Proceedings of the 7th JFPS International
Symposium on Fluid Power, TOYAMA 2008
September 15-18, 2008

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ADVANCES IN MINING AND CONSTRUCTION MACHINERY THROUGH COMPUTERIZATION

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ABSTRACT

Recently developed construction machinery continues to advance from machines only capable of performing a stated task or function to machinery that provides automatic feedback regarding where and how the equipment is being used and the unit's current status. A number of such construction machines equipped with optional computerized construction features have even proved capable of interpreting construction designs and automatically regulating tools such as bulldozer blades. These new developments have led to conventional approaches to construction - such as continually interrupting operations in order to take measurements and check the project's finished status - no longer being necessary, thereby allowing for extremely effective and streamlined operations. In this study I will present specific examples of the application of this information technology to construction machinery and consider how such construction machinery will continue to advance.

KEY WORDS
Asset management, Remote operation, RTK-GPS, 3D-MC, Autonomous Haulage Sytstem

Use of IT in Construction and Mining Machinery

As shown in Figure 1., the increasing use of IT in construction and mining equipment can be viewed in terms of adding IT as part of electronic control of such machinery, and use of IT in support of this machinery or in aiding users' operating activities. Use of a core IT infrastructure allows for overall control to be brought to bear by working in close coordination, thereby differing markedly from conventional machines whose function is limited by only having access to onboard installed equipment. This paper will introduce a monitoring function that uses the internet and mobile communications, as well as mining and construction machinery that combine computerization and high accuracy GPS systems with automatic control functions. Due to these intelligent mining and construction machines operating in response to electronic signals and construction designs, they can even be referred to as robots in a broad sense of the meaning.

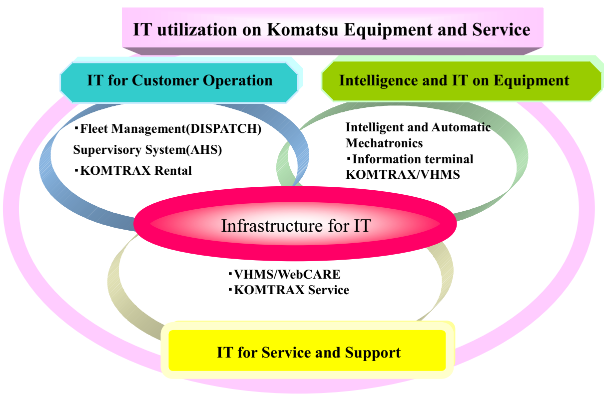

Figure 1 Use of IT in Construction and Mining Machinery

Remote Operating Control of Mining and Construction Machinery

Testing aimed at transmitting data regarding status and position of mining machinery equipped with onboard GPS and communication devices has been ongoing for several years now. In 1990 the U.S. company, Modular Mining Systems, successfully remotely operated a large capacity dump truck and loader within a mine from the company's offices using a computer and wireless LAN transmission system, with the computer sending optimized dispatch orders that were reflected on the truck's onboard monitoring screen with the operator being able to track the machine's status by viewing the data being transmitted back to the office's computer. Despite this success, however, as the use of construction machinery differs from that of mining machinery - such as the unrestricted nature of operating location - this means control by wireless LAN is an unrealistic option for the construction industry. This therefore required the development of a system with the ability to transmit wireless data at low cost while being capable of covering an extensive area.

As the use of mobile phones continued to expand, this heightened expectations for the development of such a data transmission service, leading to the drawing up of an initial concept for this system. At the time in 1995, however, in considering the high cost of mobile phones, usage fees, and poor coverage rate in areas of low population, it was decided that their use would be overly prohibitive, therefore requiring the adoption of an alternative service.

1999 saw the launch of a satellite-based data transmission service from ORBCOMM, and this was subsequently tested as part of an equipment monitoring system for construction machinery by Komatsu - marking the start of development of the KOMTRAX system. This study will introduce the KOMTRAX system and subsequent development of construction machinery that utilize the system.

Radio Controlled Unmanned Construction

Radio control is one of the earliest attempts to integrate information and communication technology with operation of construction machinery. In 1992 a high accuracy GPS and radio control device were integrated as part of an unmanned construction system used to prevent the spread of the Unzen-Fugen Dake eruption, with all operations being performed using radio controlled machinery. Figure 2 shows the remote operation control room used in this work. One of the challenges involved in using this system, however, was that remote operation was relatively inefficient in comparison to operation using onboard systems installed on the machines themselves. Of the technical proposals floated as potential solutions to this problem, use of an economical video transmission system capable of sending high-resolution real time images from a wide spectrum of machinery, or automatization of radio-controlled finishing operations were both viewed favorably. As described below, the integration of the computerized construction system using high accuracy GPS was an integral part of this development.

