State-of-the-Art Construction Sites Realized with ICT Construction Machines

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ABSTRACT

In recent years, there are growing needs to utilize ICT (Information Communication Technology) in the construction industry to increase productivity, reliability, and eliminate labor shortage. This is realized by connecting "Construction Workers", "Construction Sites", and "Construction Machines". The ICT Construction Machines are featured with advanced technology such as machine guidance (MG), machine control (MC) to assist the operator, and the site management system to process productivity and work progress data. In general, it requires years of training and experience to become a highly skilled operator, but with the newly developed machine control technology for ICT construction equipment, by combining the GNSS (Global Navigation Satellite System) positioning technology and the electrical control technology of components, it will enable novice operators to become as productive as highly skilled operators. At the same time, productivity and work progress are processed into data and sent via internet to be consolidated in the site management system, visualizing everyday progress without having to leave the office. Komatsu has commercialized these technologies which are immensely contributing to the industry. This is an introduction of the ICT Bulldozer, ICT Hydraulic Excavator and the solution service called "SMART CONSTRUCTION" innovating the construction model of job site.

Key words: *ICT Construction Machine, Machine Control, Machine Guidance, Bulldozer, Hydraulic Excavator*

1. Introduction

1.1. Social background

The recent environment surrounding the construction industry in Japan is the declining population, falling birthrates and aging. They cause labor shortage, reduction of skilled workers and difficulty of skill transfer. Meanwhile, the amount of construction work is increasing, corresponding to the maintenance of aging infrastructure and the creation of new infrastructure with saving energy and using renewable energy corresponding to aging society.

If we look to the world, especially focusing on emerging countries, because of increasing in population, increasing demand of energy and food, urban centralization of population, etc., resource development, infrastructure and housing augmentation are becoming urgent issues. However, in emerging countries, skilled workers are short, and development and construction have not progressed at a sufficient pace.

1.2. Issues in construction industry

In Japan as well as in other parts of the world, the following five items are regarded as important in the construction industry.

1) To maintain quality and strictly adhere to the construction period
2) To realize safety work
3) To reduce the cost of the site
4) To shorten the construction period and increase the number of orders
5) To realize an attractive job environment where the number of employees increases

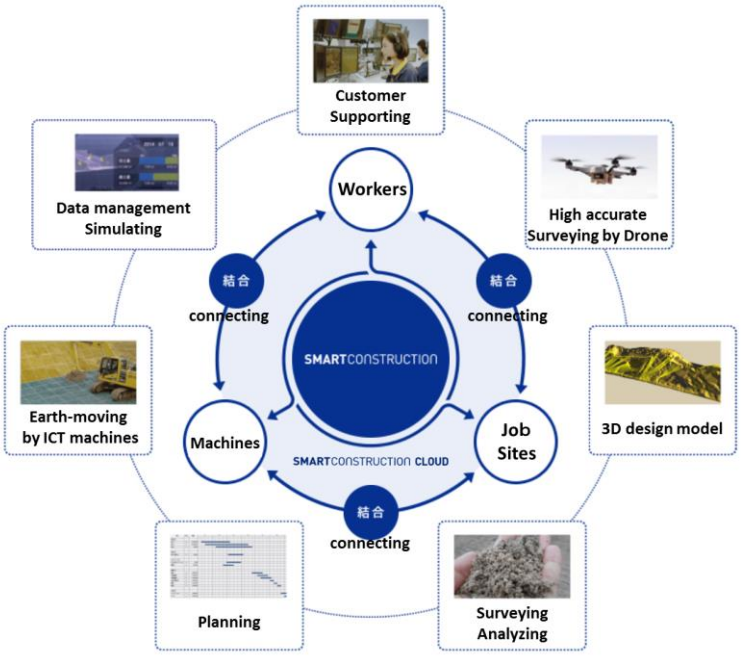

Fig. 1 Concept of SMART CONSTRUCTION

1.3. Solution

In order to solve these issues, it is expected that the demand for "Information Construction" will further expand in the construction industry regardless of developed countries / emerging countries. Therefore, Komatsu launched a construction solution service to solve the issues facing the construction industry beyond the traditional framework of manufacturing and selling construction machines, with the new business strategy of "SMART CONSTRUCTION".

In this service, workers, job sites and construction machines are tightly connected as one circle by ICT (information communication technology). As an important role in the circle, Komatsu believes that ICT construction machines with innovative functions and high durability will maximally contribute to the improvement of efficiency of construction work.

