult to manage.

Dedicated e-reading devices have been considered the right tool for e-text reading. Lemken (1999) defines e-book readers as “mobile, physical devices to display electronic (i.e. Digital) documents” (p1). Schilit et al. (1999) call for electronic reading appliances that not only imitate the best quality of paper, but also allow people to exploit extra capabilities, such as distributing and receiving documents on the road, organizing, searching and filtering documents, and providing support for different modes of reading. Marshall and Bly (2005) envision devices that “let readers annotate, clip, search, gather and interact fluidly in ways that not only captured the affordances of paper, but also transcended paper's limitations” (p225). These comments illustrate the high hopes
attached to dedicated e-reading devices. However, dedicated e-reading devices currently occupy only a niche market. This paper surveys existing devices and research in the field, examining the state of the art, the direction of development, and the challenges that researchers in the field are facing. Section 2 recounts the evolution of e-reading devices; section 3 examines critical aspects of these devices, including form factor, display, interaction methods, connectivity, and e-text distribution methods; finally speculations on the future of e-reading devices are presented.

Brief history of dedicated e-reading devices
The vision of electronic reading devices has a long history. Alan Kay and others at Xerox PARC envisioned an interactive electronic book in the 1970’s (Schilit et al. 1999). However, early attempts to turn the vision into products mostly failed. The first e-book reader, the Sony Bookman, was released in 1992. It was CDROM based, heavy, hard to read, expensive, and it proved to be a spectacular failure in the market (Coburn et al., 2001). Towards the end of the 1990’s, interest in e-reading devices reached new heights. SoftBook Press’s SoftBook and Nuvomedia’s Rocket e-book were released in 1998. In 2000, Gemstar bought both Nuvomedia and Softbook Press, and cooperated with Thomson Multimedia’s RCA division to produce REB-1100 (the successor of Rocket e-book) and REB-1200 (the successor of Softbook). These devices can hold dozens of books in their memory, with a battery life ranging from several hours to 20 hours. They tended to be bulky and heavy (more than 1 lb; the SoftBook weighed as much as 3 lbs). These “second generation” e-reading devices also failed to achieve market success. With the crash of technological sector in 2000, enthusiasm for e-reading devices subsided, and some devices in development, such as EveryBook reader and Librius Millenium, were cancelled (Coburn et al., 2001).

The development of e-paper technology spurred another generation of e-reading devices. Many new devices have been launched since 2006. Some notable examples are the Sony eReader, Amazon’s Kindle, the iRex iLiad, and the Hanlin eReader made by the Chinese company Jinke, all of them using the display produced by E-Ink Corporation, one of the most successful vendors of e-paper technology. These devices are easier to read, especially in direct sunlight. They have much longer battery life, usually enough to display 5,000 to 10,000 pages, which translates into many days of reading for typical readers. They are also much lighter, making them more comfortable to hold for long-time reading. They all come with hundreds of megabytes of flash memory, enough to hold several hundred books. While there is no lack of enthusiastic followers of these devices, it still remains unclear if they can break into the mainstream.

Critical aspects of e-reading devices

Form factor
One of the most important advantages of books as reading devices is the form factor. Their page sizes are large enough to support sequential reading, skimming, annotation, and many other reading activities. Yet they are generally light, small, and highly portable. They can be carried anywhere, and read in any position that the reader is comfortable with. Successful e-reading devices need to fulfill the same form factor requirements. While the earlier generation of e-reading devices were usually normal book sized, they tended to be heavier than most books. In Wilson and Landoni’s studies (2003), both the SoftBook (over 3lb.) and the Rocket eReader (22 oz.) were found heavy and cumbersome. E-paper technology allows the newer generation of devices to be much lighter, usually well below 1 lb.

However, while the e-reading devices are close to books in terms of size and weight, they typically offer a display size considerably smaller than a book’s page size, not to mention that an opened book allows readers to see two pages at one time. Having two display surfaces at the same time is more than just a matter of screen real estate. Alder et al. (1999) found that more than half of the tasks that people perform during work-
related reading require two or more separate display surfaces. Card et al. (2004, cited by Chen et al., 2008) argue that viewing two pages side-by-side helps comparisons and sense making. There has been much research and commercial interest in dual-display e-reading devices. In 1998 Everybook Inc.’s prototype dual-LCD device raised significant media attention (Martin, 1998). In 2007, iRiver also demonstrated a prototype device with 2 touch-sensitive e-ink displays (Block, 2007). However, neither of these devices reached the market. In May 2008, One Laptop Per Child (OLPC) announced that the next generation of OLPC laptop would have two touch sensitive screens in the form of a foldable e-book (Greenberg, 2008). Chen et al. (2008) report a unique prototype dual-display e-book reader. The two displays of their prototype can be detached to allow greater flexibility and to better support reading involving multiple documents.