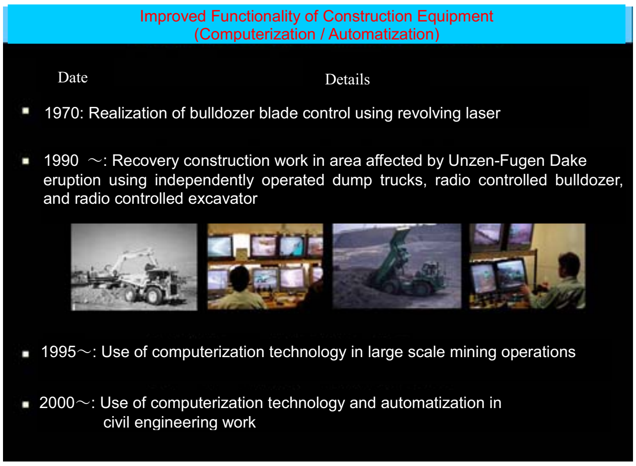

Figure 2 Remote Operation Control Room

Computerized Construction

This area of operations also has a history of use stretching back decades, with a blade control system consisting of a laser emitter and receiver being used to ensure a finished horizontal surface in rice field construction dating from the 1970s. From 2000, the increasing use of high accuracy GPS together with a system known as 3D-MC that takes advantage of 3D geometry to automatically finish a project in line with the original design, meant that this marked the start of the spread of full-scale IT construction in civil engineering work. The installation of onboard high accuracy GPS on machines has allowed for easier operation and their use has continued to attract attention in recent years.

Equipment (Construction Machinery) Monitoring System

As shown in Figure 1., while construction equipment continues to advance intelligently through the use of technology such as mechatronics in developing independent products that are part of technical development, products that include services using new IT have become essential to any infrastructure, with the intended use of these being support and operations, meaning that providing information through mediums such as mobile wireless communication and internet are key. To apply this fast evolving technology to long-life machinery requires work on this product development. This will also require joint development between manufacturers with little knowledge of content development and long-term management by users.

System Overview

Komatsu refers to its equipment control system for construction machinery as KOMTRAX, and beginning in 2001 we launched this as a regional standard in the Japanese market as we planned for its gradual rollout. From 2004 the system was released as standard in China, and then in North America and Europe from 2005. Models in line to receive this system installation continued to expand, and by 2008 KOMTRAX had come to be installed in almost all Komatsu construction machines.
Calculating net growth of these new units by subtracting newly registered machines, gives an estimated net figure of 300,000 units expected to be in operation by 2010. Figure 3 shows an overview of this system.

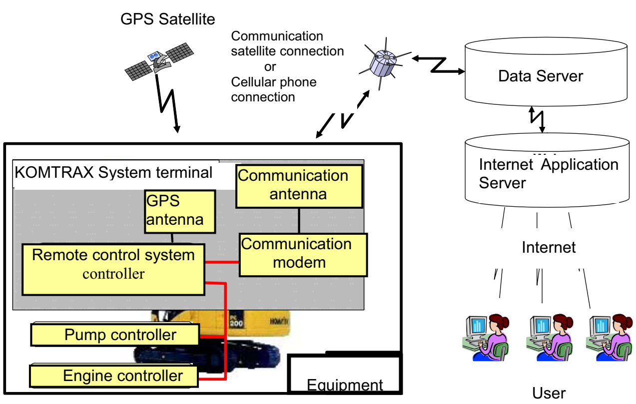

Figure 3 Overview of KOMTRAX System

Case Study Using the System

Using KOMTRAX allows information to be provided not only to the end user, but also to the sales and service outlet and other points, including the manufacturer.
Table 1 shows the main menu used for providing information with KOMTRAX.

