Remote maintenance and service support systems for construction machinery

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Abstract

Remote maintenance and on-site support of operators and maintenance personnel is becoming increasingly important for efficient use of complex machinery.

For enterprises active in global markets, the provision and support of a worldwide service network produces high cost on top of product prices and service cost. Both imply major drawbacks for competitiveness.

The use of modern ICT can support the improvement of maintenance processes and after-sales services regarding effectiveness, cost, flexibility and availability. By introducing facilities for remote access of machines from a service station and providing a cooperative working environment between the manufacturer's place and the machines in external sites, the support of service personnel as well as of machine operators can be heavily improved.

In the following paper the basic idea, the state-of-the-art and industrial requirements from supplier's and from user's side will be discussed. An approach for solution and related technology will be described. The first realisation of an application in construction machinery will be presented.

1 Introduction

Idle times of machines and facilities due to breakdown or regular maintenance operations cause high cost in today's industrial production. This is specifically true in the cases, where a group of people is dependent on only one or few machines, like in construction industry. If e.g. a crane breaks down, material flow is interrupted and the whole construction site stands still, resulting in loss of time, in unproductive hours of personnel and even in loss of material.

Short-term availability of maintenance staff, easier diagnosis of faulty machines and easy maintainability at the construction site is highly evident for successful market introduction of increasingly complex machines and equipment. The machine manufacturers are therefore forced by the customers to provide service networks, either decentrally organised by dealers or centralised in own service departments, both expensive in establishment and supportive cost. A high rate of unproductive working hours of service personnel during travel times is quite normal.

Investigations of cost structures in service departments of german machine manufacturers showed, that labour and travel cost in average sum up to about 75% of total cost, whereas cost for materials and spare parts only amount to around 20% [1].

Especially for the high number of small and medium sized enterprises these cost are not bearable on own expenses and have to be passed on to the customers. Life-cycle cost of machines increase, thus the competitivity of products decreases.

The use of latest information and communication technology enables already today many companies to reduce the cost for provision of adequate service and maintenance networks or departments. Remote maintenance, remote software updating, remote monitoring, adaptation of process parameters and technical support of machine operators will in future increase quality at lower cost in all areas of after-sales services, which remains one major decisive criteria for customers for buying machinery [2].

2 Scope of work

One major handicap for introduction of new technologies into construction equipment lies in the increasing technical complexity, which implies higher expected failure rates in combination with more complicated maintainability. The reliability of machines is virtually decreased.

The integration of additional modules always means additional fault rates, which could lead to machine failures if not handled properly. Especially the integration of analog or digital components for process control means additional risk of failure compared to the former mechanical control mechanisms [3]. Increasingly complex, distributed controllers in combination with dedicated bus systems are often difficult to diagnose. In case of failures, an on-site diagnosis is due to non-availability of adequate testing equipment not possible, and complete systems or modules have to be exchanged, in most cases without recognising the true reasons for breakdown. This effects in unnecessary, sometimes temporary repairs, only curing symptoms but not revealing the true causes.

High investments for complex machinery require the minimization of unplanned idle times due to failures or malfunctions to reach high operational capacity. Preventive maintenance will help to better foresee repair or maintenance works and schedule them into work pauses or times of low use. Important requirements for preventive maintenance are the provision of a machine-specific logbook and the unbiassed access to all relevant machine and process parameters.

The on-site machine user plays a major role in remote maintenance operations, normally being the interface between the service technician at the manufacturer's site and the machine on-site. Information content of the data exchanged is today mainly depending on the qualification and judgement abilities of the machine operator. The communication facilities have to provide an environment to support the local operator and enable a cooperative work and correct understanding between the persons involved. Instructions to the local user need to be accompanied by an unbiassed access to the machine and by the transmission of acoustic and visual information.

3 Primary goals for manufacturers and users

The primary goals of future developments should be seen in increasing the effectiveness of the existing service organisations by introduction of dedicated ICT.

In the following paragraphs major achievements for machine manufacturers as well as machine users will be described.

- cost reduction for manufacturers and users

  The high rate of on-site employment of service staff today produces high travel expenses and unproductive labour cost. Especially during the introductory phase of new products with enhanced funtionalities the mobilisation of well trained service technicians is necessary, often only due to misuse, wrong operation or false parametrisation of machines. These cost have normally to be borne in total by the manufacturer due to warranty or fairness reasons.

- shorter reaction times in case of breakdown

  Throughput time of maintenance operations has to be reduced, starting with the 24-hour-availability of 'hotlines' for support and determination of faulty parts, leading to the accurate identification and immediate delivery of spare parts and finally to sending out of maintenance personnel if required. Inefficient travels of personnel for diagnosis or identification of spare parts and the following second trip for the repair of the machine need to be reduced to a minimum.