2. Changing of construction processes

2.1. Conventional process and issues

In conventional way of construction process, most of the processes, such as calculation, surveying, staking, earth-moving, checking and inspection, are done by human hand-works or manual operation. It causes several issues and obstructs high efficient progress in entire construction process.

This situation causes following typical issues.

1) Difficult to make planning properly.
2) Difficult to recognize accurate progress because it is updated by daily paper reports.
3) Productivity could be various depending on the operator's skill and experience.

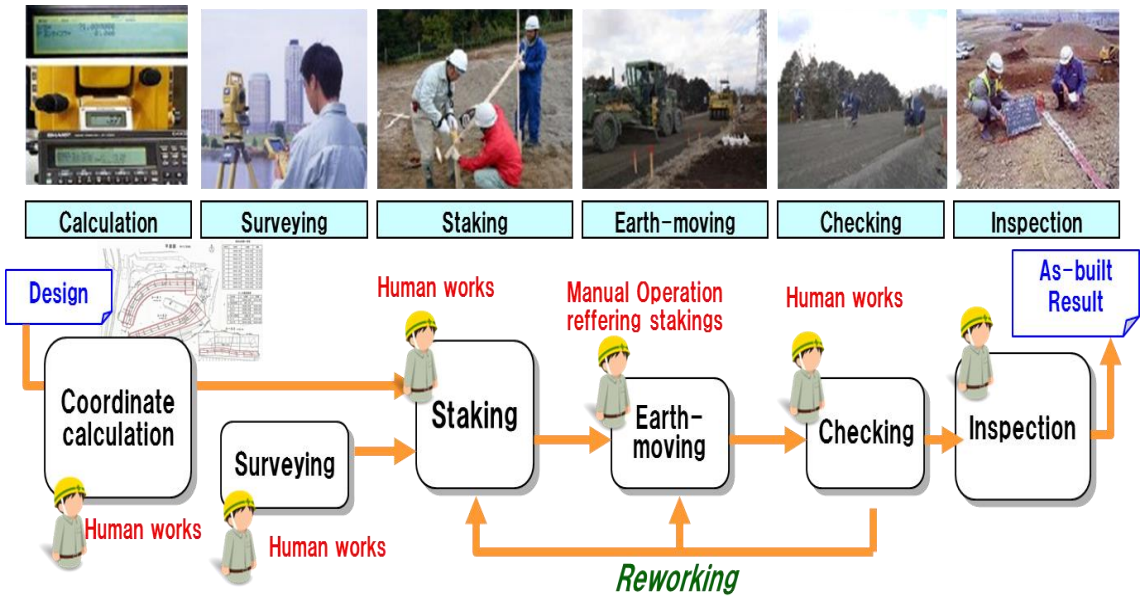

Fig. 2 Conventional process of construction

4) Hard to predict problems and troubles that may happen in job sites.

2.2. New process and solution

SMART CONSTRUCTION concept provides construction job sites with a completely new method of construction process by utilizing digitized information gathered in KomConnect server and helping by ICT construction machines with Semi-automatic control system thought the entire progress of construction job site (**Fig. 3**, **Fig. 4**).

This new solution solves current issues.

1) Automatically generate accurate planning during the entire construction process by utilizing a drone for surveying the current terrain, creating a 3D digitized design model and simulating the construction progress in KomConnect server.
2) Automatically calculate and visualize the everyday construction progress. A site manager can easily recognize progress and can feedback for the following days planning.
3) Productivity could be even regardless of the

