Online-Collaboration for pen based Computers[1]

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Abstract.
This paper presents a software solution called MMA (Multimedia Maintenance Assistance) for remote service of aircrafts using pen based computers. We first describe different maintenance situations, in which expert know how is needed. We then discuss the boundaries and requirements for mobile software solutions in aircraft maintenance and show some advantages for an integrated approach supporting Offline and Online remote support. We describe, how user interface design for pen based devices differs and how new functions can improve the efficiency and quality of maintenance tasks. The proposed integrated solution can help to reduce the time needed for accurate and complete inspections and service and improves the quality of both.

Keywords. computer supported collaborative work, CSCW, wearable computing, mobile computing, remote service, video conference, aircraft maintenance

1 Introduction

In maintenance of vehicles and industrial installations, expert know-how is an important resource. It is provided differently depending on the situation:

1. Standard Cases can be treated by training and technical documentation.
2. Non-critical Out-Of-Standard Cases require external help from an engineering or service group. Sometimes it is difficult to locate the actual source of a problem. Technical documentation can be difficult to interpret or there are lacks in qualification or language. The problem is presented to an external support centre by fax or e-mail and the expert's advice (or further questions) are sent to the problem location.
3. In critical Out-of Standard Cases interactive remote help is needed. Experts have to travel to the location, carry appropriate spare parts and fix the problem. Traveling experts are a source for delay and cost. Exact identification of the problem is needed to make sure, that spare parts (and expert) fit.

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In all cases, the problem is to transfer the know-how fast and accurately. Modern computer and communication equipment improves interaction between remote sites and services centers, but today the three cases described are treated with separate equipment and procedures. This leads to undesirable delays, esp. when down-time is expensive. Supporting the described scenarios with one integrated system is an interesting approach, which will now be described based on the existing workflow.

2. Existing Workflow and Remote Support

2.1 Technical Documentation

In inspection and service technical documentation is used in paper and electronic form. Typical procedures are described by means of textual description, tables and figures. Electronic documentation is more and more enhanced by multimedia parts e.g. video clips showing the sequence of steps in a procedure or animations of a structure's topology. Notebooks are not the first choice to access electronic documentation for a mobile user, since they require two-handed input in parallel to the operation of other equipment.

2.2 External Support

In case of problems, external Support can be requested by fax or phone. Usually additional information about the problem is needed. Today, still images are taken and reach the remote expert by fax or e-mail. This way of communication is time-consuming and often leads to errors. In critical situations remote service as described in the following section can prevent the expert from traveling to the problem location.

2.2 Related Research Projects

Telec and EOS [1, 2] describe stationary remote support solutions for production sites. Multimedia communication is possible and helps to locate the problem. However, mobile devices are only supported to incorporate changes in the programming of PLCs and other control systems.

Often wearable belt or backpack computers are considered to replace notebooks. They allow hands-free operation and augmented reality scenarios. Winspect [3] suggests using a data glove for user input. Arvika [4] is also based on a belt computer and allows tracking and annotations in the video stream to direct the maintenance engineer. Both solutions offer completely hands-free operation and can be very useful in critical situations. However, for daily operation this is not crucial, the systems are very expensive and can experience acceptance problems.

Pen based devices are not a focus of current research, though they are beneficial for integrated usage (normal and special situations), offer some interesting possibilities and allow cost optimized solutions.

3. MMA – Multimedia Maintenance Assistance in different support scenarios

The MMA system (Multimedia Maintenance Assistance) is designed to integrate multimedia documentation and offline and online collaboration with a service centre. This has significant advantages, since daily usage avoids missing experience with equipment, which is only used in (rare) critical situations.

Another advantage of an integrated solution is that it can work with context-awareness. Information sent to the remote expert can be accompanied by information about the object of inspection, the location and the currently used documentation and equipment. This gives the integrated system a wider application field than pure remote support systems. This becomes clear by looking on the three different usage scenarios.

3.1 Normal situations

In normal operation the mobile device carries existing inspection and maintenance documentation including multimedia content in electronic form. Mobile devices in an service site receive updates from a central documentation server, which is linked to an intranet (vehicle owner) or an extranet (vehicle manufacturer).

3.2 Offline Remote Support

If support from a service centre is required, the MMA system is used to send information to the remote expert. This can include data from measurement equipment and pictures or video clips from a digital camera. This way the remote export has a faster and more accurate view on the problem. The same system can receive advice and further technical information helping to solve the problem.

3.3 Online Remote Support

In critical situations, video supported remote service has proven to be a powerful way of avoiding the traveling expert. In complex locations like aircrafts or industrial installations it is crucial to show the exact position and appearance of a problem. Again an integrated solution has advantages compared to normal remote service systems, since context information makes the situation more transparent.

