Technical Paper

Construction jobsites of the future developed by construction equipment manufacturer in centering intelligent Machine Control equipment (Introduction of SMARTCONSTRUCTION)

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Labor shortage has become a serious problem in the construction industry. To meet a certain amount of construction work while ensuring the necessary quality under such circumstances, it is required to improve productivity through enhancing streamlining, efficiency, and sophistication of the construction production system. In response to this issue, we have launched a new service "SMARTCONSTRUCTION" (hereinafter "this service") that helps improve productivity and safety at construction jobsites through construction equipment utilizing Information and Communication Technology (ICT).

Key Words: *Computerized Construction, Intelligent Machine Control Hydraulic Excavator, Intelligent Machine Control Bulldozer, UAV Surveying, Stereo Camera*

1. Introduction

Construction investment was about 84 trillion yen at its peak in fiscal year 1992, but dropped to about 44 trillion yen in fiscal year 2010. However, it is currently showing an increasing trend thanks to demand relating to Earthquake Disaster Reconstruction, 2020 Tokyo Olympic Games, renewal of aging infrastructure, and so on. Yet, under the influence of order dumping or heavy burden imposed on subcontractors due to the preceding sharp decline in construction investment, a shortage of workers has become a serious problem, caused by decrease of the number of skilled operators, aging of workers, and decrease of new graduate employees. In fact, the number of construction industry employees was 6.85 million at its peak in fiscal year 1997 and then declined to 5.05 million in fiscal year 2014, dropping 26.3％ compared to the peak.

Even under such circumstances, the construction industry needs to assume maintenance and management of infrastructure as well as improve productivity and safety (mitigation of hazardous work) at jobsites.

In response to these issues, unmanned construction equipment or robotization of equipment is being promoted along with securing employment of workers and developing their skills.

2. Approach by Construction Equipment Manufacturer

To solve problems at construction jobsites having such various issues, efforts of construction companies as well as each involved manufacturer are essential. We consider that construction equipment manufacturers need to provide not only construction equipment using the latest technology to construction jobsites but also a mechanism to help customers make the best use of such equipment. Accordingly, we have launched a new service improving productivity and safety at construction jobsites through construction equipment utilizing ICT (**Fig. 1**).
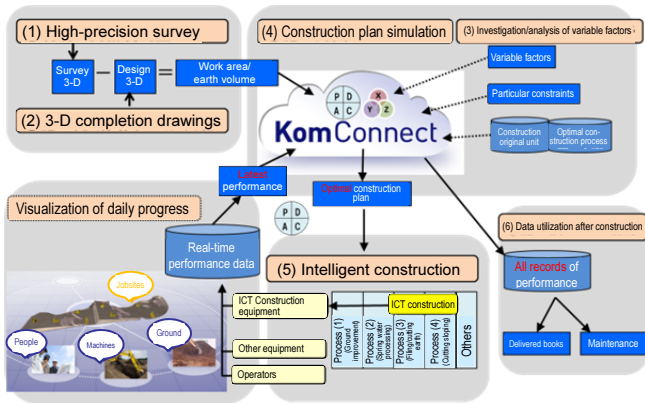
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Fig. 1   Overview of SMARTCONSTRUCTION

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The purpose of this service is to improve productivity of construction jobsites significantly and realize safe, smart construction jobsites by organically connecting all people, machines, and things involved in construction at jobsites through ICT.

We have introduced construction equipment utilizing ICT, such as intelligent Machine Control bulldozers introduced in 2013 and intelligent Machine Control hydraulic excavators in October last year. Thanks to such intelligent Machine Control models, even unskilled operators have become able to work with precision like skilled operators, regardless of their experience. Also, operation processes like staking and inspection have been reduced substantially compared to the conventional construction work.

However, regarding the whole construction industry, the computerized construction utilizing intelligent Machine Control equipment has not become as popular as we had expected.

In the pre-construction process of the conventional construction method, processes such as staking to indicate the design surface at sites are included. On the other hand, in the ICT construction, only development of three-dimensional (3-D) data necessary to operate equipment is required in the pre-construction process, which reduces man-hours at jobsites. Yet, with regard to the post-construction process, all formats of delivered books after construction completion have not yet been changed to formats in line with the computerized construction. Thus, even though construction has been implemented by intelligent Machine Control equipment, it takes time to convert the digital data obtained through ICT into the previous format. Due to this fact, the advantages of introducing intelligent Machine Control equipment have been likely to be reduced.

That is why, from the viewpoint of customers, we have decided to provide not only intelligent Machine Control machines but also a total solution including the above-mentioned pre- and post-construction processes so that customers can make the best use of capabilities of such machines.