Fig. 3 New process realized by SMART CONSTRUCTION

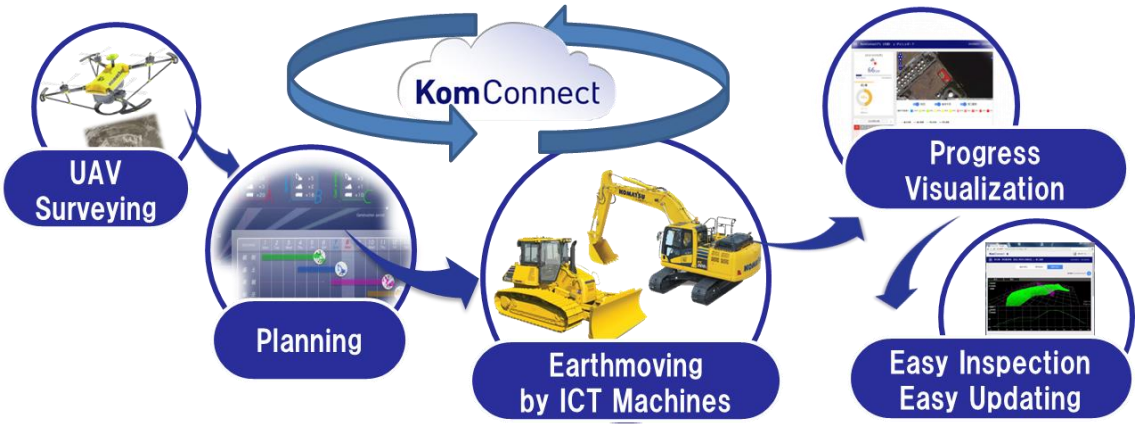

Fig. 4 All information is gathered in KomConnect

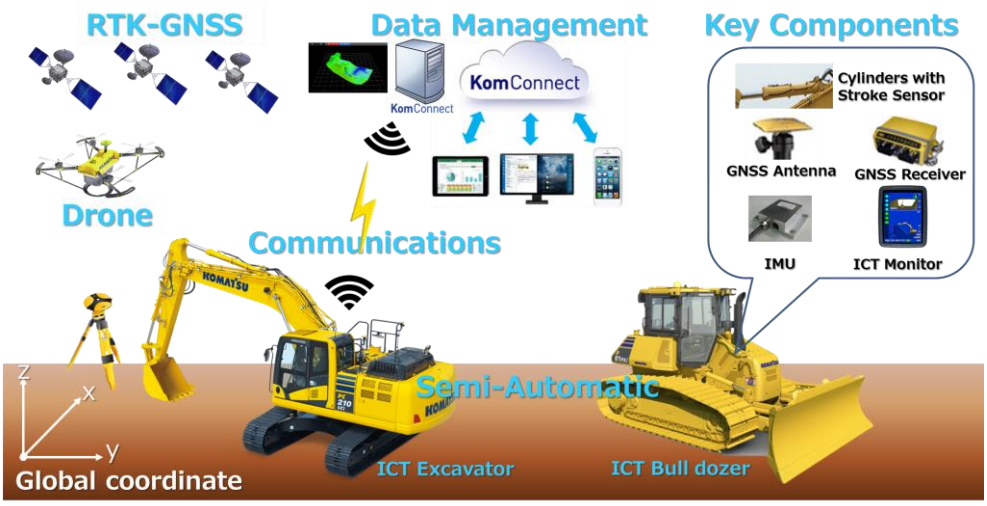

Fig. 5 Key technology

operator's skill by utilizing the machine control technology installed on ICT Excavator and ICT Dozer.

4) Easy to predict problems and troubles that may happen by recognizing and visualizing everyday progress.

3. Key technologies for SMART CONSTRUCTION

In what follows, these key technologies are utilized to realize SMART CONSTRUCTION concept.

1) RTK GNSS technology
2) ICT related key components
3) Semi-Automatic ICT construction machines
4) Drone for efficient and accurate surveying
5) KomConnect data management server
6) Communications via internet

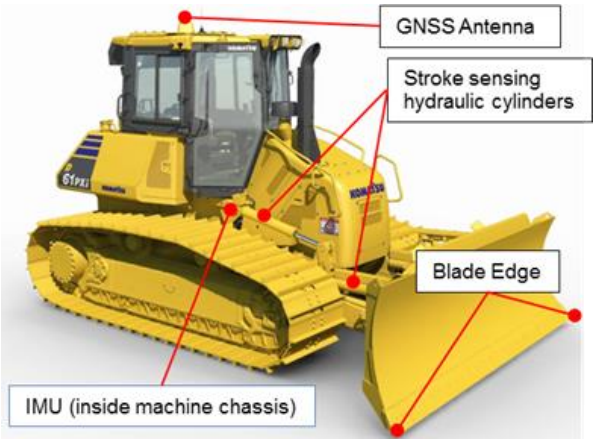

Fig. 6 ICT Bulldozer

4. ICT Construction Machines

4.1. Positioning of work equipment edge

Fig. 6 shows the exterior and components of the ICT Bulldozer, **Fig. 7** shows that of the ICT Hydraulic Excavator. **Fig. 7** also represents the mechanism of Bucket edge positioning.

Both machines use stroke sensing hydraulic cylinders to calculate the Bucket edge (2) position relative to the GNSS antenna (1) mounted on the machine with high response.