3.4 MMA System Design

MMA is based on two pen based systems with a low and a high level software version. When choosing mobile systems size and weight are important aspects. Display resolutions smaller than 640x480 pixels (like in most PDAs) are not accepted by users, since PDF files cannot be displayed as complete pages. Further requirements in-

clude bright and non-reflective displays, ruggedized hardware and connectivity to measurement equipment and digital still image cameras. User Interfaces have to be very simple and optimized to mobile hardware and service/inspection situations.

3.5 Hardware Approach

Ruggedized (IP54/65) pen based mobile computers seem to be the best choice for use in inspection and service applications. They can be used both for standard (documentation-oriented) situations as well as for online remote assistance. Experiences with more than ten pen based computers from different manufacturers lead to the following recommendations. Due to the need for documentation access esp. for viewing PDF documents full page, display sizes of 8" or above and 800x600 pixel are desirable. Weight should be between 1 and 2 kilogram. Depending on the location, the display brightness should be adjustable between 50 and 150 cd/m². Reflections on displays often make the work difficult, but seem to be unavoidable. It is very useful to have function keys and adapted software, since taking the pen and re-inserting it are typical sources for delay and problems. I/O capabilities should include slots for camera memory (e.g. compact flash) and wireless communication models (e.g. Wireless LAN or GSM).

It is suggested to use two different devices per location. A small one (Windows CE based) is available for each service and inspection engineer. These units have a low level software version, featuring all offline and some online service (no video communication). Larger and better equipped devices (Tablet PCs, Windows XP) carry the High-Level-Version with the same user interface as the low level version, but additional features for full online collaboration service.

3.6 Operating System and GUI Framework

When using with mobile devices the choice of operating systems is reduced. On pen-based systems Windows is very common. Linux operation is possible, but most special features and access to important peripherals is limited. Consequently the MMA software was developed for Windows systems (incl. CE). The low-level MMA version runs on a Web Panel with Windows CE.NET. Its weight is less than 1kg and it has an 8.4" screen with 800x600 pixel. The High-Level version uses a 2kg industrial tablet PC with a 900 MHz Centrino and Windows XP Tablet PC edition.

For a comfortable GUI design, a powerful class library for the user interface is needed. In the desktop and notebook world there are good reasons to choose Java, but on CE based devices the situation is difficult. Portable libraries for a variety of operating systems (like Qt or wxWidget) are not available for the operating system Windows CE. This leads to the usage of .NET and the Compact Framework in the MMA project. The software development is based on C++ and C#.

3.7 Wireless Networks and Robust Multimedia Communication

Usually it is not possible to reach the service centre via an intranet or extranet connection. Other ways of establishing the WAN connection depend on local availability and organizational aspects:

- In some cases it is possible to use local telecommunication networks for WLAN/ ISDN or WLAN/analog routing providing data rates between 30 and 128 kBit/s.
- In other cases local telecommunication infrastructure is not accessible and mobile phone networks (GSM, Satphone, Inmarsat) with data rates ranging from 9.6 to 64 kBit/s need to be used.

The MMA software uses standard communication and transport protocols for data oriented collaboration. For audio/video communication the integration of several commercial [5, 6] and one open source solution [7] are possible. The commercial solutions offer optimizations for low data rates using efficient audio/video codecs and methods to reduce the overhead (e.g. header compression similar to RFC3095 [8]).

3.8 Software Architecture

The software architecture of the MMA system is divided in three layers:

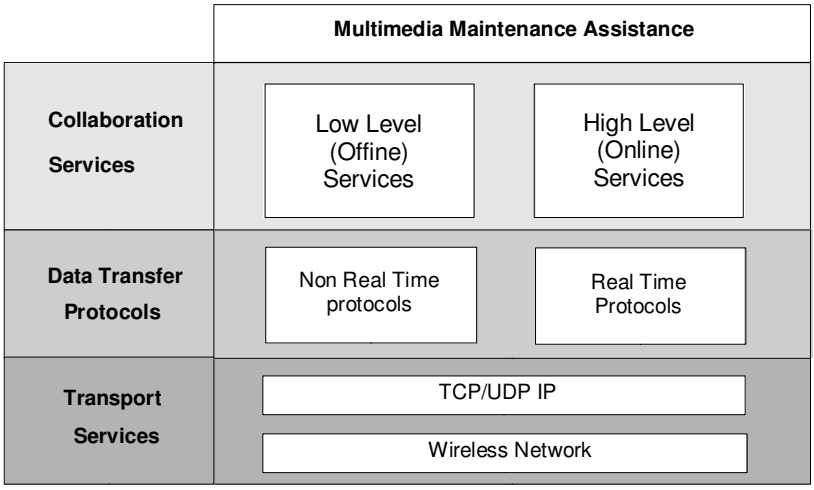

Fig. 1. Software Architecture

The application works with different collaboration services divided into two groups:

- 'Low Level Services' like report and image transfer are designed to run on Windows CE and Pocket-PC based devices with a minimum 200 MHz processor.
- 'High Level Services' add several real time collaboration services esp. audio/video conferencing. They require a Windows 2000/XP operating system and a processor with at least 800 MHz e.g. in a Tablet-PC.

