Concept and Design of Electronic Performance Support System in Industrial Maintenance Work

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Abstract—**The concept of HUB Maintenance is a platform application for work performance enhancement that stores and retrieves explicit and tacit knowledge anytime and anywhere. The system provides an environment in which on-site workers can solve their problems themselves; if needed, they can call an appropriate assistant and receive expert advice or coordination from remotely-connected web browsers. This system also provides opportunities to extract tacit knowledge from experts and store tips, know-how, or advice in databases. Providing such a collaborative environment effectively promotes knowledge transfer. This system can be applied to many categories of business and industry, including remote healthcare, warehousing, or building maintenance. The system's framework can also be extended to various purposes combined with other software or hardware.**

Index Terms— **Electronic Performance Support Systems, knowledge transfer, tacit knowledge, work-based learning**

I. INTRODUCTION

In Japan, improving maintenance performance has become a major concern in industrial companies because the issues of human resources, knowledge management, and cost are being exposed more than before. A great number of experienced employees are retiring; however, there is no adequate method to transfer knowledge to their inexperienced replacements. Knowledge must be managed practically.

David Snowden defined knowledge management as follows: "The identification, optimization, and active management of intellectual assets, either in the form of explicit knowledge held in artifacts or as tacit knowledge possessed by individuals or communities. The optimization of explicit knowledge is achieved by the consolidating and making available of artifacts. The optimization of tacit knowledge is achieved through the creation of communities to hold, share, and grow the tacit knowledge. The active management of intellectual assets is the creation of management processes and infrastructure to bring together artifacts and communities in a common ecology that will sustain the creation, utilization and retention of intellectual capital. [1]"

Knowledge management and Electronic Performance Support Systems (EPSSs) are closely related. Gloria Gery defined EPSS as "an integrated electronic environment that is available to and easily accessible by each employee and is structured to provide immediate, individualized on-line access to the full range of information, software, guidance, advice and assistance, data, images, tools, and assessment and monitoring systems to permit job performance with minimal support and intervention by others. [4]" Barry Raybould defined it as "a computer-based system that improves worker productivity by providing on-the-job access to integrated information, advice, and learning experiences. [5]"

Electronic Performance Support Systems have been developed for maintenance work support. LandMARC [6] provides Maintainer's Electronic Performance Support System (MEPSS™) [7], a decision support system developed to assist job performance [7]. NGRAIN® [8] products, which are 3D performance support solutions that include applications and commercial-off-the-shelf software tools, improve the performance of maintainers and operators and increase equipment availability and reliability. HUB Maintenance, described in this paper, is an intuitive EPSS for maintenance work support that is based on the dualism of explicit and tacit knowledge.

II. CHALLENGE OF MAINTENANCE WORK

Information and communication technologies continue to develop rapidly, and they contribute to support performance in various business domains and consumer behavior. When we purchase something, for example, reviews from other consumers on price comparison websites suggest what we should buy and where. The utilization of bits of knowledge actually seems to be working. In companies, on the other hand, sales support, accounting, purchase, and personnel systems are crucial for corporate management. The number of users who utilize Internet for knowledge management is 8.5% in April, 2007 [9].

Manufacturing industries in Japan must improve work efficiency to increase competitiveness. These companies have facilities or products with long life cycles such as power plants, gas turbines, vehicles, bridges, airplanes, garbage-disposal facilities, machine tools, building facilities, industrial robots, and ships. The engineers who designed, built, and maintained these objects have much significant tacit knowledge. Such knowledge must be transferred to inexperienced engineers at work fields at the right times as well as during pre-training courses. At the same time, renewed or up-to-date information should also be added as feedback to reform and regenerate further knowledge.