Flexible display technology goes further to provide both portability and adequate display size. Traditional computer screens require rigid, usually glass backing. However, researchers are developing paper-like displays with a flexible substrate such as metal foil or plastic. Polymer Vision is planning to release its Readius, a pocket-sized e-reader, in 2008 (Eisenberg, 2008). Readius incorporates a 5-inch rollable screen into a cellphone. Flexible displays make it possible to develop e-reading devices which are much smaller and lighter than typical books, yet still have screens large enough for comfortable reading.

Display
To afford comfortable reading, any viable e-reading device needs to have a display surface with sufficient size, resolution, and contrast.

The latest generation of e-reading devices generally uses e-paper display. There are several approaches to e-paper technology (“E-Paper”, 2008). EPD technology, which is used by E-Ink, uses tiny bubbles that contain both white and black ink. Electronic charges can be applied to bring either white or black ink to surface, which stays at the surface even after the charge is removed; thus no power is required to maintain the image. ChLCD technology (a.k.a. BiNem) uses a special spiral arrangement of LCD to achieve bi-stable effect, which allows the LCD to remain black or white even when no power is applied.

E-paper displays have significant advantages over the LCD displays used by previous generation of e-reading devices. The reflective nature of e-paper technology makes these displays easier to read, especially in bright sunlight. They reduce eyestrain, as they do not require periodic refreshing. More importantly, e-paper displays need neither backlight nor power to maintain image. As a result, they allow much longer battery life, and help reduce the size and the weight of the devices because smaller batteries suffice.

While all current e-paper products on the market use only greyscale display, research into colour e-paper is receiving a lot of attention. E-Ink has developed a demonstration version of colour electronic paper, and plans to have a colour product in 2010 (Paulson, 2008). Polymer Vision also announced a prototype rollable 65k colour display. Colour e-paper technology can greatly improve the capability of e-reading devices to display image-rich e-text.

Even though e-paper display has many advantages over LCD display for e-reading devices, it also has some severe limitations. One of the limitations is that there is no way to backlight e-paper display; thus extra lighting is required for reading in darkness (“E-paper”, 2008). More importantly, the refresh rate of e-paper display tends to be very low. The latest E-Ink Vizplex requires 750ms to update (“E-paper”, 2008). As a result, current e-reading devices are not suitable for displaying the video, animation and interactive material available on the Web. Hannon (2008) notes that many textbook publishers have created rich multimedia materials to accompany their texts, but current e-reading
devices cannot take advantages of such material.

**Interaction method: navigation**

Navigation through text is one of the most fundamental interactions in reading activities. Most web pages have a continuous layout, and require scrolling when the size of the document exceeds what one screen can display. By contrast, the layout of books is page-based. Schilit et al. (1999) argue that pages promote spatial memory that helps readers’ orientation in the book, and this memory provides readers with an excellent overall sense of a document. Most e-reading devices adopt a page-based layout and navigation paradigm, enhanced by the ability to follow hyperlinks.

Most existing e-reading devices use physical controls, such as buttons or wheels, to facilitate page turning. When the sizes and placements of these controls are properly designed, they can be very effective. Some even find that they are less interruptive than turning a paper page (Wilson & Landoni, 2003). However, these controls inevitably take up space on the device, often at the expense of screen size. Devices with touch screen can use on-screen soft controls to facilitate navigation, but they still take up screen real estate, and finding them on the screen can be awkward. Gesture-based navigation may provide a better solution. Readers can make simple gestures with fingers on the screen to issue navigation commands. Harrison et al. (1998) designed a device where a right-to-left flick on the upper right corner of the display indicated “turning one page forward”, while a left-to-right flick on the upper left corner indicated “turning one page backward”. Their test users found the manipulation intuitive and obvious. New interaction techniques such as multi-touch can make users’ gestures even more expressive (“Multi-touch”, 2008).

Chen et al. (2008) experimented with literally emulating the physical movement of page turning on their prototype dual screen device. Readers can turn the page by fanning one screen towards the other, or by folding the two screens back-to-back and flipping the device. However, their test users found that these physical movements required too much effort without marked advantages. While embodied interaction should not be dismissed, this result does suggest that that literal emulation of paper-based interaction may not work for e-reading devices.

**Interaction method: active reading**

Reading as an activity goes far beyond flipping pages. Alder et al. (1999) find that work-related reading is frequently accompanied by some sort of writing. It is important for e-reading devices to support this type of interaction for active readers.