- improved facilities for machine and process diagnosis

  The unbiassed temporal access to machine and process data by use of existing or additional sensors and the availability of tools for data logging, presentation and evaluation of parameters enables the technician to better understand causes and effects, thus reducing the probability of false estimations and increasing the effectiveness of repairs. The backflow of correct information about causes for malfunction will enable the continuous improvement of machines and production processes of the manufacturer.

- improved support for on-site machine operators and service technicians

  Well-trained technicians are expensive and only available to a certain extend. These resources have to be used efficiently, meaning, that the productive time has to be maximised against unproductive time like travelling. Telecommunication facilities would enable the transfer of their expert knowledge in short term to most places without travelling. Even if the service technician is personally needed on-site, the availability of all machine related information like e.g. design data, circuit diagrams, operation manuals and test instructions are needed in up-to-date versions. For application, all necessary information has to be exchanged between the construction-site and the manufacturer's site. Exchange of multimedia information (audio, visual, still-motion pictures, live video) is strongly required.

  Competence of machine operators as well as service technicians will be improved by getting support and on-line help from well experienced personnel. The cooperative work between the on-site personnel and the manufacturer will optimally support company-internal knowledge transfer and 'training-on-the-job' for operators.

4 System architecture

4.1 Cooperative working environment

The functional structure of the remote maintanance and support system is shown in fig. 1.

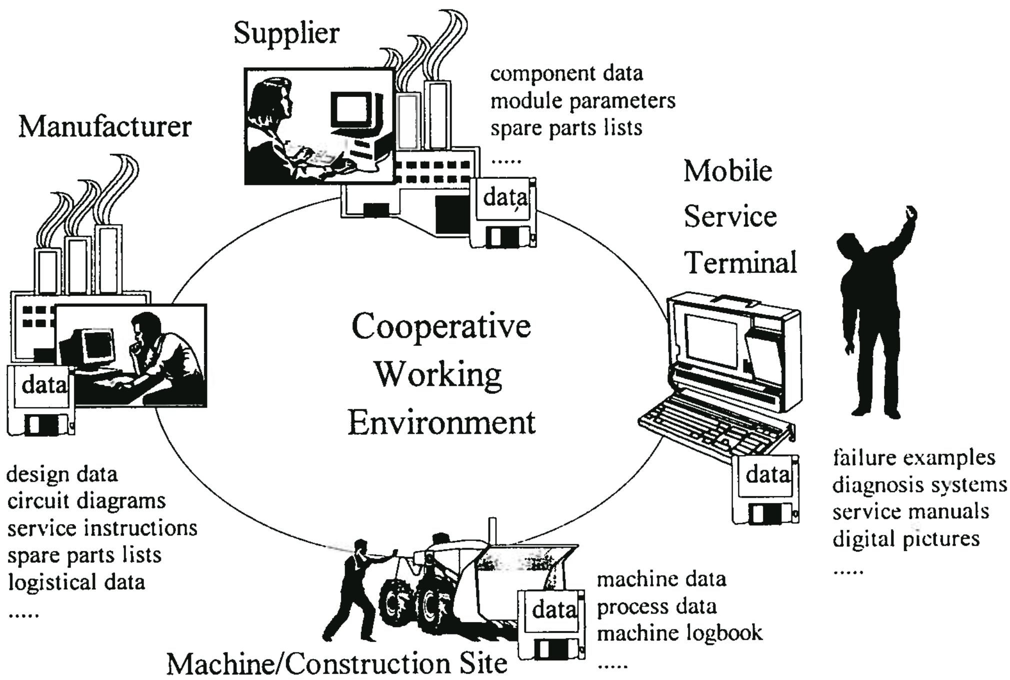

Figure 1: Functional structure of cooperative working environment and available data

By the establishment of the described functional architecture, all parties involved in the service process will obtain access to all information required. The provision of a cooperative working environment will help to find quick and easy solutions in personal discussions. Of course, access rights have to be granted to all participants, in order to guarantee confidentiality of specific information.

The integration of services like video-conferencing, whiteboards, distribution of camera pictures and exchange of data files enables all participants to collaborate on a personal level, what is estimated to be crucial for success.

4.2 Physical structure and communication lines

A major factor for implementation of the described remote maintenance system is the availability of communication infrastructures and networks. As the physical communication facilities are today in rapid change, full independence has to be reached by a clear distinction between the physical transmission of data and the applied standards for transmission protocols. Table 1 gives an overview of today existing physical transmission lines.

