USING OLPC LAPTOP TECHNOLOGY AS A COMPUTER SCIENCE CASE STUDY TEACHING TOOL*

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ABSTRACT

The One Laptop Per Child project has succeeded in developing a novel computer that is tailored to the particular needs of the developing world. The use of this example of a modern computer systems design challenge can be a valuable case study as a teaching tool in computer science. The OLPC laptop is a multiple-purpose computer that is rugged, low-power, mesh-networked, and inexpensive. An overview of the technology in the laptops is given, as well as curricula suggestions for using the laptops in an undergraduate computer science curriculum.

INTRODUCTION

The mission of the One Laptop Per Child foundation, spun out of MIT's Media Lab, is to "create educational opportunities for the world's poorest children by providing each child with a rugged, low-cost, low-power, connected laptop with content and software designed for collaborative, joyful, self-empowered learning" [9]. The result of several years of research and development efforts is the XO Laptop, a remarkable multi-purpose mesh-networked computer with no moving parts, that uses no more than 6 watts of power (with an average of 1-3 Watts), and is currently manufactured for $188 [3, 6, 14]. This novel platform can provide a timely and interesting teaching tool for many computer science concepts, especially computer systems design. Many interesting design decisions during the development of the XO were the result of the over-arching need for low power consumption and low cost. In a broader liberal arts context, the laptop can also be used to discuss the use of technology in education, the use of technology in the developing world, issues of appropriate technology, and the digital divide.

Information about the OLPC Project is exclusively on-line (www.laptop.org) and largely in the form of a wiki maintained by OLPC (wiki.laptop.org). Because of the dynamic nature of on-line content, getting accurate and complete information about the project can be difficult. The purpose of this paper is to gather and synthesize accurate information relevant to the use of the XO laptop as a case study tool in the teaching, and provide references for further in-depth study of any single topic discussed within.

XO PROCESSOR

The processor chosen for the XO is an older 433 MHz AMD Geode which uses only 0.8 watt of power and does not need a cooling fan. In an era of better, faster performance, this step backwards can be an interesting discussion point, pointing to the overarching XO design considerations of low power and low cost. An in-depth look into the core electronics yields more information that can lead to an interesting case study in a computer organization or architecture class. The Geode processor is x86 compatible, with 64 kbyte level 1 separate instruction and data caches and 128 kbyte level 2 cache, translation lookaside buffer, embedded 2-D graphics controller, and integrated FPU that supports the MMX instruction set. A display controller is on a separate chip from the main processor [1, 6]. The XO design places the motherboard directly behind the screen, instead of in the base of the laptop, which keeps the heat from these electronics away from the lap of the user and more able to dissipate. In tropical climates, this can be an important design consideration.

The most innovative processor design that is implemented with the Geode processor was at some time referred to as "extreme suspend", but lately seems to simply be referred to as the suspend and resume features of the XO laptops. This is one of the keys to the overall low power consumption of the XOs, in which power to the processor chip is cut off when the CPU is inactive; any action on the part of the user or network that requires the CPU causes it to re-activate, within 0.2 to 1 second (depending on various settings). When the CPU is suspended, the mesh network is still active, so the network may cause the CPU to be re-enabled. The screen may be on or off when the processor is suspended. If it is on, the separate display controller chip is in charge of the screen, as in eBook mode. This conserves energy since the whole processor does not need to be active during idle times or when the laptop is being used in eBook mode. The length of time that the processor is inactive before power is cut seems to be configurable [12, 15].

