The fins shown schematically as horizontal but are vertical in reality to be in line with airflow direction

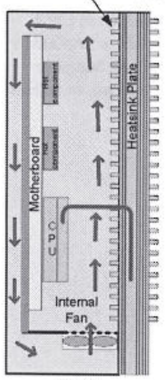

Fig 2
Adding an internal fan and internal fins assist in collecting the internal heat and transferring it out of the system

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System and software to identify display resizing and adapt screen content

Abstract

2008 will see the shipping of the first of many foldable and rollable display products on mobile devices, initially the PolymerVision Readius from Telecom Italia. New sensing capability and software solutions are needed to adapt screen content in response to mechanical resizing by the user. Minimizing power consumption is an over-riding concern with mobile devices, and previous work by HPL staff has focused on turning off or dimming unused portions of displays that are detected via a software method (monitoring focus in an X-windows server system). With a rollable display, an operating-system-independent hardware method is useful to detect portions of the screen that are not in use. A partial "screensaver" based on sensing the degree of unrolling of a scroll has the potential to save significant power in a handheld device. The positioning of different kinds of information on a partially unfurled display will also critically affect the device's ease of use. Keeping certain kinds of windows on-screen at all times is desirable, while other kinds of data may be docked off-screen as a default. Charging position-dependent fees for paid content on larger mobile displays is a future business opportunity.

According to previously published HPL research ("Energy-Adaptive Display System Design for Future Mobile Environments," Subu Iyer, Annie Luo, Robert N. Mayo and Parthasarathy Ranganathan, Proceedings of the First International Conference on Mobile Systems, Applications, and Services, May 2003), displays consume a majority of the power of handheld devices. As flexible electronics such as that developed in the Information Surfaces Laboratory makes larger screens possible for portable devices, the fraction of power consumed by the display is likely to increase. New electrophoretic and OLED displays may require less power than LCDs, but they will likely still dominate handheld power usage.
Minimizing power consumption without impacting usability and convenience is a major design goal. Flexible screens on plastic substrates are on the cusp of availability, with the first product being a mobile handset that is scheduled to ship in summer 2008 from Telecom Italia. The display in the Telecom Italia product is manufactured by PolymerVision and will include 3 segments that fold up when not in use. Earlier prototypes exhibited by PolymerVision were rollable, with two handles, inside one of which the screen retracted like a window shade. Other manufacturers, notably Samsung, Plastic Logic, Cambridge Display Technology, PrimeView International, Liquavista and Philips are developing slightly different flexible screens that will have diverse form factors and stowing methods. Details aside, each of these screens will benefit from a scheme to reduce unnecessary power consumption.
The advent of larger mobile displays will change the way that users interact with handheld devices, most obviously by making functions like window resizing, docking, iconifying and the like more important, as they are on desktop systems. More subtly, the ability to move windows in and of out of the visible display area will effectively enable multiple workspaces which can display different kinds of information.

Prior Solutions

Screensavers are the classic display power reduction strategy. A screensaver blanks the display when the user has been inactive for a period of time. Screensavers are effective in reducing power consumption, but they can be annoying when the user is passively reading the display. Traditional screensavers blank the display in its entirety.

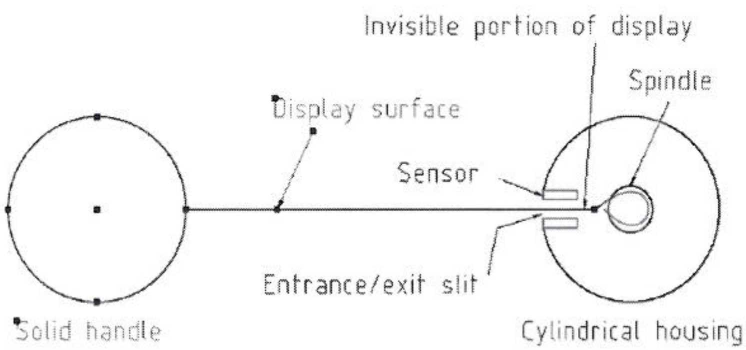
In 2003, a new approach to dynamic display segmentation for reduction of power consumption was implemented by an HP Labs research team. (See S. Iyer et al., cited previously.) The team used an X-windows server running on Linux to monitor which window on the screen of the display of a handheld computer had "focus," meaning the attention of the user. Other windows and the screen background were automatically dimmed ("dark windows") or reduced in color gamut instead of blanking the whole screen after a delay. The method demonstrated a significant power saving with a high degree of user tolerance, and even some user preference for dimming unused portions of the screen.