Combining with this GNSS positioning and machine attitude from the IMU, the edge position in the world coordinate system can be calculated.

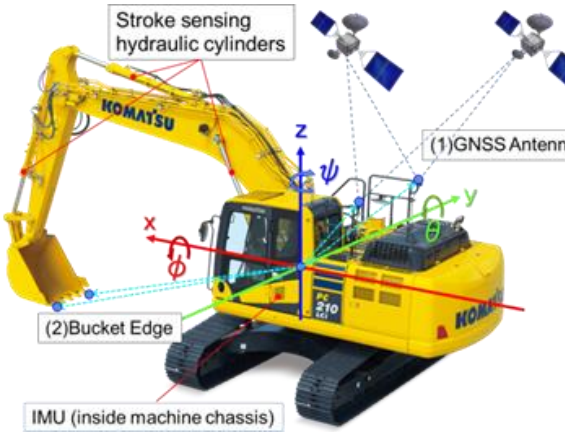

Fig. 7 ICT Hydraulic Excavator

4.2. ICT monitor

Inside the cabin of both machines, an ICT monitor is installed in which the 3D design model with the world coordinate system is uploaded via internet or USB memory stick. By utilizing this 3D design model, the controller can calculate where the bucket edge should be controlled. During the operation, the operator can easily recognize where the machine is in the job site, the distance between the bucket edge and the target design surface, and the progress of operation by color mapping on the screen.

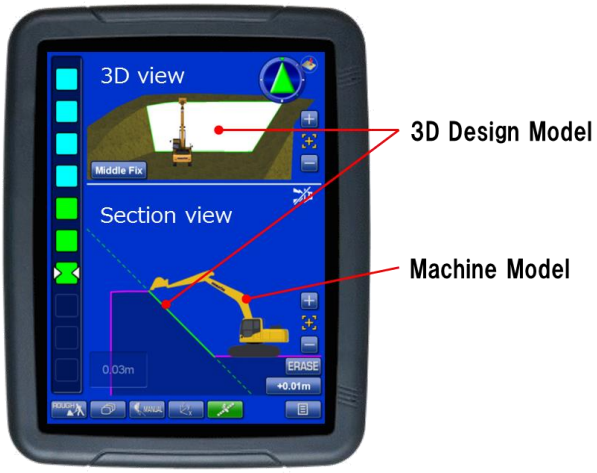

Fig. 8 ICT monitor

5. ICT Bulldozer

5.1. Three Is and No Three Cs

Fist feature of the ICT Bulldozer is visibly understandable by the exterior design of machine. Compared with the system installation of conventional machine control functionality, there are no more sensors on blade so that all outer cables connection between the blade and the machine body can be eliminated. It allows that machine owners to be relieved from frequent cables replacement.