Key Information	Web Display, Report, Mail Forwarding Service
Service meter	Daily/Accumulated operating time
Equipment location	Current location; previous movement history
Operating history	Date / Operating Map Operating Time Daily log; equipment and operator monitoring
Error / Caution	Early warning of any abnormalities
Operating time	Analysis of work content
Fuel consumption rate	Provides fuel efficiency report
Handling	Monitors operating load (handling)
Remaining fuel	Daily display of remaining fuel
Radiator temperature	Displays radiator temperature

Table 1 Information Supplied by KOMTRAX

Use by End-Users

KOMTRAX's benefits to businesses with a large number of machines include daily collation and monitoring of operating performance information, allowing for optimal allocation of machines for improved efficiency in busy workplaces. Other benefits include control of planned maintenance - leading to lowered maintenance costs - and improving operator performance by monitoring operating costs for each operator. Anti-theft function and tracking function also come as standard.

Use by Sales and Service Outlets

Advantages for businesses who have installed KOMTRAX in service vehicles include the ability to integrate control of onsite repair personnel and construction machines. This also allows for effective planned servicing, with KOMTRAX receiving praise for ensuring a speedy and accurate response for dealing with emergency repair requests.
Information that is sent via KOMTRAX - including operating site details, operating times, errors and caution information, fuel costs, and hydraulic pressure frequency - are combined to calculate load factor

information for the machine. The system can also be used for machines that are sold under an installment plan to estimate return based on weekly or monthly operating time, and is useful for credit management purposes based on its ability to monitor any non-authorized resale.

Use by Manufacturers

This system's use by Komatsu is highly anticipated as bringing wide benefits in areas such as marketing, servicing, development, and manufacturing. KOMTRAX can also be used in rational stock and production management for products and spare parts based on monitoring operating status by region and machine type. Another effective point is the ability to significantly improve the accuracy of information regarding its use for product planning and development.

Computerized Construction System and Applicable Construction Machinery

The increasing accuracy of high accuracy GPS and reduction in time required for surveying have resulted in some eye-catching devices, with the RTK-GPS being able to capture data in real time up to 2 cm level of accuracy. Due to space limitations the theory behind RTK-GPS measurements is omitted here, but using this GPS technology in surveying allows for both construction and measurements to be performed simultaneously, while eliminating the need to redo any finished construction and providing for construction being carried out in a rapid and accurate manner using computerized construction. This also allows for integration of a design and construction database, and due to its ability to plan for visualization of construction control, both mining and construction machinery are being developed in response to this.

Overview of Mining System

Due to the high cost of applying high accuracy GPS to construction machinery, the system was first installed in mining machinery as part of large-scale mining operations. The system's use in mining machines is mainly focused on operator guidance. This is reflected in providing guidance for determining boring position for boring machines, monitoring earthwork quantity for bulldozers, regulating quality levels for loaders, and guidance for drilling sites for production control, when used in conjunction with mining control systems. Most mining control systems look to maximize allocation of vehicles used in mines such as coordinating multiple ore transport dump trucks and loaders to ensure optimal drilling and transport of material, so that the use of GPS allows computerized calculation of such vehicles' position and speed - thereby sending programmed destinations to be displayed on the onboard display in each truck installed in the operator's cabin. An overview of this system is shown in Figure 4.

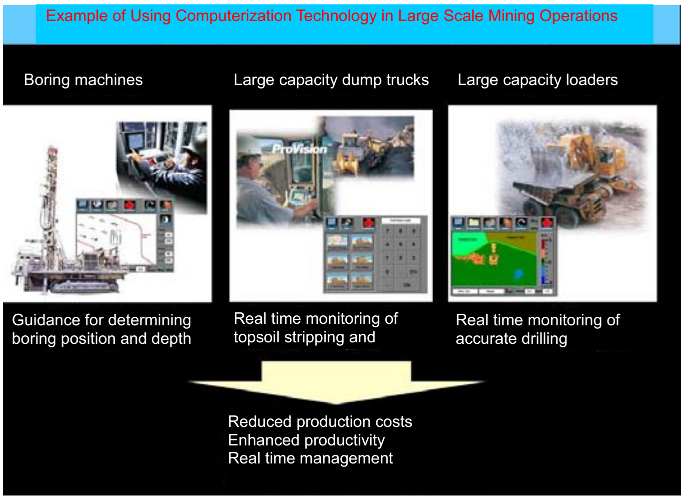

Figure 4 Computerized Construction System for Mining

Overview of System for Use in Civil Engineering

Following on from developments in the mining sector, from around 2000 an onboard GPS system debuted in construction machinery used in the civil engineering. Figure 5 provides an overview of this system. This was intended to be applied to use in construction and road building, and due to factors such as the automatic controlled blade requiring a more accurate GPS than that used in large scale mining operations, and need for integration with a 3D CAD system, this required some time before any commercial realization could be achieved.