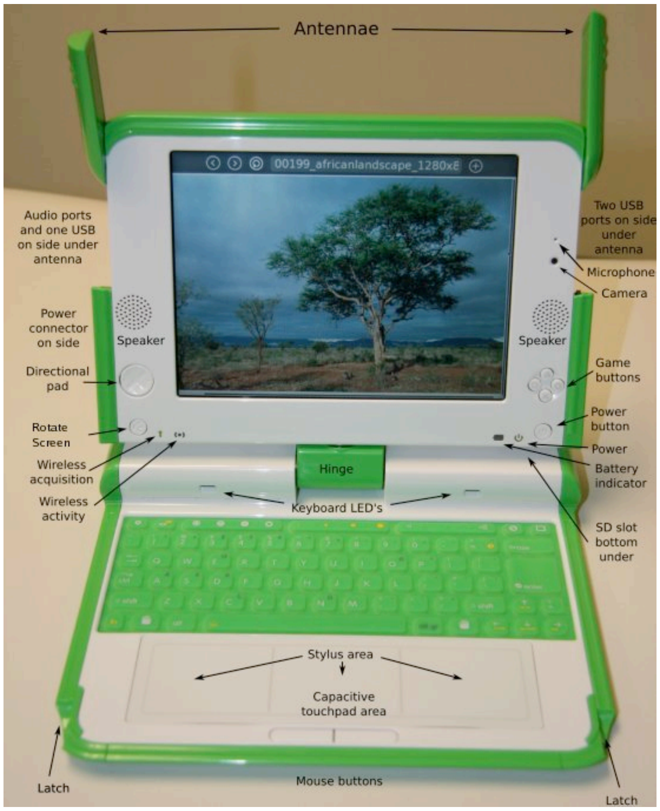

Figure 1. Diagram of the XO laptop [6]

XO SCREEN

The LCD screen of the XOs was a major design consideration, since a laptop screen is simultaneously the largest power consumer and also one of the most expensive elements of the machine. Size had to be small enough to be cheap, while also large enough to be readable and usable. The technology needed to be relatively rugged, relatively low power, and relatively cheap. Sunlight readable was also a design goal, since many children in the developing world spend a majority of their time out of doors, even during school hours. The result was a dual reflective-backlight mode display consisting of a lower-resolution backlit color LCD display overlaid on top of a higher resolution reflective monochrome LCD display. The black and white reflective LCD is relatively low in cost and power, and sunlight readable. The more expensive color LCD is of lower resolution (133 dpi) so it is not as expensive, but by overlaying the lower resolution color on top of the higher resolution black and white (200 dpi), it gives the appearance of a higher resolution color display in backlight mode. This kind of innovative design is an excellent example for computer science students, in which design tradeoffs must be carefully weighed, and when they cannot be reconciled, new innovations sought. The lead innovator of the XO LCD screen was Mary Lou Jepsen, a strong example of a modern female computer engineer, who has since formed her own company, Pixel Qi, to further develop and commercialize the technology; we should see these screens in our cell phones, and other technology, soon [4, 6].

Another display screen design consideration pertaining to ruggedness and power is the use of an LED backlight instead of the more typical cold cathode fluorescent tube backlight. The LED, which uses less power and is more rugged, is also positioned in the laptop where it can be easily removed and replaced if necessary [6].

MEMORY AND STORAGE

The XO laptops have no hard disk, and in fact, no moving parts at all, leading to its impressive durability. Units are drop-tested at 150 cm (almost five feet), something none of us can imagine doing with our Dell and Toshiba laptops [7]. Instead of a hard drive, mass storage is accomplished by 1 GByte NAND Flash memory. In addition, 256 MByte DRAM memory and 1 MByte BIOS ROM is included. Modest by today's multi-media and game-ready computer standards, the assumption is that students would have access to a central server (also the internet server if internet is available), onto which programs and files can be stored and saved, leaving modest storage capacity of the individual XO laptops for immediately needed programs and files [6].

MESH NETWORKING

The XOs use a still-being-developed new interconnectivity standard, the 802.11s for mesh interconnectvity. The standard is still in draft form before the IEEE. Interconnectivity was a design priority, although it was recognized that children in developing countries would have limited access to the usual wired or wireless connectivity infrastructure (routers, repeaters, Ethernet, modems). The 802.11s was pursued as a self-organizing multihop mesh networking standard, in which the System on Chip (SOC) wireless adaptor runs on each laptop's CPU. It uses a WiFi interface to access the network and to relay traffic from other mesh points. However, the laptops are able to route traffic as a mesh point even if the main CPU is off, an added power saving feature [8, 13]. The study of this new standard and the mesh path selection and forwarding protocols would be a valuable and state-of-the-art case study in a computer networks class.