Fig. 9 Komatsu ICT Bulldozer

Fig. 10 Conventional machine control system

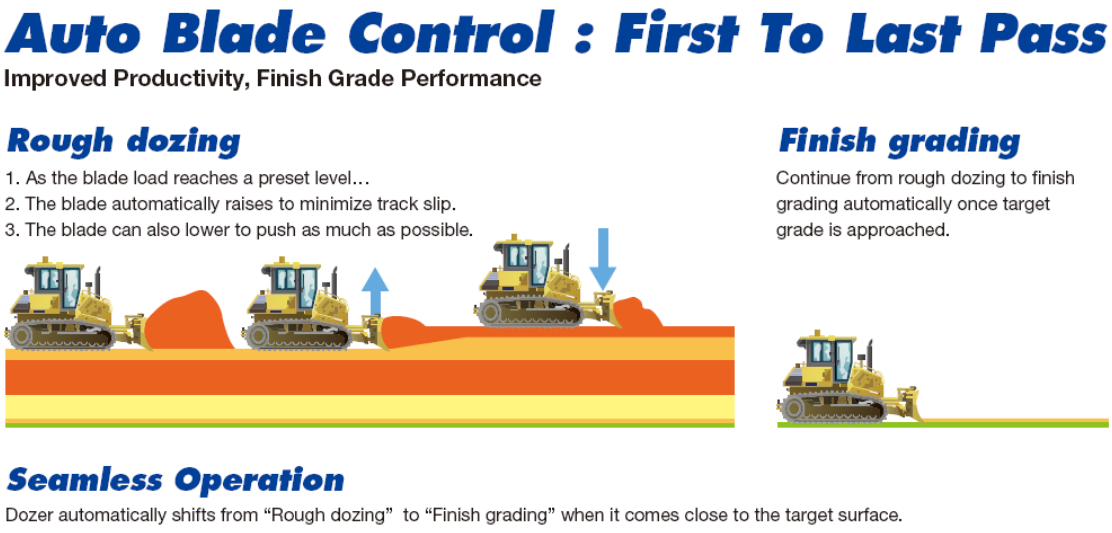

Fig. 11 Blade load control

In addition, all necessary components are factory-installed and sensor calibrations are done before shipment. Thereby the machine could be ready to utilize automatic control, intelligent features, when delivered to the customer's job site.

5.2. Blade control, Rough dozing and Finish grading

The biggest feature of the ICT Bulldozer is the load control called "Rough dozing" which maintains the optimum load in front of the blade. Conventional machine control systems could only control the position of the blade targeting the design surface. Hence should the load exceed the limit, the tracks would start slipping and the machine would lose traction, which limited the usage to light loads.

On the other hand, the ICT Bulldozer calculates the load based on the input from the transmission sensors, and controls the blade to match the preset drawbar pull to maximize the machine performance, thus expands the usage from low to high load applications.

Also, as the work progresses and approaches the target surface, automatically switching from Rough dozing mode (blade load control) to "Finish grading" mode (blade height control) enables seamless automatic operation without worrying about overcutting the target surface.

5.3. Mode selection

Automatic blade control allows the operator to select the optimum dozing mode from the four modes according to the types of work. In addition, the target blade load for Rough dozing can be selected from three modes according to material/dirt condition and the types of work. Switching modes cyclically by touching the icon on the ICT monitor screen (**Fig. 12**). Since the icon switches to an illustration that imagines each mode, the operator can easily view the currently selected mode (**Fig. 13**).

6. ICT Hydraulic excavator

6.1. Auto Stop and Auto Grade Assist control

As for the ICT Hydraulic Excavator, there are two major features which allow the operator to operate without having to be cautious not to overcut the design surface.

With the conventional MG systems, the operator would operate watching the distance between the bucket