Starting in 2003, a blade control system incorporating high accuracy GPS began to rapidly spread across the U.S. in use in bulldozers and graders. The significant effect this development had on the efficiency of finished work led to a reduction in construction period and improved operating rates. Despite being an expensive system to operate, its use has continued to spread in popularity. In Japan, however, this system is relatively expensive compared to the U.S., and the small scale of construction projects that are ordered within Japan has resulted in only a small number of projects capable of using the system and a low annual operating time, which means the system's depreciation cost is relatively high and it remains at an early stage of market penetration.

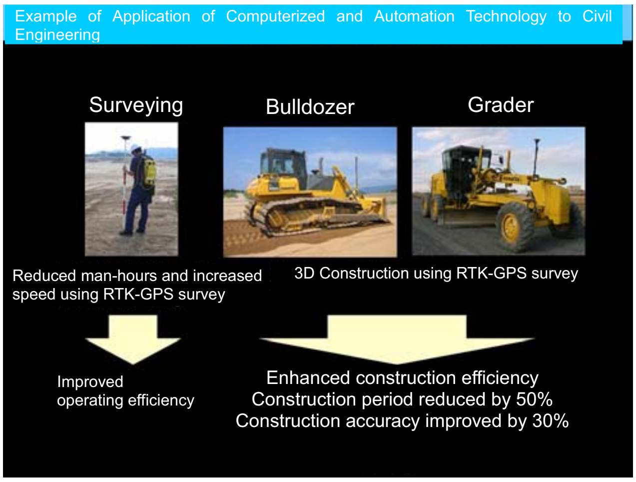

Figure 5 Overview of Computerized Construction System for Construction Machines

This section will provide an overview of the onboard installation of the system, using an example of its installation in a bulldozer. As shown in Figure 6., the GPS antenna - used to detect the horizontal and vertical position of the operating tool (the blade) - is directly attached to the blade through the pole. The reverse side of the blade has a tilt sensor attached to it, which detects the blade's tilt angle.

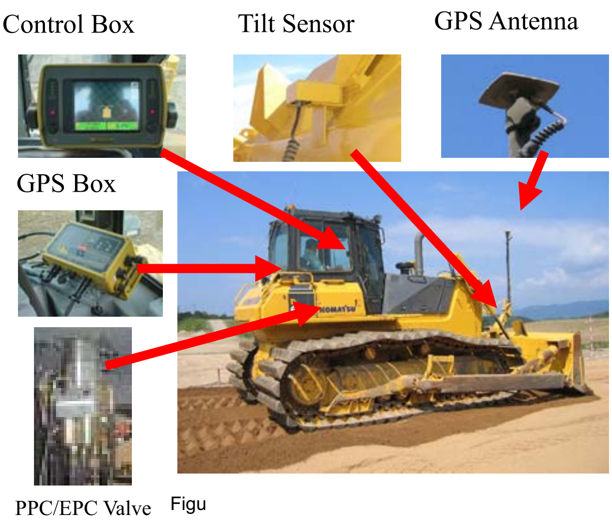

Figure 6 Computerized Construction System for Bulldozers

Construction plan data consisting of data created using 3D CAD is installed into the integrated control box consisting of the color indicator located in front of the operator's seat and control unit using compact flash memory that is also used in digital photography.

The control box color indicator constantly updates the display in real time of the machine's current position on the construction plan display, and this has been constructed so that the operator can confirm the operating status of the machine at any time (refer to Figure 6).

The control box can also be used to control the blade by comparing the actual position of the blade with the construction plan data in real time and manually operating and activating the valve.

