Project Proposal:
PEN (Personal Electronic Notebook)
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Abstract

We will design a system to replace loose-leaf notebooks in school and the workplace. Paper notebooks offer incredible viewing resolution and unrivaled flexibility, but are environmentally wasteful and become difficult to store after a prolonged educational or occupational career. Our system will incorporate current display and interface technologies to provide a writing surface as intuitive and useful as paper, with electronic storage and processing options to simplify protracted use.

Introduction – New Paper for a New Era

The problem with paper is that it has very few problems. It is extremely flexible, can store any type of codified information, offers enormous viewable angles and near infinite resolution. It has been the basis of modern progress for millennia, allowing intelligent men to record their progress for future generations to build on.

However, the few problems paper *does* have are becoming increasingly limiting in this Information Age. Paper occupies physical space, which means that a single person, over a lifetime of taking notes and generating documents, will eventually be saddled with dozens of cubic feet of stacked paper. Worse, this stacked paper is in no way inherently indexed or searchable; the best one can do is to invent a filing system, and then ensure that every document is properly filed. An improperly filed document is lost – paper does not have error-checking abilities. These rooms of paper represent a dead-end for the natural resources involved in paper's creation, as they molder unused in storage.

By contrast, electronically generated documents are easily searchable, and millions of them can be stored in the palm of a hand. The current solution to bridge this gap is scanning; some poor sap sits at a scanner, converting "hard" paper documents into "soft" copies that are then electronically indexed and stored. However, men elsewhere continue to generate more and more hard copies, easily outpacing the rate at which they can be scanned into soft copy.

We propose a system that makes generating soft copies as intuitive and simple as generating hard copies, eliminating the bottleneck of scanning and providing an environmentally and spatially simple way to contain humanity's staggering intellectual output. We call it PEN – the Personal Electronic Notebook. The PEN will be roughly the size of a piece of paper, lightweight, and staggering simple: no operating system, no advanced interface, just a blank white sheet of electronic paper, which the user is free to write on with a provided stylus.

The PEN will incorporate existing "touch-screen" technologies, memory technologies, and the USB serial data transfer interface. It will run on a lithium-based battery, similar to a laptop computer. Its primary advantage is its simplicity: by removing the "high-level" software represented by an operating system, the PEN can be made extremely resilient, resistant to crashes, freezes, and other quirky computer behaviors that might discourage more traditionally-minded users. PEN will be just as friendly as a paper notebook, but at the end of the school year, the contents of your pen can disappear invisibly into your PC instead of crowding your bookshelves.

Background

The primary reference work for the PEN is the modern "tablet PC," an adaptation of the notebook computer that uses a touch-sensitive display as the primary user interface. Tablet PCs are marketed and manufactured by several companies, including Gateway, Wacom and Toshiba. The PEN will be a "lobotomized" tablet PC, in that it will use a similar user interface but without a full operating system to manage internal resources.

Aside from the user interface, the PEN will incorporate three well-developed computing solutions:

- Memory management will be performed by an onboard microcontroller, moving information between the screen and internal memory;
- Image encoding algorithms will convert raw screen data into universal file formats, to allow exportation of pages as images;
- Disk management software and hardware will enable movement of page "images" from internal memory to external storage via a USB interface.

Basic System Concept

The base-line PEN system will allow users to write and erase on a sheet of electronic paper in black ink. The system will contain hundreds of these sheets, and the user will be free to write to a sheet and store it in memory, then call it up later to work on it further. The user will be able to browse through thumbnail summaries of the pages stored in memory, and quickly move to whichever page he or she is seeking. A USB interface will provide a means to move pages on and off the device, with an intuitive GUI to interact with the PEN's memory and the external USB storage device.

PEN will be considered as successful as it is accepted by the target audience. The primary anticipated users of PEN are technical students and professionals, who use great deals of scratch paper in their daily tasks and include both text and diagrams/equations in their work. If PEN is attractive to these people as an alternative to paper, and is practical enough to replace their traditional notebooks, the project will be considered an overall success.

On a more localized level, the primary success metric for PEN is resiliency. PEN should *never, ever* crash. It should be simple enough to use that "computer illiterate" professionals should still find it convenient and practical. The features it offers should be intuitive and near invisible, much like paper, in the sense that their use and application requires little or no thought. If extensive use of the PEN proves it to be reliable and resilient, the primary design goal will be satisfied.