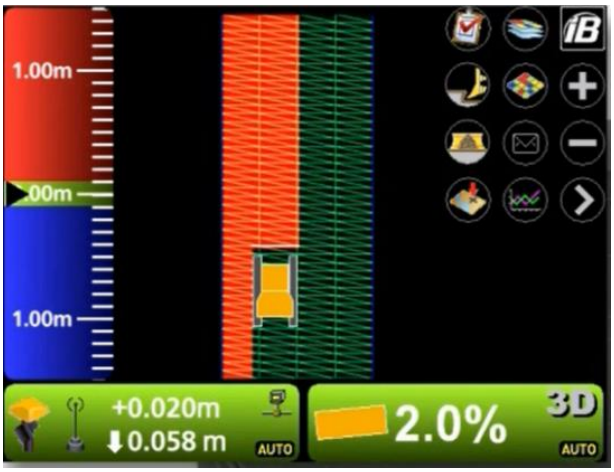

Fig. 12 ICT monitor for Bulldozer

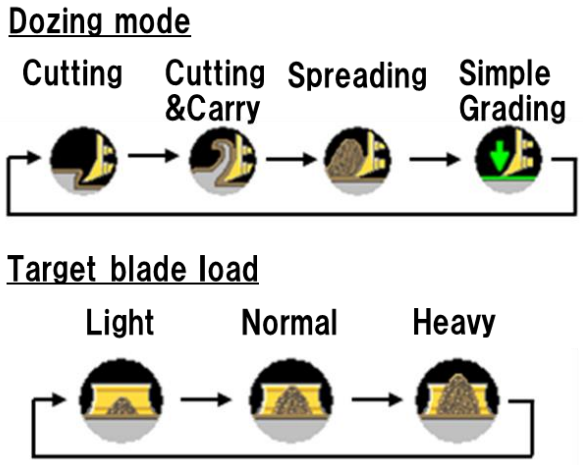

Fig. 13 Mode selection

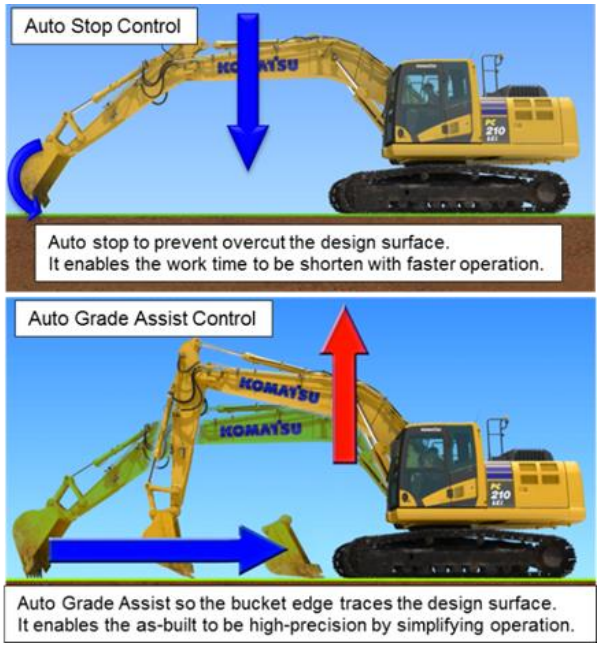

Fig. 14 Auto Stop & Auto Grade Assist control

edge and the target design surface through the monitor, cautiously controlling the implement lever manually to prevent overcutting.

On the other hand, with the ICT Hydraulic Excavator, the operator can control the implement towards the target design surface and the machine will automatically stop the movement to prevent overcutting. This is called "Auto Stop" (**Fig. 14** upper). Next when the stick is pulled back towards the operator, the boom will automatically raise/lower so the bucket edge will trace the design surface. This is called "Auto Grade Assist" (**Fig. 14** lower)

6.2. Closest distance control

In the case of a slope plane construction (**Fig. 15**), if the machine direction is not directly facing the slope surface, the bucket needs to be controlled to prevent over cutting at the point of the closest distance portion on the bucket cutting edge (**Fig.16**).

The control point of the bucket cutting edge is selectable by the operator from four choices such as the center of the bucket, the left end, the right end and the closest distance point. When the closest distance point is selected, the Auto Stop and Auto Grade Assist control is performed at the portion closest to the target design surface. These controls function not only for bucket cutting edge but also for bucket bottom surface and bucket contours, thus high accurate finish grading by using bucket bottom is also possible.

6.3. Facing compass

Further, the usability is improved when constructing a slope plane (**Fig. 15**) by utilizing the facing compass function (**Fig. 17**, **Fig. 18**) which is highly visibly displayed on the ICT monitor screen and allow the operator to easily understand the state of machine body direction to the target design surface.

7. Concluding remarks

SMART CONSTRUCTION service and ICT construction machine, such as ICT Bulldozer and ICT Hydraulic excavator, have provided a solution to the issues of the construction industry such as labor shortage, reduction of skilled operators, and difficulty of skill lore. Furthermore, it has brought economic benefits to the customers by maximizing their business efficiency. As a result, both have gained a high reputation in and outside the country.

Fig. 15 Slope construction by Hydraulic excavator

Fig. 16 Bucket control point and closest distance control

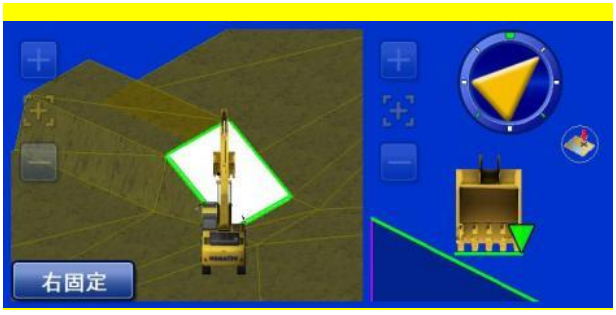

Fig. 17 Facing compass, not facing to slope

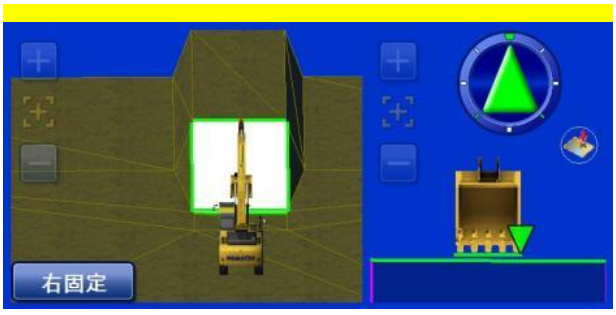

Fig. 18 Facing compass, facing to slope

8. Acknowledgements

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