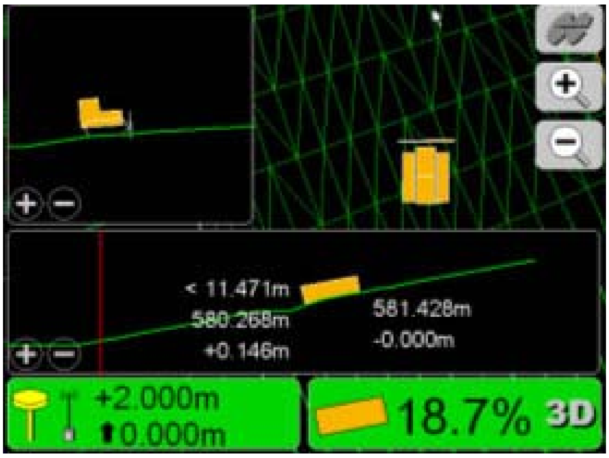

Figure 7 Insertion

Future Trends and Issues

One future direction for the development of mining and construction machinery lies in increasing robotization. Based on a combination of a computerized construction system and radio-controlled remote operating system, this will allow for future application of remote construction operating systems to mining machinery, in which integrated work can be performed from the comfort of a control room to direct drilling of mines and transport. Autonomous Haulage System in mining operations is already a reality, and there is a high possibility of drilling and material-handling operations in mine operations becoming a viable proposition in the near future. Areas that have to be overcome in order to make this a reality, however, include bringing effective real-time wireless image broadcasting technology online. Also, in order to enable remote or automatic operation of such systems, it is essential to use external confirmation sensors (laser, radar, vision system) and confirmation technology to ensure the safety of the surrounding area. However, manual operation will still be required following the introduction of such systems and machinery, such as for maintenance and repair work, meaning that the realization of an actual unmanned system faces a considerable number of hurdles to become reality. Figure 8 shows an idea for Autonomous Haulage System

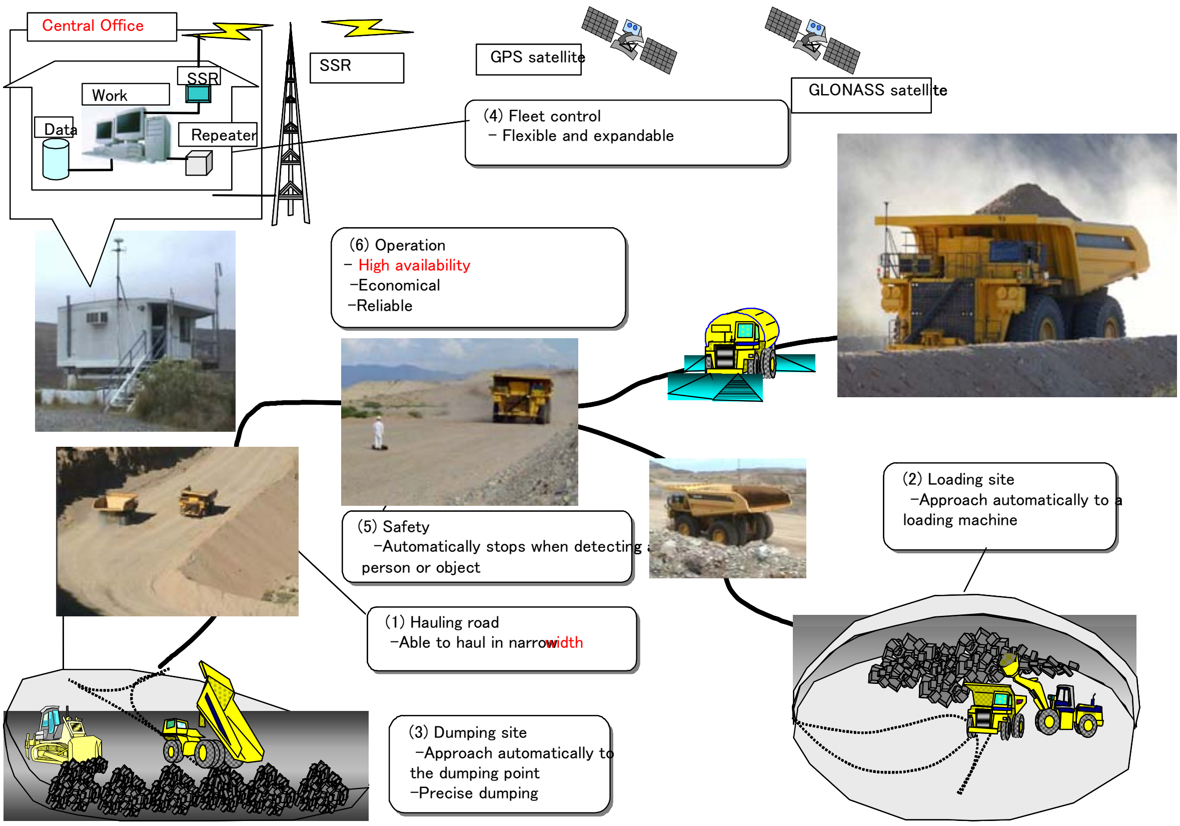

Figure 8 Autonomous Haulage System