The previous energy-adaptive algorithm was innovative and useful but was designed with a rigid, fixed-size display in mind. The advent of flexible, resizable displays like the PolymerVision Readius offers new opportunities for power-saving via improved algorithms.

The algorithms associated with window management will also need to be adapted for larger mobile displays. Windowing is a minor concern on existing handhelds since typically the smaller screens display only one application at a time. For example, electronic books like the Amazon Kindle and the iRex iLiad display only one window even though under the hood they are Linux systems that could be running an X-windows server. User interaction with mobile windowing systems will present novel problems and opportunities for the system software designer.

Description

Two different types of stowing mechanisms have been proposed for portable displays: fan-



folding and rolling. PolymerVision has released photos of both types of prototypes but will evidently ship a fan-folding unit first. Both kinds of mechanisms provide opportunities for novel power reduction strategies that go beyond looking at which application is in use.

Power-saving strategies associated with fan-folding displays are analogous to those for notebook computers, which use a lid switch to determine whether the screen is visible. Similarly a fan-folded screen with arbitrarily many segments can use pin switches or even hinge-mounted rotary sensors to determine when a portion of the display is not readable and can safely be powered off.

The situation with rollable displays is more novel and complex. The position of a rollable display that stores inside a cylindrical handle can be monitored using a sensor in the opening slit of the handle. Sensing methods that determine the position of the edge of the visible portion of the screen can be either based on contact (like a potentiometric measurement) or non-contact (optical, inductive or capacitive measurements). A potentiometric method could be based on sliding contact to a strip electrode along the edge of the display, but would be prone to problems with unpredictable contact resistance due to wear and contamination. Optical and inductive sensors could read digitally encoded tracking information along the edge of the display or interspersed among display elements, and would not be subject to wear difficulties, although optical methods may still be troubled by dirt that obscures fiducials. Inductively coupled sensors like a Hall-effect device or magnetoresistive element are relatively dirt-insensitive and can read out a magnetic strip as on a credit card, or magnetic ink as on a bank check. The lowest power and most reliable position-sensing solution is likely to have a capacitive sensor read a digital sector code that is embedded in the edge of the display or interspersed among the display elements. The sector code could be embodied by grounded or biased electrodes that are patterned into a dot or bar code. A rollable display could also employ a potentiometric rotation sensor integrated into the spindle of the cylindrical housing. If a knob that is mounted on one end of the housing is used to roll and unroll the screen, then an optical encoder or potentiometric method can be used to sense the position of the knob. Alternatively the presence of an uncoated plastic leader at the end of the screen could be sensed via optical or electrical methods. In another embodiment, an accelerometer mounted in the housing can be used to sense motions of the unit which correspond to rolling and unrolling. Or finally, a simple and inexpensive method that does not need any sensors is to just use the range of the mouse and keyboard movement to figure out how much the screen is visible.

Rather than incorporate dedicated position codes into the display web, another approach would be to use the emission from the display itself or potentials on its working electrodes to represent a digital position code. For example, a high-carrier-frequency signal that was faster than the pixel response time could be added in a position-dependent fashion to the electrode bias voltages. This signal could be picked up and demodulated by a capacitive sensor at the edge of the cylindrical housing. Alternatively, if pixel response time is faster than human vision, rows of pixels could be flashed in a high-frequency fashion as they pass by an optical sensor at the entrance/exit slit of the housing. The encoding of the position information can be accomplished by any familiar scheme such as frequency modulation, amplitude modulation, etc.

Another position-sensing scheme can be envisioned where rollup on the spindle is directly sensed by dedicated electrodes or the display electrodes. The proximity of a conducting ground plane on the backside of the screen's plastic substrate could be capacitively sensed by the pixel electrodes on the front side. The position of the boundary between electrodes that were close to the ground plane (rolled up) and those that were not (unrolled) would indicate to what degree the display was furled. Similarly, with an OLED display, the pixels could be used as photodiode detectors in addition to light sources, allowing potential optical detection of the proximity of a reflective coating on the backside of a rolled-up display. These position sensing methods are less direct and perhaps less reproducible than direct measurement of the edge of the visible area and thus are likely to be less reliable. Either capacitive proximity measurements may be fooled by the presence of objects other than the display backside. Optical proximity measurements could be protected against confusion from extraneous light sources by using a lock-in detection technique, but still could be fooled by nearby reflective objects.