Table 1: Examples of existing data transmission lines and comparison of important parameters

physical channel	transmission mode	bandwidth (bit/s)	mobility	availability
public phone, analog	analog	~1k..50k	no	worldwide
public phone, digital (ISDN)	digital	64k..128k	no	europe
local radio links	analog/digital	~1k..10k	yes	local, 0.1 km ..1 km
wireless LAN	digital	..2M	yes	local, ..1 km
cellular phones (GSM)	digital	9.6k	yes	europe/ incom-plete coverage
Modacom	digital	2.4k	yes	europe
Internet	digital	..10M	no	worldwide
satellite	analog/digital	2.4k..64k	yes	worldwide

Especially the requirements concerning mobility and worldwide availability are essential factors for most applications in construction machinery. It is estimated, that in the near future industrial solutions for both satellite transmission and ground-based cellular networks will be available [4]. Of course, combinations of the mentioned transmission lines are in principle applicable, but normally produce higher cost.

On protocol layer, the whole system is based on available Internet standards. All data transmission protocols are following TCP/IP standard thus enabling the use of browsers and existing development tools. SGML and HTML formats can easily be used for all documentation purposes [5, 6], enabling links to existing document administration systems of machine manufacturers. JAVA applications and applets can be used in addition for specific functionalities [7]. Thus, independence to commonly used hardware and operating systems is mostly implied. Fig. 2 shows the resulting physical structure.

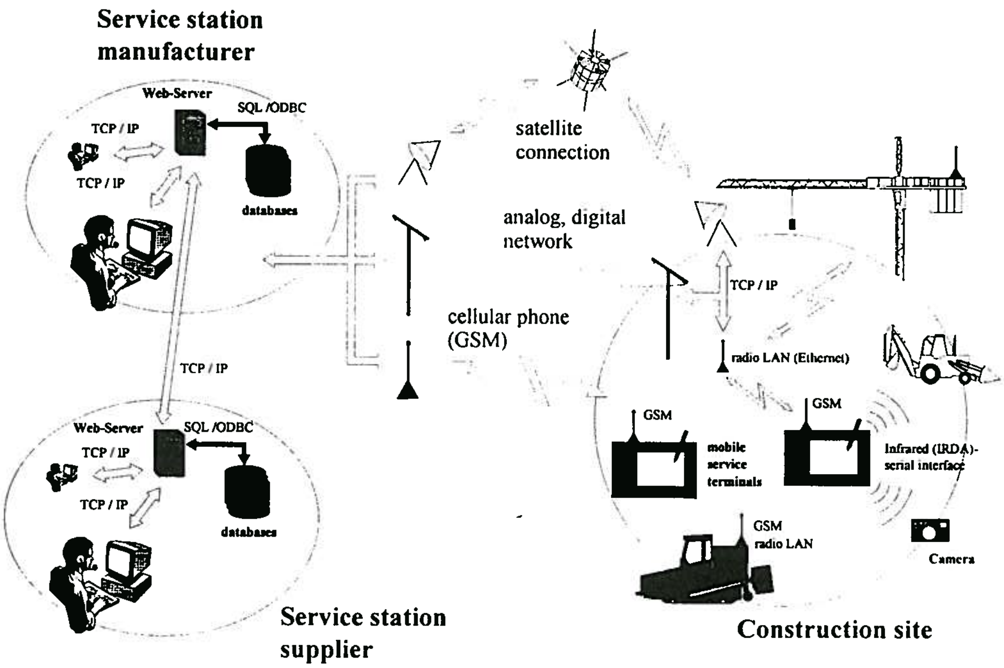

Figure 2: Physical structure

4.3 Functionalities provided by the system

Using the above mentioned tools and facilities, the following basic services will be provided for the application in construction machines:

- mobile service terminals for communication and visualisation between the machine operator, the service technician and the machine controller (could also be integrated directly into the machine);

- connection of the mobile service terminal to the machine controller for transparent access to machine and process data;
- bi-directional voice transmission between the mobile service terminal and the manufacturer/supplier service station;
- shooting, transmission and cooperative evaluation of pictures taken by digital cameras or extracted from databases;
- on-line access to all local and distributed data bases and information managers, e.g. spare parts management, maintenance instructions, circuit diagrams, diagnostics and testing instructions, manuals, machine logbooks, etc.;
- physical transmission lines can be specifically selected due to cost, availability and required bandwidth;
- administration of access rights.

5 Conclusion

Increasing demands on the availability of construction machinery in combination with prolonged maintenance cycles, the need for preventive and effort-related maintenance methods and the requirement for fast and effective service provision call for new structures and methods in machine service departments of manufacturers as well as construction companies. Due to the ongoing developments of ‘out-sourcing’ of service departments and the increasing amount of externally leased machines on construction sites, old-fashioned service structures will in future no longer work.

Integration of new technologies enables machine manufacturers and users to implement new functionalities in the machines and processes, which will pave the way towards more effective use of the resources. If the incorporation of these functionalities is already foreseen during the design phase of new machines, the price on top of today’s machines will be bearable. Return-on-investment can be estimated in short time scales, for the manufacturer as well as for the customer.

Like already shown by applications in other areas [8], remote maintenance and remote operator support as product-inherent means for improved after-sales services will in future become a determining factor in the market of high-tech machinery.

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