The reason why we want to offer a solution to the whole construction work as a construction equipment manufacturer is that we are aiming to remain a company that is indispensable to our customers in the future as well. To realize this, we consider it is vital to understand customers' jobsites more deeply and continue to promote "Innovation" creating new value at customers' jobsites. Construction know-how acquired at jobsites promotes evolution of technologies and products, which can, in turn, be reflected on the jobsites speedily. We believe such positive cycle continuing to generate new value consistently can lead to a true solution required by Japan's construction industry.

For this purpose, we would like to evolve ourselves by entering in the jobsites and obtaining on-site knowledge by ourselves from persons involved in construction and operators at jobsites so that we can realize jobsites of the future in collaborating with customers.

In the following, we introduce solutions to realize these.

3. High-precision Survey Before Construction by UAV

Although surveying jobsites before construction through ICT has become popular recently, such as the use of Total Stations and 3-D laser scanners, it still takes manpower and time.

Thus, it is considered effective to conduct 3-D surveying by unmanned helicopters (aerial vehicles) (hereinafter "UAV") that can realize high-precision surveying of broad areas of construction sites in a short time and with fewer workers (**Fig. 2**). As the use of UAV is currently increasing rapidly, application to diverse sectors is expected and development of laws and regulations such as the revision of the Civil Aeronautics Act has been undertaken.

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Fig. 2 UAV surveying

comprehended accurately (**Fig. 4**).

Fig. 3 Intelligent Machine Control bulldozers 3-D construction data

The method of surveying jobsites before construction by UAV is as follows. By transferring the flight path information created in advance to UAV, UAV flies automatically without deviating from the planned flight path and takes photographs automatically. When aerial photographs are uploaded to the cloud server, 3-D point group data is automatically generated from the photographs taken using the stereo matching principle. Moreover, point group data unnecessary for calculation of the volume of earth, such as trees and artifacts appeared in the photographs, is filtered automatically so that the data is processed to generate point group data with only the present surface (present status 3-D data).

In the conventional construction in civil engineering projects, surveying of each survey point has been conducted based on the design drawings before starting construction in order to calculate the volume of earthwork by the average cross-sectional method or mesh method. From now on, as high-precision 3-D data of jobsites before construction can be generated automatically without difficulty, the present status can be grasped not in a linear manner but as a surface in a short time, which could never have been achieved by hand. This enables a more accurate calculation of the volume of earthwork.

4. Three-dimensional Construction Plan Drawings

Three-dimensional construction drawing data is indispensable for operating intelligent Machine Control equipment. Management of blades of bulldozers or cutting edges of buckets of hydraulic excavators is conducted based on such construction drawing data (**Fig. 3**). In addition, the difference between the present status 3-D data obtained by surveying described in the previous section and the construction plan 3-D data is calculated automatically so that the area and the volume of earth to work on can be

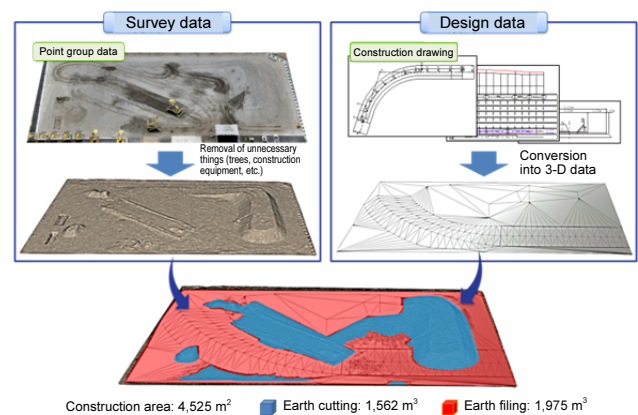Construction area: 4,525 m²   ■ Earth cutting: 1,562 m³   ■ Earth filing: 1,975 m³

Fig. 4 Earth volume calculation method

5. Investigation and Analysis of Variable Factors

There are several factors affecting the construction efficiency at construction sites, including weather and unexpected ground conditions such as spring water. In general, although the ground investigation is carried out by boring or other means at the design stage, it is not always the case that the number of points of investigation is sufficient. Also, if there is any change in design, ground information of the points required may not necessarily be available. Therefore, we are currently under study whether we can offer a simplified tool to grasp in advance factors causing uncertainty at construction sites up until now, or at least a method that serves as materials to create proposal documents and helps prompt additional implementation of the ground investigation.

By clarifying uncertainty factors at jobsites, it will become possible to anticipate problems that may occur in the process of proceeding construction and reflect on the construction plan so as to minimize the impact if problems arise.