To replace hard paper, the PEN has several obstacles to navigate:

Durability. Paper doesn't "break": if you drop your notebook, you can pick it up and write on it. Toward that end, PEN must incorporate durable hardware and be designed for use and, to a certain extent, abuse.

Portability. PEN must be lightweight and compact enough to be practical for almost any situation. It must be equally at home in a briefcase, backpack or desk drawer.

Longevity. PEN must offer a long battery life, significantly longer than the average laptop computer. Paper does not need to be recharged, and to the extent possible, neither should a PEN.

Viewability. Paper is usable in low- and high-light situations, and has a very wide viewing angle. To the extent possible, PEN needs to offer adjustability for varying light conditions, and provide a high contrast to increase angular visibility.

Applicability. Paper can be used by writers, poets, artists and students. It can contain text, diagrams, doodles and equations. Although PEN will probably never replace an artist's sketchpad, it must be able to reasonably represent detailed and unusual inputs to provide the same usefulness as hard paper. Just as paper can be erased and reused, either partially or wholly, the PEN must allow users to alter previous inputs or delete them entirely.

Storage. A notebook contains upwards of 50 sheets of paper; likewise, the PEN must have memory sufficient for dozens of pages, as well as a method for archiving existing pages outside itself so as to free up internal pages.

We intend to build PEN to these standards, providing a simple and attractive alternative to paper notebooks.

Design Flow and Milestones

PEN's design will be broken into three distinct phases, known as Alpha, Beta and Gold. Each phase consists of a series of hardware and software design tasks.

Alpha:

The primary goal of Alpha phase is to ensure that all the primary hardware components – processor, memory, screen output and digitizer input – function correctly together. To this end, the first design objective is to produce an output on the LCD screen; afterward, an input must be successfully read from the digitizer. Once the input/output hardware is correctly interfaced to the processor, a single sheet of electronic paper can be implemented, where "writing" on the screen produces a corresponding mark. A bank of push buttons will be tied to the processor to provide specific inputs such as power-on and power-off signals; one of these buttons will be specifically tied to a full-screen clear function. Finally, a memory map will be established, tying the many pages in the PEN's ram to corresponding Flash Memory locations, and a period backup algorithm will be

implemented, routinely copying the working versions of each page to the more permanent flash memory to avoid losing work on power-down.

Interfacing between the various hardware components in the Alpha phase can be accomplished using established protocols and channels. The Basix m400 processor runs Linux, and drivers for the LCD display are readily available. The Basix processor will output screen signals as a TTL parallel signal; this signal will be converted to an LVDS serial signal by a TTL-LVDS transmitter module. The Digitizer interfaces to the processor via a standard UART serial signal. GPIO pins on the processor board will pass push-button signals to the OS.

Alpha phase is projected for completion no later than 1 July 2006. Upon completion, PEN will be functional as a basic notebook. It will contain dozens of pages, each of which can be written to and stored within the unit for later recall and edit. Each page will be fully clearable.

Beta:

Beta phase focuses primarily on power supply and management, as well as minor software and hardware improvements. On the software side, a point-eraser function and a brightness adjustment popup GUI will be added. On the hardware side, a battery will be selected, and a charging system will be built around a standard DC power source. (The system will be designed to run with a generic AC/DC adapter.) For prototyping, a lead-based battery will be used, to avoid difficulties and dangers inherent in Lithium-based batteries; in production, custom made lithium batteries will be used to reduce the unit's final weight.

Once the battery system is built and all components are drawing power from the battery, the OS will be enhanced with power-oriented features. A power level monitor will be built from analog components to monitor battery levels. The output from this monitor will be connected to the processor, providing the OS with a warning when battery levels become low. Power saving routines will be implemented that will respond to sudden losses of power by dumping the SDRAM contents into Flash Memory, avoiding losing work. To prolong battery life, power-saving algorithms will be implemented that put the processor into sleep mode and reduce screen brightness or deactivate it entirely when the system is idle for prolonged periods of time.

Beta phase is projected for completion no later that 1 September 2006. Upon completion, PEN will be running on fully portable power with a maximized battery life.

Gold:

Gold phase focuses on file management and the PEN's off-unit backup capabilities. The Basix USB interface will be activated, and data import and export functions will be implemented and tested. File formatting algorithms will be added to the OS, which will encode outgoing data as .jpg image files and decode incoming .jpg image files into screen data. To facilitate file movement, a file-browsing GUI will be added to the OS, accessible by a push-button. Alongside this file browser, a page-browsing GUI with page thumbnails will be incorporated into the OS. Finally, all the components will be printed onto a single circuit board and a plastic case will be fabricated to contain the various parts. Interfacing to the USB system will be accomplished using built-in transfer commands provided the Linux USB driver.