Collaboration services use different protocols for data communication. The choice depends on the character of the data transmission and the content. Transport services

are IP based, since all communication networks allow IP transport. For low data rates the use overhead optimized solutions is very important.

3.9 Collaboration Services

The following figure shows the architecture and the collaboration services in detail.

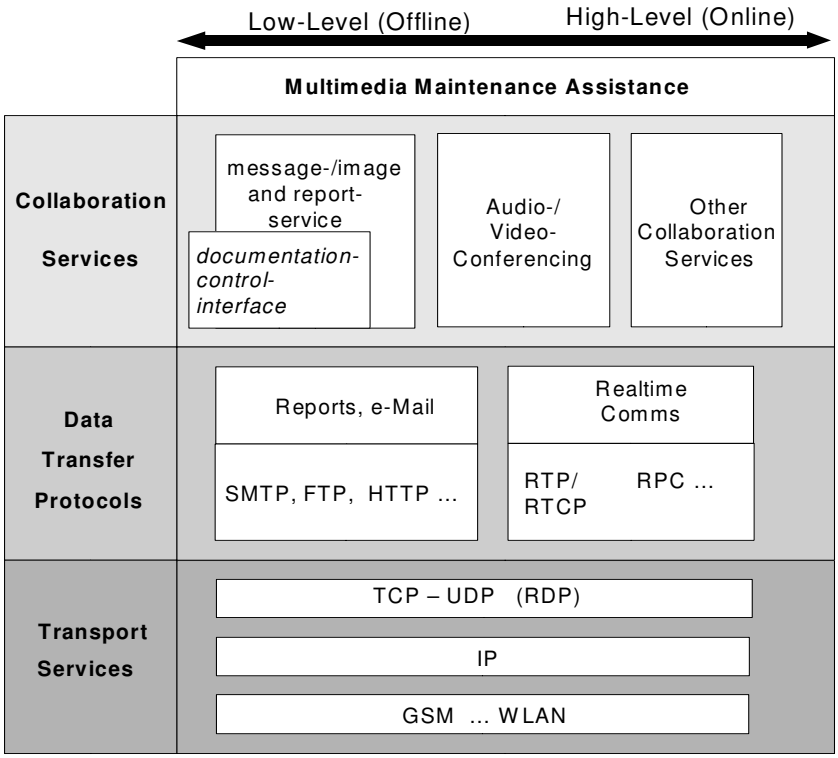

Fig. 2. Software Architecture and Collaboration Services (detailed)

The session and the presentation layer are strictly separated from the transport- and network layer to enable the support of multiple network types like Ethernet, ISDN, GSM, DECT, etc. The following collaboration services are included in the MMA Low Level version:

- A message exchange including still image and video clip transfer allow the remote expert to receive an impression from the local situation. Pictures can be annotated to point to interesting regions and get a good understanding of the problem. Still Images are the first choice for treating static problems.
- Dynamic information like views on carrying out the procedure, movement of parts and dynamic measurement data can be important as well. Video clips can be acquired by attached video cameras or separate digital cameras. They are transferred by an email or FTP service, depending on file size and the existing infrastructure.

- In the future, the message transfer service will be extended by context aware information like provided by multimedia documentation or a central information system. Examples could be product type, year of construction, serial number, location of inspection, documentation parts used, procedure identification.

In addition to the Offline Services, Online Services include:

- 'Still Image Exchange and Annotation' also known as Whiteboarding allows the online manipulation of images in 'shared virtual workspaces'. Important parts of an existing image can be marked. As in the editing mode, the image can be annotated with pointers and freeform lines. Changes in annotation are transferred to the remote side synchronously and allow solving the problem by interactive cooperation. Though online, this service is included in the low level version.
- In critical situations audio conferencing is needed for still image collaboration. In the low level version it is replaced by a graphical chat as shown in the next chapter.
- In addition, real time video communication helps the remote expert to locate and understand the problem. He directs the local engineer and observes his operations.
- Application and Document Sharing is planned to allow the remote expert to configure measurement devices or to navigate in the technical documentation concurrently with the local engineer.