XO SOFTWARE

The XO operating system software is called Sugar, based on the Fedora Core Linux. Sugar uses less than 200 Mbytes, which leaves another 800 Mbytes available for other software content. This is as opposed to the typical Microsoft Windows installation, in which the core operating system uses about 1.65 (XP) to 15 (Vista) Gigabytes of storage [2]. The cost of the XO software was the major consideration for open source; here image size also affects cost, since large operating systems require large memories and mass storage to hold them. Open source software also facilitates volunteer software developers; currently 28 core "activities" (applications) come with the current release Sugar image, although activities can be removed and new ones installed easily. Users can develop new activities and post them to the OLPC wiki. Sugar has its own icon-based GUI, meant to be more accessible to children who speak different languages and/or do not read English. The XO software can be an interesting launching point for discussion on open source vs. commercial software and grass roots computer software creation [5, 11].

In addition, Sugar's use of Linux permissions and issues of security are an interesting case study as well. OLPC claims that Sugar "is both drastically more secure and provides drastically more usable security than any mainstream system currently on the market" [10]. Sugar follows the general Linux standard that provides a system that is highly secure by default, but allows users that have become increasingly sophisticated to tailor the security of their machines to their own liking, eventually allowing the user to customize or "hack" their own machines as they see fit [10]. A study of OLPC's approach to system security would be an interesting tool by which students could investigate security issues in an operating system or computer networks class.

Issues of theft and security can also be discussed with regard to the XO laptops and the OLPC project. A common question asked with regard to the OLPC project is, why wouldn't kids just sell the laptops and use the money for food or other needs? OLPC's response to this perceived problem is three-fold. First, the lease system, implemented via the school or local server, can be configured so that any laptop registered to the server that does not "check in" (that is, operate within mesh network detection of the sever) at least once every X days (the number of days is configurable) would shut itself off. Only a USB key, given to a trusted ministry or school official, would reactivate such a laptop. Therefore, there is little incentive for someone outside the vicinity of the server to buy such a laptop, since it would soon become useless. Second, the OLPC goal of saturation means that all children in a certain geographic region would receive laptops; therefore, there would be no need to steal a laptop locally, since everyone in the region would know some child who had one. Lastly, the registry of stolen laptops can identify laptops that are reported stolen and turn them off remotely, whenever and wherever they gain internet access. The three methods combined are an interesting approach to theft security for the XOs [10].

BROADER EDUCATIONAL CONNECTIONS

If broadening computer science concepts and connecting to global issues is part of the curriculum, as is more common in liberal arts schools, there are plenty of opportunities for such connections and discussions with the OLPC project and the XO laptops. Connections to global economics (e.g. *The Fortune at the Bottom of the Pyramid* by C.K. Prahalad) are clear. The near saturation of cell phone technology, as well as an increased development and deployment of not just OLPC technology, but also Intel's Classmate PC and NComputing's virtual desktops that connect many monitors to one PC are lower-cost computing devices that are also being sold at increasing rates in developing countries.

Another topic that can be introduced in conjunction with a discussion about XO technology and the OLPC project is the educational realities in developing countries that necessitate programs such as OLPC. Many American students, who have grown up with a high-quality free educational system, may be surprised to learn about the status of education in some developing countries: cases in which education is not free; or education is not practical since children are needed at home to haul water or collect food; or cases in which it is too far to walk to school and no one has bicycles let alone cars; or cases of schools with not enough teachers, or untrained teachers, or teachers who are trained in rote-learning methodologies only; or schools in which no textbooks are available for students. Another topic for discussion is the digital divide, the reality that those with access to technology will necessarily have an advantage over those who do not. All of these topics can be used to educate global citizens and cause them to reflect upon the appropriate place of technology in our global society and issues of justice, especially as pertaining to access to technology. There is not necessarily a right or wrong answer or approach, but there is educational merit to the informed discussion.

CONCLUSIONS

The XO laptop, developed by One Laptop Per Child, is a novel and timely case study that can be used to teach computer science students about computer system design considerations. Because the XO is not simply a “better, faster” laptop, it provides a step back from the current design trend. A study of the XO can provide students with a ‘thinking outside the box’ design model when faced with difficult problems, both in school and after. Computer science classes that may benefit from the use of the XO laptops include computer organization and architecture, operating systems, and computer networks. In a software engineering class, students might work to develop educational content for the laptops. In addition, the OLPC project provides an alternate view for aspiring technologists to consider the place of technology in education, in global economics, and in human rights endeavors.

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