Displaying Personalized Feedback to Encourage Energy-Saving Computer Usage

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ABSTRACT

Leaving a computer on full power when not in use wastes energy and money, and yet it remains a common practice. In order to examine the motivations behind this behavior, we studied the perceived and actual computer usage patterns of laptop and desktop users through daily surveys and instant messaging status records. We found that users generally seem unaware of their idle time, with 72% of users supplying inaccurate ranges for their daily idle time. Guided by our observations of computer idle periods in the context of users' attitudes toward energy saving, we have developed three variations of a visual feedback system aimed at encouraging users to apply more energy conscious power settings on their computers. We plan to test these feedback systems with users to determine the effectiveness of personalized suggestions in causing user behavior change.

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INTRODUCTION

Conservation is a vital component of efforts to reduce energy costs and combat global warming. One area with potential for conservation is personal computer usage. A 2001 study found that office technology consumes 74 TWh/year, or 2% the annual energy use in the U.S. [4]. With increasing computer use each year, these numbers are only expected to rise. Much of the energy consumed is wasted powering idle computers, that is, computers left on but not active [3].

The past decade has seen the development of advanced automatic power management on new computers intended to reduce the computer's energy consumption during these idle times [1, 3, 5, 6]; however, it is apparent that a significant number of users are either bypassing these settings or not using them correctly [3, 9]. Therefore, we believe that this problem demands a system that can confront the human users individually and convince them to adopt more sustainable computer usage habits.

Even a single computer left on for at least 10 hours daily contributes approximately 1,200 pounds of CO2 to the environment each year [10], so it is certainly valuable to change behavior on the individual level. The question is how to design a system that will encourage a user to make potentially inconvenient changes to his or her daily life. In order to address this issue, we first must understand the status quo—what power settings people are currently using and why. Once we have established the current behavior and the motivation behind it, we then must decide the most effective means of conveying information to the user about the impact of their computer use and potentially instructions on rectifying any wasteful behaviors.

We designed an AOL Instant Messenger bot to record the activity status reported for a user's screen name in order to determine when a user's computer was idle. Responses to daily surveys provided information about the user's perceived idle time. By comparing these two data sets, we found that 72% of users misreported their idle time, suggesting that simply increasing user's awareness about their idle time will be a key component in encouraging more energy conscious behaviors. Based on survey responses and several in-depth interviews concerning energy saving attitudes, we have designed three variations of a feedback system that will test the effectiveness of personalized feedback on causing user's to change their behavior.

The next section of the paper describes the setup of our study, including a description of the instant messaging bot built for the study. This is followed by a description and analysis of our results. We then examine related research involving computer sustainability and persuasive technologies, and finally, we present conclusions and plans for future work.

METHODOLOGY

Overview

Our two-week study consisted of five primary components: an upfront survey about computer use and energy consumption, daily surveys about computer use, screen name status logging by an instant messaging bot, a diary study on the last day of the study, and an in-depth interview by instant message with a random selection of participants. In the last few days of the study, we began logging CPU and TCP usage with a sensor program, but there was not enough data provided by this component to draw any solid conclusions.

Participants

We observed the idle status patterns of 26* computer users for two weeks. An initial screening process ensured that each participant typically spent at least 3 hours online per day so that there was a sufficient amount of activity to observe. Each participant also had to have an AOL Instant Messenger screen name so that the user could add to their friends list our instant messaging bot, which logged status events during the study and communicated with the participants. The participants consisted of 20 users who stated that a laptop was their primary computer and 6 who primarily used a desktop computer.

Surveys

The users first completed a survey asking them how much time they spend on their computers. The survey also asked how long their computers typically spend in an active state. We asked how long their computers spend idle and whether they automatically or manually reduce their power settings during these idle times. The survey also contained several questions concerning attitudes toward energy-saving behaviors. One of these questions asked how often the user performed particular energy-saving behaviors, and another asked them to rate their level of agreement with various statements for or against reducing energy consumption in general.

Each user also completed a daily survey each night of the study. The key questions on the daily survey concerned the amount of idle time the user felt they had logged throughout the day. One question asked, "Throughout the day, how long was your computer performing assigned tasks that did not require interaction from you (e.g. file downloading, virus scans)?" Another asked, "Throughout the day, how long was your computer on but not performing any assigned tasks?" The responses to these two multiple-choice questions provide a measure of the user's perceived idle time total. We also asked an open-ended question about idle time: "When your computer was idle (to your knowledge), describe why you left your computer and what you did during that time. (Answer for all times that you believed your computer to be idle)." This question would not produce quantifiable data, but was intended to help illuminate reasons behind idle time.