Figure 1 shows the cost performance by task complexity and skill level. The horizontal axis means task complexity, and the vertical axis means the worker skill level. The work tasks in Quadrant 2 denote simple and repetitive tasks performed by skilled, well-trained, or veteran workers, all of whom are very expensive. And, the work tasks in Quadrant 4 mean complex, difficult, or

time-consuming tasks performed by less experienced workers, whose costs are reasonable. To reduce the total employment cost, the work jobs in Quadrant 2 should be reduced and those in Quadrant 4 increased.
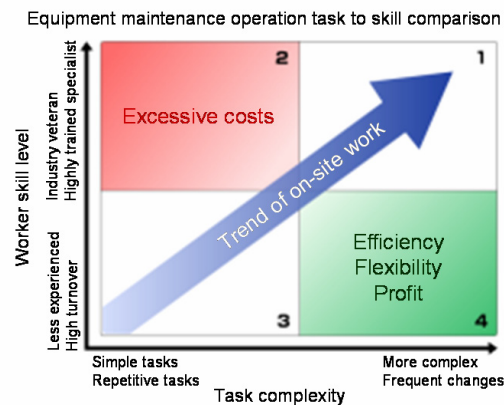

Figure 1.   Cost performance by task complexity and skill level

Industrial companies in Japan face the following problems:

– Maintenance work that depends on artisan skill
– Maintenance work difficult to mechanize
– Increasing age-limit retirements of skilled workers (originated with composition of population)
– Control of employment costs
– Decreasing opportunities to learn from experts
– Transfer of technological knowledge
– Teaching and learning efficient work procedures
– Changing employment patterns (less lifetime employment)

Focusing on industrial maintenance work creates the following problems:

– Operation error caused by lack of experience
– Unproductive and repetitive field visits
– Paper-based manuals, records, and forms
– Time-lag of information updates
– Undetectable alterations of work reports
– Inefficient scheduling and worker assignments
– Digital divide

Adequate performance support systems must be introduced to resolve the above problems.

III.   HUB MAINTENANCE PHILOSOPHY AND SYSTEM REQUIREMENTS

A.   HUB Maintenance philosophy

The concept of HUB Maintenance is a platform application for work performance enhancement that stores and retrieves explicit and tacit knowledge anytime and anywhere. Supervisors, on-site workers, and content authors mutually communicate among themselves (Figure 2). Each worker possesses both explicit and tacit knowledge about maintenance objects, workers, and things to which to relate. Such employees can create, edit, modify, annotate, store, search, retrieve, request, or respond to any bit of information. Explicit knowledge can be in the form of text, graphics, and any other digitalized data. Tacit knowledge cannot be described, so the system supports worker communication or discussion among themselves by video and voice through communication

tool. Desktop layout and presentation fashion are designed to be intuitive and legible without causing stress to the users.
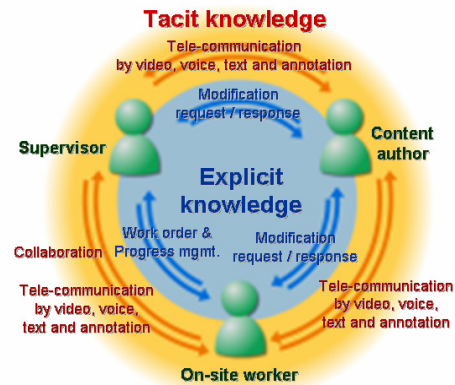

Figure 2.   HUB Maintenance environment

B.   HUB Maintenance system requirements

HUB Maintenance supports the work performance of on-site workers by providing both focused and related information in appropriate presentation fashions that reflect the situation. It also provides opportunities to extract tacit knowledge from experts and stores tips, know-how, or advice in databases. Pieces of such information are often very helpful for novices at the actual point of need and improve understanding. Providing such collaboration environment effectively promotes knowledge transfer.

