# Chapter 27
# Display Energy Management based on Eye Tracking

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## ABSTRACT

*With the explosive use of personal computers or PCs, reducing computer energy consumption is paramount for sustainability. The display is the largest energy consumer in a personal computer. Current display energy management technologies ignore the attention of the PC user and therefore may either switch the display off when the user looks at the screen or lose energy by keeping the display on when nobody looks at it. This chapter discusses a new display energy management technology and outlines its implementation in a personal computer system. Unlike existing technologies, which "sense" a PC user through keyboard and/or mouse or the other sensors, this technology "watches" the user through a single camera or CMOS vision sensor. The technology tracks the user's eyes, keeping display active only if the user looks at its screen. Otherwise, it dims the display down or even switches it off to save energy. The authors implemented the technology in software and hardware and present the results of their experimental evaluation.*

## 1. INTRODUCTION

As personal computers become more intertwined with everyday life of people, minimizing their energy consumption becomes very important. According to SMART 2020 report (Climate Group, 2008), the number of PCs globally is expected to increase from 592 million in 2002 to 2 billion in 2014 and 4 billion in 2020. The vast majority of these PCs are expected to be portable devices, which rely on rechargeable batteries. Unfortunately, the battery capacities are increasing at a much slower pace than the overall power consumption growth of such PCs. Therefore, it is critical to develop energy-aware design methodologies to keep the energy consumption of portable PCs in line with the battery capacity increase.

Portability is by no means the sole force behind the push for energy reduction. There exists a strong pressure for producers of desktop computers to

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decrease power consumption. For desktops or servers, high power consumption raises temperature, deteriorates performance and reliability. Besides, due to the large grows of PCs, their share in the total ICS CO2 emission footprint will rise by 2.7 times in comparison to 2002 and reach 57% in 2020 (Climate Group, 2008). According to the International Energy Agency, the energy used by computers will not only double by 2022 but increase threefold by 2030 (IEA Press, 2009). From the global warming perspective, the improvement of energy efficiency of computers, reducing their energy consumption during lifetime has become an urgent issue for global sustainable development.

The primary goal of the emerging discipline of IT sustainability is to enable firms to develop and use computing resources more efficiently while maintaining or increasing overall performance (Harmon, 2010). The first wave of these efforts is commonly identified as "green computing" where the emphasis has been primarily minimizing power usage for datacenters and technical equipments, such as computers, projectors, etc.

In a typical personal computing system, display accounts 30% ~ 50% of the total energy (Mahesri, 2005; Robertson, 2002). For example, 19" Sony SDM-S93 LCD monitor (1280 x 1024pixels) burns in active mode 50W or almost 38% of the total desktop system power (130W). With large popularity of video and gaming applications, LCD makers are being called on to cut power consumption while providing better images. Rapid utilization of multiple displays - each consuming tens of watts—throughout homes, offices, and buildings increases cost and environmental impact of energy consumption significantly. Although most computer displays support power management, new robust methods are needed for evolving display usage scenarios.

This chapter discusses a new camera-based approach to display power management and outlines its implementation in personal computer system. Unlike existing display power management technology, which "senses" its user through keyboard and/or mouse, our technology "watches" the user through a single camera. The technology tracks the user's eyes keeping the display active only if the user looks at the screen. Otherwise, it dims the display down or even switches it off to save energy. We implemented the technology in hardware and present the results of its experimental evaluation.

The chapter is organized as follows. In the next section, we survey related research. Section 3 describes the proposed camera-based display energy management approach. Section 4 presents the design and outlines its implementation features. Section 5 reports on experimental evaluation. Section 6 summarizes our findings and outlines work for the future.

## 2. RELATED RESEARCH

The first widely used adaptive display power management technology was introduced almost two decades ago with adoption of VESA's Display Power Management Signaling Specification. The technology specifies one or more power states (e.g. standby, sustain, and off) that are intermediate between *on* and *off,* turning the display to low power state after a specified period of inactivity on mouse and/or keyboard. Over the years, many additions and revisions to this technology have occurred, including Advanced Configuration and Power Interface (ACPI, 2004), developed by HP, Intel, Microsoft, Phoenix, and Toshiba. The OS-based ACPI links the display brightness as well as inactivity intervals to application[1].

One problem with ACPI is that it strongly depends on inactivity intervals, either set as default (see Table 1) or by the user. From one hand, if the inactivity intervals are improperly short, e.g. 1 or 2 minutes, the ACPI can be quite troublesome by shutting the display off when it must be on. From another hand, if the inactivity intervals are set to be long, the ACPI efficiency decreases. Because modifying the intervals requires system setting, most users never adjust the power management of

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