4. Ergonomic Aspects

4.1 Mouse versus Pen based GUI design

The layout of the user interface differs between desktop computers and pen-based computers. The MMA GUI structure is shown in figure 3:

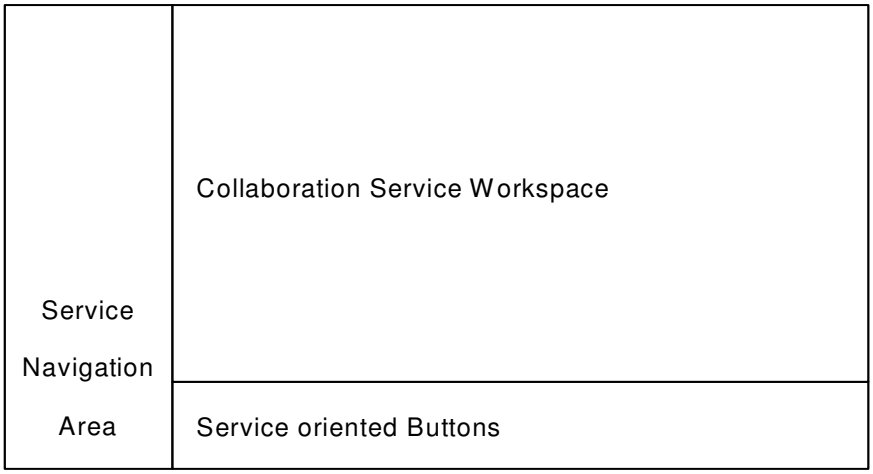

Fig. 3. Proposed Graphical User Interface layout for pen based mobile devices

In the proposed user interface navigational buttons are placed in a vertical column on the left side (like in many web pages). Action buttons for functions inside a service are placed in the bottom part of the screen to prevent covering the actual content with the hand (holding the pen). This is a difference to the menu orientation found in ”normal” desktop oriented user interfaces.

4.2 Hands-free or One-Hand operation

Figure 2 shows the graphical user interface of the application. With the buttons on the left side the user can select different collaboration services. The button arrangement from bottom to top permits the user to carry the Web Panel attached to one arm and control it with a finger.

The number of buttons is minimized to reach a very simple workflow. Button have a minimum size of 96x48 Pixel to allow the control of the standard functions of the application by finger. The following figure shows the Still Image Collaboration Service combined with a graphical chat:

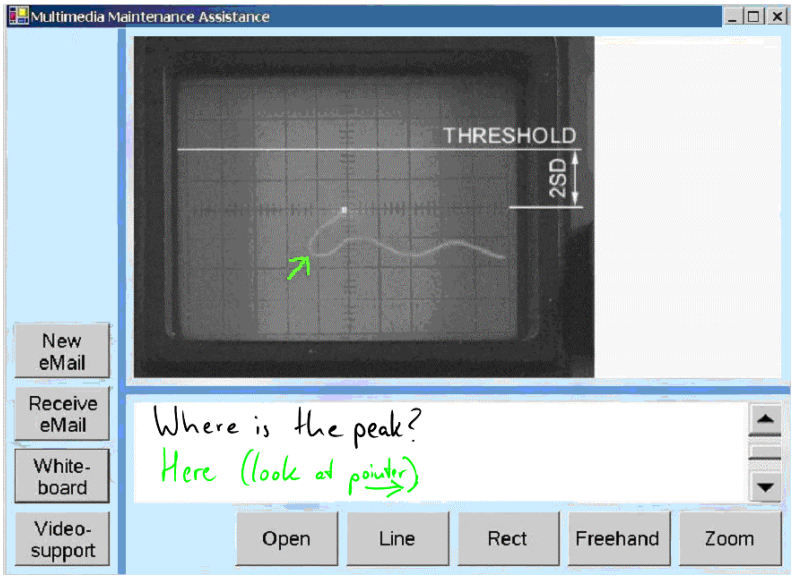

Fig. 4. User Interface with Still Image Collaboration and graphical chat

The graphical chat is a useful replacement, if audio communication is not possible.

4.3 Alternative input methods

In parallel to user inputs with a pen or finger, other input methods are investigated:

- Simple actions can be linked to function keys and make standard work possible without using the pen.

- Off-the-box speech recognition as well as several speech SDKs were tested. It was observed, that only command oriented solutions have low failure rates under noisy environments typical for industrial locations.

6. Conclusion

We have shown an integrated hardware/software solution with pen based computers for inspection and maintenance for large vehicles. To allow an optimal transfer of expert know how, it is crucial to cover standard as well as critical situations with the same user interface approach and similar mobile devices.

The integrated approach with a small pen based mobile device for daily access to electronic technical documentation and an extended version with powerful real time collaboration services seem to be a good mix to speed up and improve inspection and maintenance operation.

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