Gold phase is slated to end no later than 1 December 2006. PEN Gold will be completely portable, featuring an intuitive and crash-free interface for quick and easy browsing, editing and moving of hundreds of electronic pages.

Testing

The following is a comprehensive list of features, along with rough testing strategies.

Alpha:

- LCD: can be tested by programming preset patterns into the video memory.
- Digitizer: can be tested by outputting position measurements to the SCI console output built into the m400.
- Input-output coordination: tested by putting pixels at the location of the stylus input
- Page storage: tested by writing to a page, moving to another page, and recalling the previous page

Beta:

- Power charging: tested by draining the battery, charging it and measuring incident voltage
- Power monitor: tested by comparing monitor output to analog measurement devices
- Power loss compensation: tested by draining/removing the battery and verifying memory contents following power restoration
- Power management: tested by measuring longevity with and without management algorithms

Gold:

- File export: tested by exporting memory contents over USB into a recognizable file
- File import: tested by importing a file and observing a (randomized) pattern of pixels
- File formatting: tested by exporting files that are readable to PC .jpg viewers, and importing .jpg files viewable by the PEN
- File browser: tested by extensive situational file movement scenarios, including destination disk full, read-only, file name conflicts, and other common file system problems
- Page browser: tested by extensive use and monitoring

Anticipated Risks and Problems

The primary concerns at this point can be grouped into two categories. The LCD/Digitizer combination represent a significant variable, in that they do not necessarily conform to universal standards, and no team members have previous experience with such devices. As such, designing software to accept digitizer data and drive the LCD output could take longer than initially anticipated. To defray such concerns, our team has chosen equipment from a leading vendor with excellent documentation available.

The second point of concern is in designing an analog power source capable of driving a power-hungry LCD inverter, and in creating power management software to maximize PEN's longevity. We intend to rely heavily on faculty experience and textbooks in the creation of an efficient power system, based on a store-bought laptop battery. The design and form of power management algorithms will be examined in greater detail at the Beta phase.

Required Resources

PEN's success and design revolve around the LCD display; obtaining this display will determine the shape and pace of most parts of the project. A survey of technologies widely available to fit this need indicate a price range of $100-800 US. Most microprocessors and memory systems will satisfy PEN's needs, and we anticipate finding an economical solution to our computing needs.

Beyond readily available computer components, PEN will require a custom made plastic enclosure. We have contacted Mechanical Engineering students, who have offered to assist in the design and construction of a case prototype when the Beta development phase is complete. Given these considerations, we intend to construct the PEN for a total cost of approximately $300 US.

At present, the current bill of materials is:
- HP/Compaq TC1100 LCD Screen and Wacom Digitizing Unit with stylus, approx $150
- HP/Compaq TC1100 LCD Backlight inverter, approx $40
- Processor/memory board – Gumstix Basix m400, $150
- Lead-acid battery, 12 V DC (to be replaced by Li in production), $35
- USB interface (onboard the Gumstix breakout gs board), $30
- External buttons
- Plastic case (to be designed in Gold phase)
- Nexcom EBK LVDS2 18/24-bit TTL to LVDS LCD transmitter module, approx $60

The Gumstix processor package includes 64 MB of SDRAM and 16 MB of flash memory for long term storage. Gumstix also pre-installs the Linux OS on the processor, and a general-purpose C compiler (gcc in our case) will be used to compile OS additions. Hardware drivers for Linux for the LCD display, USB interface and UART interface are widely available online.

HP/Compaq will provide additional screens upon request, although in production the exact screen model may be changed to a different model. Nexcom and Gumstix both sell their parts online, at www.nextcom.com.tw and gumstix.com.

Construction, testing and fabrication equipment will be furnished by the University of Utah, and all development will take place within Dept. of Engineering laboratories. We anticipate frequent consultation of University

faculty and staff, and intend to cite their expertise and advice in our documentation as we incorporate it into our final design.

Summary

Humanity is processing information in new ways; digitalization is opening doors for academics, professionals and citizens across the globe. As our means of searching through and processing information change, we need to give strong consideration to our means of generating information. PEN provides a simple bridge between hi-tech search and archiving methods and lo-tech pen-and-paper input methods. We have every confidence that PEN will be seen as a must-have by large segments of the modern population.