IM Bot

Purpose

In order to measure the idle time for each user in an unintrusive manner, we implemented an instant messaging (IM) bot that could record the status events for all of the users on its Buddy List. We also used the IM bot to send daily survey reminders to each participant. The IM bot facilitated the diary study on the last day.

Implementation

We implemented the instant messaging bot in Java, using the AOL Instant Messenger SDK. An instant messaging bot is a program that can assume a screen name and participate in instant messaging with other screen names. We programmed the IM bot so that each time it received a status change event for a participant, it would record the event along with a user ID and timestamp to a file. The IM bot could also respond to commands from the experimenters. For example, sending a certain instant message to the IM bot's screen name would cause it to send out survey reminders to everyone on its list. Other commands could cause users to be added or removed from the survey reminder list. Another command caused the user to be added to the diary study list. The IM bot was programmed so that each time it received an "unidle" event for someone in the diary study list, it would send that person an instant message asking about the circumstances surrounding their idle time. The responses were recorded to the log file.

Limitations

One restriction placed on such bots is that they can only communicate with users who also list it as a "buddy." Therefore, we instructed the participants to add the screen name of the instant messaging bot to their Buddy Lists. We also asked the users to send a message to the instant messaging bot. We programmed the IM bot so that any message it received caused the sender to be added to the IM bot's Buddy List. This way, we could both confirm that the participant had added the IM bot's screen name and avoid manually adding each person to the IM bot's Buddy List.

The IM bot was also rate-limited, meaning that it could only send a certain number of messages within a short period. This only became an issue during the survey reminders, which had to be staggered for this reason.

Diary

Each participant kept an idle time diary in the last day of the study. This diary was facilitated by the IM bot, which sent the following message to each user upon their screen names return from being idle:

> Hello, it looks like you just returned from being idle.
>
> 1. What were you just doing just now?
> 2. What was your computer doing this time?

We hoped this diary component would provide contextualized details about the user's idle time behavior that may be missed by the surveys.

Interview

After the completion of the two-week observation period, we conducted in-depth interviews with a random selection of 9 of the 26 participants. These interviews focused on the user's interactions with the computer on the day of the interview. The interview, like the diary and the open-ended survey questions, was meant to draw out deeper motiva-

* We began with 50 users, and of those, 26 finished the study and had at least one logged idle event.

tions and perceptions concerning computer use and idle time. In the interviews, participants were also asked to provide feedback on our preliminary feedback designs (Figure 2). The interviews were conducted via instant message.

RESULTS

We gathered both qualitative and quantitative data in such areas as perceived versus actual idle time, motivations for power setting choices, and opinions about feedback. We are still in the process of analyzing the data.

Self-Reported vs. Actual Idle Time

To determine the range of self-reported idle time, we added the results of the answers to survey questions about how much time a user's computer was on performing assigned tasks without user input and how much time it was on but not performing any tasks. The answer choices for these questions were less than 15 minutes, 15 to 30 minutes, 30 minutes to 1 hour, 1 hour to 2 hours, 2 hours to 4 hours, more than 4 hours, and not applicable. We then compared the measured idle time from the instant messaging status data. Days in which the recorded idle time falls within the range supplied by the user for that day were marked as "accurate" and the other days marked "underestimated" if the user's range was too low and "overestimated" if the user's range was too high. Figure 1 shows the results of this comparison for each day on which there was both survey and IM bot data. The users provided accurate ranges only 28% of the time. The rest of the time, responses were nearly evenly distributed between overestimated and underestimated.

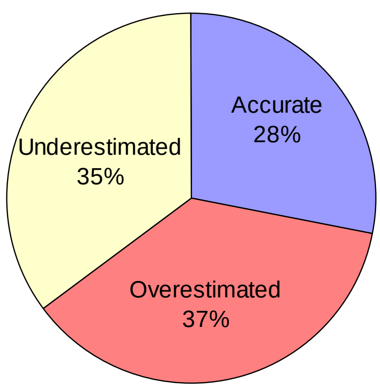

Figure 1: Accuracy of users' daily idle time estimates

Idle Sessions

The global average length of an idle session across all 26 users was 64 minutes, or just over an hour. However, the majority of idle sessions logged were 60 minutes or less. The most common reasons for these short idle periods included running errands outside the house and performing a quick task somewhere else inside the house. Several users left their computers on overnight, which accumulated a large amount of idle time, but this was not as common as expected.