The following are the major design elements of HUB Maintenance:

– Usability
Users receive suggestions about subsequent steps

Consistent layout and screen allocation

– Portability
System can run on a mobile PC, a rugged PC, a laptop computer, or a PDA

On-site workers can operate buttons and control objects easily and accurately

– Scalability
The number of users can be varied without changing the basic structure when introduced on a large scale

– Extensibility
System can be integrated with or communicate with other information systems, especially since most companies already have their own information systems

The system can communicate with such information tags as IC tags and barcodes

– Reliability
On-site workers can call supervisors or other workers

Supervisors and workers receive alert signals during an emergency

Supervisors and on-site workers are informed of the metrics such as temperature, atmosphere pressure at workers if needed

– Productivity
Users can receive environmental and useful information for accelerating the current task

Workers can receive assistance or support from remotely-connected workers

– Flexibility

The system can gather scattered pieces of information to the desktops of supervisors and field workers

– Availability

The system can be used anytime and anywhere

– Connectivity

On-site workers can access the content either online or offline

– Accessibility

Users can customize the following preferences: screen layout, color, and font name and size

Screen preference can be selected for both well-lighted areas and such dark places as tunnels

– Simultaneity

Supervisors can monitor such on-site worker environmental information as work progress, work status, and work locations if a GPS locator is equipped

– Traceability

Supervisors can trace the status, progress, assignees, time, and date of work orders

– Internationality

User can select the language, time zone, and country related to the presentation of figures and currency

IV. FUNCTIONS AND STRUCTURE OF DEVELOPED SYSTEM

This section describes the functions and system architecture of HUB Maintenance.

A. Functions

HUB Maintenance is composed of two major client software components, which are the on-site worker console (Figure 5) and supervisor/author console (Figure 3). These consoles can composite function components flexibly so as to adapt to target tasks or work style. The basic function of this system are classified as work order management, content allocation management, and communication and collaboration tool.

– Work order management

Work order management is used for issuing and assigning work orders, managing their status, and reporting the results with worker comments or feedback. When necessary, jobs are assigned by supervisors. To do this, a work order function is available that creates a work order ticket, assigns on-site worker(s), monitors work progress and status, and creates report forms. Work orders are created by supervisors when scheduled/unscheduled maintenance work is required, such as preventive maintenance, breakdown maintenance, or repair work. Work orders can be created automatically from another job management system as well as manually by supervisors.

– Content allocation management

Content allocation management is used for registering, updating, and locating such multimedia files as procedure manuals, designing diagrams, instruction movies, and any other related documents or frequently-asked questions.
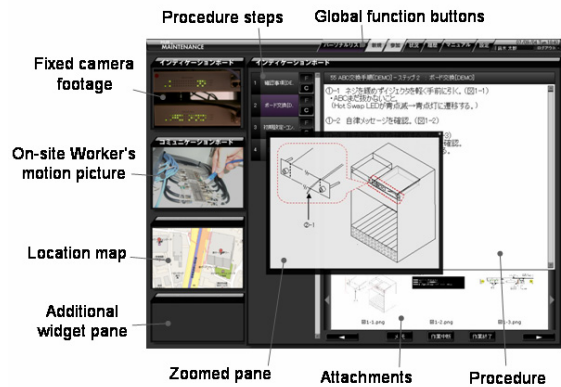

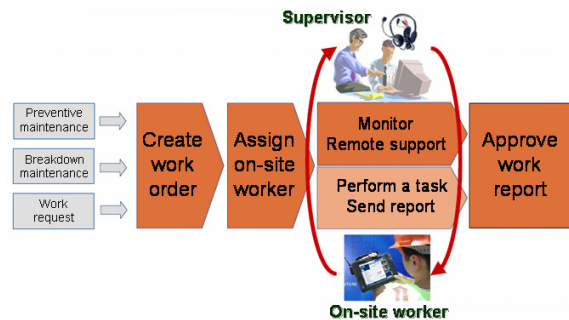Figure 3.   Work order and work procedure windows