With paper, a reader can achieve this interaction using a pen. Schilit et al. (1999) argue that pen-based annotation requires much less effort than annotation with a mouse and keyboard. Many e-reading devices from the previous generation, including SoftBook and Rocket eReader, had touch sensitive screens and supported scribbling with stylus. However, the Sony eReader does not have annotation capability, while Kindle only supports annotation using its small built-in keyboard; only the expensive iRex iLiad supports freeform annotation on its full display area. This degradation of functionality is probably due to the novelty of e-paper technology, and is likely to be remedied in future e-reading devices.

Pen-based interaction with e-reading devices can provide more than what is afforded by paper. Schilit, Golovchinsky, and Price (1998) describe three forms of note taking practices with paper: *in-situ* annotation, using notebooks, and on unbound paper, each has advantages as well as significant drawbacks. *In-situ* annotation maintains all the context, but tends to get lost in the piles of papers and books; notebooks are excellent for organizing reader’s thought, but require significant effort to record the context of the notes; unbound paper allows for flexible arrangement, but has the same problem with maintaining context, plus it is hard to manage. However, freeform annotations made in e-reading...
devices can exist both within the e-text and in a notebook at the same time, and can be turned into machine-readable text by using handwriting recognition. Thus they are easy to search, manage and review in different ways, giving reader the benefits of all three type of note taking practices and more. In PapierCraft, a gesture-based command system described by Liao et al. (2008), many manipulations of text, such as copying, pasting or emailing of text segments, tagging text with keywords, and creating hyperlinks between texts can be achieved by using gesture-based interaction with a pen.

**Connectivity and distribution method**

No matter how well designed an e-reading device is, it would be useless if there is nothing on it to read. Most e-reading devices can connect to a computer via USB to download e-text. However, reliance on computers for a mobile device can be a disadvantage, especially when the reader is traveling. Some devices provide extra means of connectivity. SoftBook has an internal modem so that the reader could dial into the SoftBook network to receive content (Chvatik, 2000). The iRex iLiad has built-in WIFI and Ethernet to connect directly to the Internet. Kindle allows readers to connect wirelessly to Amazon’s online bookstore via its Whispernet to purchase books. Kindle users can also subscribe to newspapers or magazines, which are delivered wirelessly to the device (“Kindle user's guide”, 2007).

Many producers of e-reading devices, including SoftBook, Gemstar, Sony, etc., have tried to provide services for their users to purchase e-books. However, until very recently, the publishing industry did not put serious effort into making current mainstream titles available (Forest, 2008). This combination of lack of content and the high price of e-books was a significant contributing factor to the failure of many e-reading devices. Kindle can potentially change that situation. Under Amazon’s huge influence, most major publishing houses make their new releases available to Kindle at affordable prices, resulting in an e-book library unmatched by any other e-book vendors (Mohns, 2008).

**Conclusion**

Although they hold the promise of drastically improving our e-reading experiences, dedicated e-reading devices have not become mainstream yet. The lack of mainstream adoption of dedicated e-reading devices may be explained by several factors. First of all, while they afford a better e-reading experience than with a computer or PDA, they still cannot match paper in terms of display quality and versatility of interaction. As Coburn et al. (2001) put it, “the ability of the object to foster and support the many complex relationships we have with books is missing” (p145). Secondly, they are expensive, not only in terms of the devices themselves, but also in terms of content. After spending hundreds of dollars on a device, users will find that the e-books typically cost no less than their print counterpart, making it hard to justify the upfront investment. Thirdly, the problems of “lack of content and an uncertainty surrounding modes of distribution of e-books” (Coburn et al., 2001, p. 147) still pose challenges to these devices. Publishers, either fearing the piracy of copyrighted works, or not convinced by the size of the e-book market, have been slow to make content available. The arrival of the Kindle may help to change the landscape, but the extent of its influence still remains to be seen.

The high hopes that accompanied earlier e-reading devices were unrealistic, as the development of many technologies crucial to e-reading devices is still in the early stages. As these technologies mature, and as the publishing industry starts to respond to the e-book market, future e-reading devices may indeed fulfill those promises and hopes. However, it is far from certain that dedicated e-reading devices will eventually emerge from their niche market. The technologies that drive the development of dedicated e-reading devices also benefit their chief competitors, such as portable convergence devices. With the advance in flexible display technologies, these convergence devices may be able to combine the compact form and versatility
of today's smart phones with the page-size display necessary for e-reading devices. It is likely that these convergence devices will still dominate the mainstream market in the future. On the other hand, e-reading devices themselves may strive to incorporate other functionalities. Even today, most e-reading devices can double as music players. Thus these devices may become less “dedicated” to reading activity after all. But regardless, the vision of e-reading devices has been a key driver in the field. No matter what devices we will use for e-reading in the future, the efficiency and enjoyment of our reading will owe a great deal to that vision.

**Works Cited**