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6. Simulation of Construction Plans

Construction companies have created construction plans, estimates, and execution budget based on accumulated performance and personal experience of operators by using their own systems or spreadsheet software. However, from now on, developing construction plans and others may take more time to incorporate performance of the new equipment provided by construction equipment manufacturers one after another, which includes collection of information on such new equipment. In addition, in most of the current systems, many man-hours are needed to review the plan manually during the construction work.

Accordingly, we consider it is essential to provide a simulation system that can offer necessary information at anytime so that customers are able to review the execution budget incorporating the necessary number of equipment and working days taking into account such information.

By integrating three solutions presented above, our customers will be able to have an accurate understanding of the area and the volume of earth to work on, obtain detailed ground information at the point, and make more accurate construction plans.

Additionally, by utilizing our know-how obtained over the years in the production of construction equipment, multiple simulations can be performed in a short time to select effective, optimal construction equipment or to calculate the cost and the period of construction. In doing so, the results of simulation can be provided according to the needs of each customer, for example, in the case of setting the minimum period of construction or minimum cost (**Fig. 5**).

Customers will also be able to review construction plans based on feedback of daily progress received from intelligent Machine Control equipment, the core of the computerized construction working at construction jobsites.
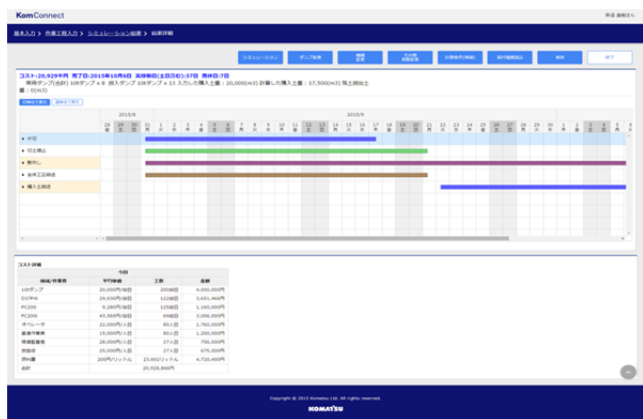

Fig. 5 Simulation results: Process calculation

7. Construction Using Intelligent Machine Control Equipment

At present, we are providing intelligent Machine Control hydraulic excavators and bulldozers to jobsites.

Our intelligent Machine Control hydraulic excavators equip with not only "Automatic Grading Assist" (**Fig. 6**) that can control the position of the boom automatically while operating the arm so that the edge of the bucket can trace the design surface accurately without excavating beyond such surface, but also "Automatic Stop Control" that can automatically stops the arm, boom, or bucket, as necessary, in order to prevent them from damaging the design surface. Thanks to these functions, intelligent Machine Control hydraulic excavators have realized more efficient digging and other work than before.
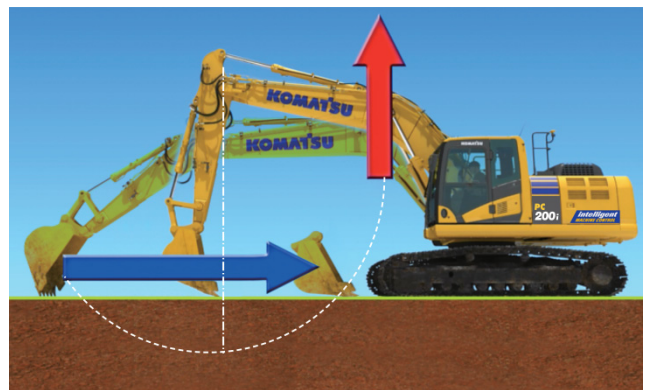

Fig. 6 Automatic Grading Assist

Our intelligent Machine Control bulldozers conduct an automatic operation in lowering the blade to the target position automatically and performing rough digging through simple grading. In addition, if the load on the blade exceeds the set limit value, the position of the blade is automatically controlled to minimize the shoe slip. Thanks to this function, damage to the design digging surface can be reduced and the work efficiency can be improved (**Fig. 7**).

1. If the blade load increases,
2. The blade rises automatically to control the load and avoid shoe slip.
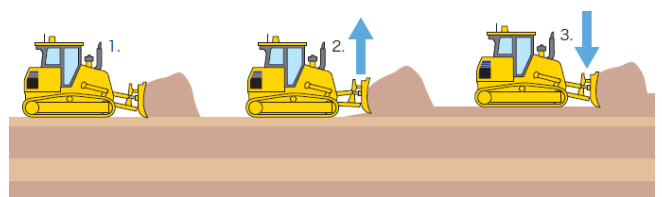3. The bulldozer can work efficiently with the maximum volume of earth to be held.