Figure 4.   Work order cycles

– Communication and collaboration tool

Communication and collaboration tool is an integrated set of remote communication function realized on a desktop. It is used for capturing images or movies with embedded or plugged cameras with microphones, drawing, annotation on whiteboard, or on captured images through touch panels. And it is used for chatting online, sending or receiving shared files, and discussing issues with attendants.
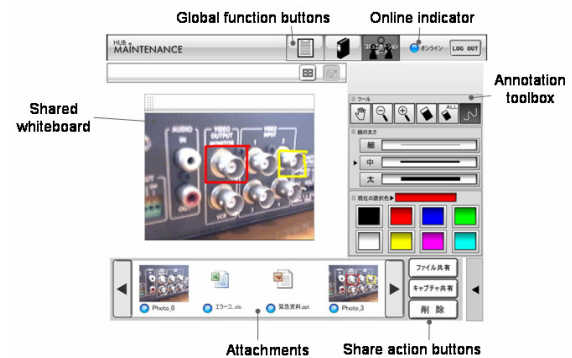

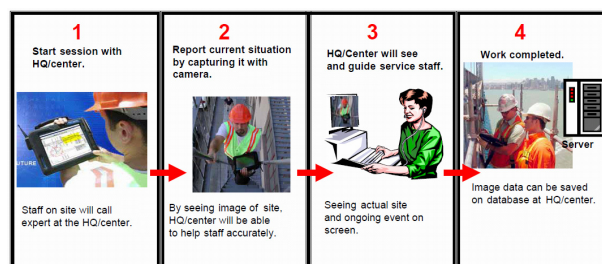Figure 5.   Communication tools window

Figure 6.   Task procedure with remote support

B. Network composition

Figure 7 shows the network composition of HUB Maintenance. It consists of a server and the two types of client consoles. A client console for supervisors and content authors, which runs on web browsers, communicates with each client application for on-site workers through the server. A rugged PC is also available for worker clients to utilize in specific environments, such as deserts, under water, or oily or dusty situations.
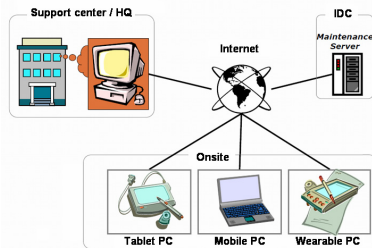

Figure 7.   HUB Maintenance network composition

C. Framework and database engines

HUB Maintenance is constructed based on HUB Engine, a database engine that enables easy connection to data structures. HUB Engine consists of four tiers: database application, data transaction, generalized ticket controller, and API. One advantage of using HUB Engine is that an application can treat its data model as simple virtual tables without programming a database schema and its access code.

V.   CONCLUSION AND FUTURE DIRECTIONS

HUB Maintenance is platform software that improves the performance of field maintenance works in various industries and service companies in manufacturing, plant engineering, maintenance agencies, distribution, and aftermarket business with on-site workers. This software is based on the dualism of explicit and tacit knowledge, and its environment offers many kinds of complete support to supervisors, on-site workers, and content authors. Using this software, a work order is issued to an assigned on-site worker, and each worker's tasks are collected on his or her desktop. Then tasks are opened, maintenance work is carried out, work progress and status are shared with supervisors, and reports are automatically generated. If a worker cannot solve the problem, he/she communicates with remotely-connected supervisors by Internet, and if needed, consults other workers. This paper proposed to increase the performance of maintenance work by providing digitalized manuals and sharing procedures, by scheduling and monitoring work orders, and by approving online work reports from remote locations. These are all realized through the functions of work orders, content allocation, and communication tool.

HUB Maintenance can be applied to various categories of business and industry, such as remote healthcare, warehousing, or building maintenance. For remote healthcare services, for example, human bodies are maintained instead of facilities, and the supervisors are probably doctors or nurses. The sick can learn first aid procedures and consult a primary care doctor on demand with our routinely-collected body measurement values that are automatically shared.

For warehousing services, on-site workers are employees and supervisors are their customers. Customers make requests by issuing a work order to remove something from storage, and then a service person is assigned the job. If the object to be sought is uncertain, then the service person can call the customer and send captured images taken from storage. As illustrated by examples, the system framework can be extended to various purposes combined with other software or hardware.

Future work will enhance the detailed design and redesign and implement function modules in various work domains and then evaluate this system by work performance and other point of views.

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