Motivations

The most common motivations for leaving the computer on full power while idle that came through in the survey and interview data were related to the instant access it provides. Variations included "I like to stay updated," "Because I like it to stay on so I can resume activities quickly," and "because I like the simple convenience of just having it on whenever I need it—no need for it to take it's little time to 'wake up.'" One of the interviewees emphasized the importance of being reachable by her boss.

Another popular reason for power setting choice was that the user did not change the default that came with the computer. One participant revealed in an interview that this was her first laptop and that she was not sure what all the settings were.

Concern for energy costs and the environment were also mentioned as motivation for power settings, but not as often as the other reasons.

Feedback Opinions

Figure 2 shows the various feedback displays presented to the interview participants. All of the windows would be constant displays, except Idle Alert, which would only show up when the user returned from being idle.

Figure 2: Feedback design mockups.

The most popular design was Idle Time, which provides straightforward information about the user's idle time today in addition to the change from the previous day. Users also tended to like the Idle Costs display, citing money as a powerful encouragement tool. The least popular display was the Idle Alert, which would be displayed whenever the user returned from being idle. Participants expressed dislike for the text density as well as the annoyance of interruption by such a pop-up windows.

Discussion

The discrepancy between perceived and actual idle time implies that users are generally unaware of the actual amount of time their computers spend in an idle state. Together with the misconceptions about power settings found through the interview and open-ended survey questions, this suggests that feedback mechanisms should include basic information about how much time a person is idle as well as details about how they can change their behavior.

The data gathered about idle session lengths will influence the suggestions to provide to users through the feedback systems. For example, an appropriate suggestion for a user with many short idle sessions would be to use an automatic sleep mode.

The preliminary opinions gathered on the feedback displays suggest that we want to provide both constant and historical data about both idle time and its monetary cost.

RELATED WORK

Attempts at reducing computer energy consumption have tended to focus on improving automatic power management systems. In [1] and [3], for example, researchers show how adjusting networks can cause them to use less energy. Lorch and Smith in [5] have adjusted scheduling behavior in Macs in order to reduce energy use during idle time.

Uniblue Research Labs has recently released a program called Local Cooling that claims to combat global warming [8]. Users download an application that claims to use “advanced algorithms” to determine when to turn off the screen or the computer. Like our application, it displays information about energy savings in terms of trees, CO_2, and dollars. However, there has been no attempt to measure the effectiveness at changing individual user attitudes or beliefs.

Much of the research concerning personalized feedback has been in the domain of user health. In [2], mailings including personalized messages were found to be effective when coupled with educational information in helping smokers to quit. Sohn and Lee in [7] have designed an instant messaging system to motivate changes in a user’s health-related activities. Their window display provides information to the user about their physical activity and smoking behavior in the past few days. Their feedback system provides detailed information about activity within social groups and relies on interaction from the user. Our idle time feedback system, on the other hand, emphasizes simplicity and will only require the user to read the information presented.

CONCLUSION AND FUTURE WORK

By comparing user responses to daily surveys and actual idle time as reported by AOL Instant Messenger status logs, we found that users supplied inaccurate ranges for their daily idle time 72% of the time.

As indicated in Figure 1, the users we observed were not fully aware of their idle time. The in-depth interviews also revealed that there are also misconceptions about the efficacy of computer power settings. Therefore, the next step is to fill this knowledge gap with information about idle time as well as suggestions for improving the energy use on a user’s computer.

We plan to design a feedback window based on the preliminary response we received to the mockups in Figure 2. Our preliminary plan for the next phase of the study where we distribute the feedback system includes a baseline where we will gather information about the new set of users similar to the information gathered in the first phase of the study. We will also use the CPU and TCP sensor to gather detailed data about the processes running on the computer during idle times. When we distribute this window for testing, one group of users will receive only constant and historical information about idle time and costs. Another group will receive in addition generic suggestions about reducing idle time. A third group will receive in addition to the idle data, personalized suggestions tailored ahead of time to their computer use patterns as observed during the baseline.

We will compare behavior and attitudes before and after the intervention stage to see which feedback system has the greatest impact on user behavior. Ultimately, we hope to arrive at a feedback system that will effectively convince users to integrate energy-saving practices into their computer usage.

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