Usability of Electronic Maintenance Manuals on Wearables and Desktops

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Abstract

This paper describes a planned study comparing the effectiveness of Interactive Electronic Technical Manuals on wearable computers and desktop computers. It details the stages of the study, and how a usability test will be conducted with Mechanical Engineering students from the University of Queensland's Formula SAE-Australasia team. This paper concludes with the expected outcomes of the study and plans for future research.

1. Introduction

Modern mechanical equipment needs regular maintenance to prolong its service life and ensure correct operation. In the past, manufacturers distributed printed manuals that guided engineers through maintenance tasks. These manuals are being increasingly replaced by electronic systems known as Interactive Electronic Technical Manuals (IETMs).

Wearable computers are designed to provide access to information immediately at any time or place. IETMs viewed on wearable computers can potentially increase the performance of maintenance engineers by reducing the time spent looking up manuals, and increasing the number of faults detected during inspections.

This paper details a planned usability study comparing wearable computer-based IETMs with desktop-based systems.

2. Background

Maintenance activities. Equipment maintenance can be classified into four categories: inspection, preventative maintenance, troubleshooting, and repairs [1]. Typical maintenance manuals for a single equipment model often contain 100,000 pages, up to 625 items in individual inspection checklists, and over 50 steps in a single maintenance procedure [1]. Most engineers will work on several models of equipment across many manufacturers, so they often carry and refer to technical documentation to perform their work. IETM versions of maintenance documentation have significantly lower distribution costs, and are far easier for the engineers to transport.

Like the majority of desktop computer applications, most IETM software has been designed on the basis that the user is stationary at a workbench, with their full attention on using the computer. This is often not the case, as using a desktop or laptop computer can be impractical or even impossible. For example, mine shafts are highly constrained spaces, and engineers inspecting cranes need both hands for climbing.

When engineers need to refer to manuals in these scenarios, they have two choices. The first choice is to guess or ignore what they have forgotten, such as an inspection step. Alternatively, they can stop their work, go to the workbench with the computer, refer to documentation, and return to the equipment to continue working. If they are frequent, time consuming interruptions such as this will significantly reduce engineers' productivity.

Wearable IETMs. Wearable computers are often touted for these scenarios as they are ideally small and highly portable, supporting the user's primary task, maintenance. Engineers can have all of their required information immediately accessible, and they are able to document their work as it is performed.

By not having to continually referring back to the workbench for the technical manuals, engineers could spend more time performing maintenance procedures. Inspections may be completed more accurately because more information is instantly available to the inspector.

There are many usability issues that may affect the usefulness of wearable computer-based IETMs. For example, issues with head-mounted displays have been well documented [2, 3]. Few wearable computers have battery lives long enough to support full work days.

Wearable computers may also generate too much heat for the user to comfortably wear.

Previous studies. There have been several studies of wearable IETM systems in the past. They were evaluated for their effectiveness as on-the-job training tools [4, 56] and performance aids [6, 7, 8, 9]. In these studies, the baseline comparison was either paper-based manuals or no easily accessible reference material.

Technical documentation is increasingly being published only in electronic formats, so there is a need to study wearable IETM systems using traditional IETMs on desktops or laptops as the control condition. This ensures that any identified benefits of a wearable IETM system are due to the use of a wearable computer, not necessarily the proximity of support.

3. Investigative Method

In my undergraduate Software Engineering thesis I investigate the design and evaluation of an IETM system for wearable computers. Usability tests will be conducted using a Xybernaut Mobile Assistant® V wearable computer and MicroOptical SV-6 head-mounted display, provided on loan by Xybernaut GmbH. There are five phases to this study:

Phase 1 – User Requirements. Contextual inquiries will be performed by visiting worksites where technical manuals are routinely used. Engineers will be observed performing their work, with the goal of understanding the nature of their maintenance work, and how they reference technical manuals.

Phase 2 – User Interface Design. A set of user interfaces suitable for the users' needs and work environment will be designed. These interfaces will build on interface designs from previous studies [6, 7, 8]. Head-mounted displays, flat-panel displays, speech input, and rotary jog dials will be supported.