Fig. 7 Shoe slip

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By deploying these intelligent Machine Control equipment, auxiliary work by people around construction equipment can be reduced, which will decrease the number of accidents caused by heavy equipment.

Moreover, in the event of sudden design changes etc., our newly established support center can directly support the customers' jobsites in order to handle changes to construction data due to change in drawings or to resolve troubles speedily.

8. Visualization of Daily Progress

What we want to realize at jobsites through this service is the "Visualization" of daily progress of construction work not only by using each technology presented above separately, but also by organically connecting everything on the jobsites, including all construction equipment and operators working at sites and earth to be moved, through ICT. By doing so, it will become possible to perform informatization of everything on the jobsites, implement the PDCA cycle (Plan - Do - Check - Action) based on such information, and review construction plans each time after the cycle in order to provide the optimal construction plans to jobsites at anytime.

To achieve these, it is key to use a system enabling centralized management of all technology concerned.

That is why we are offering a cloud-based service "KomConnect" accessible from anywhere, any terminal at jobsites.

Operation data of intelligent Machine Control equipment is transferred to this cloud service and reflected in daily execution progress. In the progress figure, each part of the earth cutting work and the earth filing work is displayed in a different color. The figure can be displayed both in two- and three-dimension, and progress on any specific cross-section surface can be checked as well (**Fig. 8**).
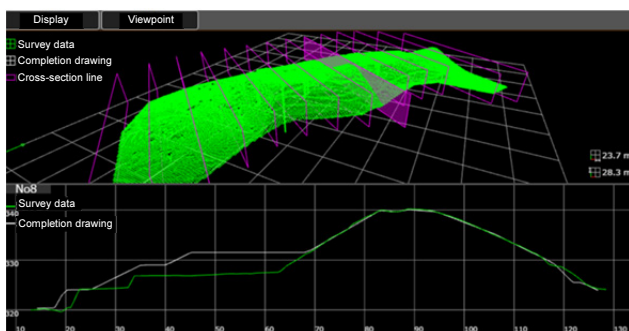

Fig. 8　Cross-section display of execution progress

However, there are also equipment other than our intelligent Machine Control models working at jobsites. Their execution information cannot be dealt with in the same system as our intelligent Machine Control equipment. Thus, execution progress of other equipment should be managed by intelligent Machine Control models equipped with stereo cameras.

By taking photographs of execution areas by stereo cameras mounted in the cabin of the hydraulic excavator (**Fig. 9**), such information can be converted into 3-D point group data (**Fig. 10**). Then, by adding such data to the executed data by intelligent Machine Control equipment, it becomes possible to understand the entire work results at jobsites.

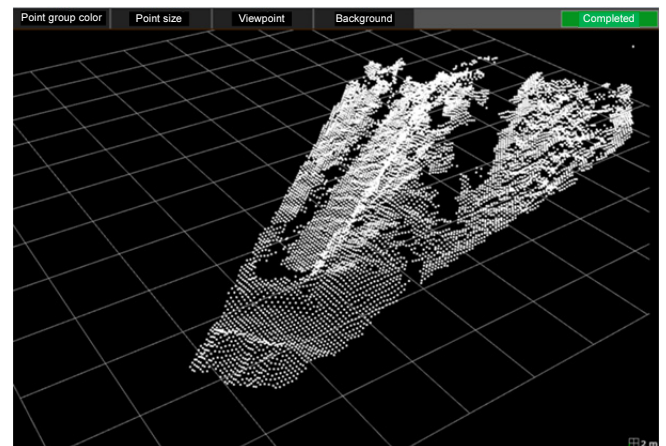**Fig. 9**　Photograph of jobsite taken by stereo camera

Fig. 10　Three-dimensional point group data

9. Utilization of Construction Performance Data

By deploying intelligent Machine Control equipment, operation and construction performance of construction equipment at jobsites can be stored on the cloud service automatically. Therefore, it is deemed that when customers

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will be able to create various forms automatically by utilizing such data, daily routine work such as filing documents can be streamlined, and persons in charge at jobsites can better focus on management of their jobsite, which will further improve efficiency.

10. Conclusion

If we can connect everything on the jobsites - people, machines, materials (things) - through utilizing ICT, efficiency, streamlining, and safety of construction work can be improved.

Furthermore, if such new way of construction site management through ICT interests young people and makes the construction industry more attractive, we consider it helps increase the number of employees in the whole construction industry.

We believe, by evolving these solutions step by step, completely unmanned construction sites can be realized in the future.

Introduction of the writers

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