The most likely rollable display configuration would involve one solid handle in addition to the cylindrical housing where the display can be stowed. In that case only one position sensor is needed. Should the display have more than one container where the flexible material can be stowed, one sensor (or more) will be needed for each container. Similarly, both sides of a flat web could be used as displays, in which power to pixels on both sides can be minimized. An infinitude of less likely display geometries can be envisioned (like a screen on the inside of an umbrella, with signals running inside the support ribs) but they are outside the scope of this disclosure.

Once the extent of the unobscured, unfurled portion of the screen has been determined, then selective dimming or power-off can implemented as in the prior art by Iyer et al. Windows and background which are completely off-screen should be powered completely off, while windows or background which are partly off-screen can be dimmed, color-gamut-reduced or powered off completely. In addition to the power used by the pixels and their drivers, processor power can be conserved by not sending repaint messages to windows that are physically out-of-view. Operating systems handle the logically out-of-view problem well. All that is needed is a simple overlay window that logically covers the physically out-of-view windows.

If only one window is presented on a long screen which is partly rolled up, the visible portion of the window should be fully powered. The methods of Iyer et al. can still be used to control illumination of windows that are wholly within the viewable area. Windows wholely or partly within the viewable area can to selectively dim if not accessed, as in a traditional screensaver. Clearly if no portion of the display is visible, it should be powered off (if not actually cleared for privacy and security reasons).

Beyond power reduction, the novel environment presented by a screen whose mechanical size is controlled by the user offers a host of opportunities. Rolling and unrolling (or folding and unfolding) represent a wholly new form of input that can complement a mouse, stylus or finger interface. For example, a user could refresh the screen and undim all windows by completely rolling and unrolling the device; or this gesture could be used to signal a wish to dim the entire screen. The edge of the cylindrical housing could afford the opportunity to resize a window by effectively "pulling" or "pushing" the window border, with intention to soft-resize indicated by pausing the border under the opening in the housing. Rapid small rolling and unrolling motions in a short period of time could switch workspaces entirely, and so forth.
A partially unrolled or unfolded screen presents wholly new issues for windowing systems. Users may wish to keep certain information (like a clock, icon dock or toolbar) visible at all times, while other information (like error logs or calendar) may be kept out of the visible area by default due to lower importance or privacy concerns. Automatic centering or soft-resizing of windows will be desirable under certain conditions and infuriating in others. Some kind of icon dock or toolbar at the edge of a partially unrolled or unfolded screen will be necessary to remind the viewer what applications are hidden out of view. Post-it note or bookmark icons or similar graphical motifs at the boundary of the visible area can intuitively indicate the availability of other pages of the display.

Larger screens also expand the opportunity for paid content to be exhibited on a mobile display. A system for charging fees to business partners based on the size and positioning of advertisements will newly be possible. A model where customers pay a higher fee to get wireless access without ads will become more meaningful.

Finally, the rolling or folding sensors can be used to track usage of the handheld product and therefore reliability of components. Reliability information is useful for HP's warranty business.

Advantages

Prior art by Iyer et al. teaches how to save power in displays for mobile computers by selectively degrading the quality of the image on those portions of a screen that are unused. The earlier work dates to 2003 and does not envision the use of flexible displays, in particular rollable ones. Rollable displays offer novel opportunities for power-saving which are described in this disclosure.

In addition to conserving lighting power, one could also save somewhat on computational power. Modern applications are often graphics heavy. Many user interface actions force repaints of the applications window space. These repaints take up substantial processing power. A portion of processing power could be saved by not sending repaint messages to windows that are physically out-of-view.

Rolling and folding are novel methods of user input to a handheld device, and afford an opportunity to make a more intuitive and convenient interface. Considerable research needs to be done in this arena to determine what features would be pleasing to customers.

The redesign of windowing systems for mechanically resizable screens is critical to exploiting their full potential from both the technical and business points of view. A simple transfer of desktop windowing conventions to handhelds would limit the utility of resizable displays.

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