Phase 3 – Prototype Development. Mincom's LinkOne IETM software will be extended to support wearable computers. This allows existing technical manual content to be viewed without modification. However, it is expected that content published for viewing on a desktop will not be effective on a wearable computer.

Phase 4 – Usability Testing. The usability test subjects will be Mechanical Engineering students from the University of Queensland's Formula SAE-Australasia (Student Division) team. Each year, they design, develop and test a Formula-style race car that is entered into several national competitions.

Participants will perform a simulated preventative maintenance and repair scenario involving the front corner assemblies (which attaches the wheels to the chassis). Normally the procedure involves disassembly from the car's chassis, crack testing the A-arms and rods, replacing damaged parts and reassembly. In this experiment, the participants will assemble the front-right corner assembly, followed by the front-left corner assembly and then disassemble both corner assemblies.

Before testing, the technical manual content will be developed and will include pictures and video clips of each step in the procedures. Both groups will be given training immediately before the usability test. The tests will be conducted in the UQ Usability Laboratory. It is expected that there will be eight participants split evenly between the test and control groups. The participants' experience levels will be classified as either novice or expert.

The tests will measure the time required to assemble and disassemble each corner assembly as the main performance metric. If wearable IETM systems are effective, then less time will be needed to complete all of the tasks. As the left and right corner assemblies are mirror images of each other, the difference in their assembly times may show variations in learning rates between the test and control groups.

The entire test process from the initial training to performing the procedures will be videotaped for review. The participants will complete questionnaires and interviews before training, after training, and at the conclusion of the tests.

Phase 5 – Analysis of Results. With the limited number of participants, range of devices, and time frame for this study, the results will need to be carefully examined for their validity and impact on wearable IETM usability.

The major metric in the study (procedure times) may be significantly affected by factors relating to the testing process and not necessarily the usability of wearable computers in general. The test subjects have had years of experience with desktop computers, but will have used the MA® V only for a few hours. The students from the test group may focus too much of their attention on using the wearable and end up taking more time than otherwise to complete the maintenance procedures.

It is expected that the video footage, questionnaires, and interview transcripts will provide insights into the usability of the software and the wearable computer. The footage will show potential problems such as difficulty in reading text on the head-mounted display or using the system in general. The questionnaires and interviews allow the participants to express their thoughts and concerns regarding the system.

Progress to date. There has been some progress on the undergraduate thesis to date. Site visits for the contextual inquiries have been arranged for several local businesses. The prototype IETM system is under development and is running on the Xybernaut wearable computer. The UQ Usability Laboratory is being set up for the experiment and the technical manuals are being developed. All eight test participants from the SAE team have been selected.

4. Outcomes and Conclusions

There are three expected high-level outcomes from this study. First, the usability tests may show a significant reduction in the time required to perform the maintenance procedures and increase in the inspection accuracy with the wearable computer. This implies that there would be no major usability problems with the system. Given the results of previous studies, this is unlikely.

Second, there are no critical usability issues with the system, but navigating the system and referencing information is too slow to be effective. For example, it may be that the system is perfectly usable, but still faster for the user to refer to a desktop computer. In this scenario, further research would be conducted to identify bottlenecks and alternative solutions.

Third, accessing IETMs on wearable computers may be infeasible because of usability issues. Some may be solved with improvements in technology (short battery lives), whilst others will be more fundamental (head-mounted display rivalry and interference).

More research is needed after this study for general conclusions on wearable IETM usability. The work environments of engineers and IETM usage patterns need more investigation. The usability tests need to include a wider range of wearable computers and input/output devices under more representative conditions across all industries.

Even if wearable IETM systems prove to be effective, external factors may prevent their adoption. Wearable computers are significantly more expensive than desktop computers and require additional staff training. The workplace culture may be negative to the introduction of such pervasive technology. Finally, there may be benefits to engineers being interrupted, such as allowing them to stretch and take a short break from the work.

There is an enormous potential for wearable computers to provide faster and more effective access to IETMs, but further research is required before it can be realised.

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6. References

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