A View of Construction Science and Robot Technology Implementation

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Abstract –

In this paper, with an aim to contributing to promotion of this field, the author describes his perspective on desirable future situations, and lists his ideas and matters to be taken into consideration in future efforts, focusing on discussions during 2005-2008. Here, the author proposes promotion of design methods in which construction improvement is incorporated in design, and a proposal that machines should be aiming towards substituting human operators in principle.

Keywords –

Construction Science; Construction production engineering; Robot technology,

1 Introduction

In the field of construction production engineering, construction improvements and efforts to utilize robot technology have been continuously ongoing. However, author believes that there is still an urgent demand to make more improvements.

In author's opinion, the basic concept should be to make people working at construction sites happy. For example, currently there are the following challenges in work sites:

1. How can production technology such as those in manufacturing factories be incorporated?
2. A system that allows individual improvements in high-mix, single-item production, "Multi-product one-type construction production technology"; how can they be diverted and reused?
3. Design improvements found from maintenance and construction: how can the result be effectively fed back to design standard?
4. How can we effectively reach the key points of improvement?
5. How can deaths from accidents be reduced?

In this paper, various images, goals, and approaches are proposed, with the aim to promote construction production engineering.

This paper proposes hypotheses that have not yet been verified or is still under verification. This paper does not cover verification of hypotheses.

2 Towards future construction site

If a work method and software can be described, it can be realized. Author's image of desirable future are outlined as follows.

2.1 Image of approach towards future construction site

2.1.1 Pessimistic and optimistic view in work sites

The population in Japan will inevitably decrease; however, the workload demand will not decrease.

A construction site that uses AI and robot technology with a fewer number of people is eagerly sought in work sites. [1]

2.1.2 How to resolve time-consuming and laborious tasks

- "Consistent data sharing from design to maintenance" is one example of good approach There are various types of support to realize this goal.
- By visualizing overall processes, changes in construction plans, adjusting arrangements / procurement for setup changes, and meetings will become much easier.
- Documents are naturally produced as output if the work process is done properly.

2.1.3 Sharing of fundamental concept that "Unsafe condition should not be allowed"

- Humans should not perform hard or dangerous work.
- Machines should do the hard and dangerous work.
- Danger should be avoided in the plan beforehand.
- Danger should be detected by various data on site.

- Eliminating root causes of human errors that may lead to an accident.

2.1.4 To continue PDCA cycle for technology on-site

- Continue improvement and PDCA (Plan, Do, Check, Action Cycle) on site. (Technology itself, human system, work method, etc.)
- The technology system itself to be also spiraled up with PDCA.
- Technology improvement integrated in the construction project (by the government).
- To be used in construction projects, and to be used in the construction field to improve.
- New technology to be supported, and the site does not stop even in case of unfamiliar or trouble occurring

2.1.5 AI support and growth for people together

- To invite input from AI engineers.
- AI will help us to be safer and the job rewarding.
- AI supports and talks, and people will grow together.
- Substitute hard work for people.

"The risk management method using AI" to be prevalently used.

2.1.6 Construction plans to also co-evolve with people and AI

At the construction site, there are many uncertain factors. There are various factors such as weather, soil quality, human factors, utilization of soil generated by other works, circumstances of supervision and suppliers. Therefore, a robust construction plan is required.

Visualization of progress makes it easier to understand how to improve the construction plan. In this case, there is a procurement system environment and an accounting system environment that allow the construction plans to be changed accurately.

The records of changes/improvements in the construction plan are learned, and the number of cases that have been examined in advance increases every year. (The front loading continues to increase.)

The construction plan should prevent accidents caused by people's carelessness and mistakes.

Reduced uncertainties and variability make them more robust, while improving plan optimization and changing flexibility. By utilizing the work robot, the variation in progress is further reduced.

2.1.7 Valuable labor for workers

Key important aspects are: high income, shortened working hours, an environment to easily take vacations, and safe workplace.

Added-value aspects are: motivated working, comfort of workplace, self-fulfillment, social evaluation, good image, etc.

2.2 Image of future construction structure

2.2.1 Easy to construct, operate and maintain

"Ease of operation/maintenance" and "Easy to make" becomes the evaluation criteria, and the learning/feedback mechanism becomes a business process.

If there is a value that has priority over "ease of maintenance" and "ease of making", it will be clearly stated.

" Maintenance" includes operation, inspection, diagnosis, repair, replacement, restoration, renewal, dismantling, disposal, etc.

The idea of "easiness" is consistent and easy to understand.

Constraints in "ease of maintenance" and "ease of making" will decrease every year due to technological improvements.

"Multi-product one-type construction production technology" will improve year by year.

2.2.2 Evaluation throughout the life cycle

There are measurement items that serve as indicators in inspections and diagnoses.

This index is measured during construction, at the time of completion, and is recorded in the electronic history ledger.

Construction/repair and new technology are evaluated for a long time. Where and who did it, and whether the work done was good or bad will be evaluated later.

This can lead to both pride and shame.

A good company will also benefit in the long run.

2.3 Digitization of the real world

The rules for recording underground data for construction excavation, boring, and geophysical exploration are being developed.

3D terrain models are usually measured with good accuracy.

The current digitalization has the following expected cases.

1. The outline can be designed without a new survey.
2. Depending on the accuracy and accumulation, the survey may be omitted.
3. Fewer modifications needed from design to construction.
4. It can be utilized for automatic operation and road maintenance.
5. We can immediately use the pre-disaster data for disaster recovery

3 Hypotheses for problem solving

3.1 Rules and system design for optimization

Since the rapid growth period, vertical and horizontal division of labor has progressed, and the main body of construction site improvement has become unclear. The people involved were forced to stay within partially limited optimization, which was limited to the area where they could improve themselves.

To expand the scope of optimization, it is necessary to make improvements and change rules across multiple parties. For this purpose, the client (owner) and the government are required to have a certain level of involvement and appropriate system design. Institutional design requires everyone to believe that those who have worked hard and made good ideas are fairly evaluated.

3.2 Various hypotheses for problems and solutions

3.2.1 Designed to improve safety and productivity

When improving material manufacturing and on-site construction, it is advisable to review the design if necessary. At this time, it is desirable to be able to review the conditions that constrain the design.

3.2.2 Overall optimization and information utilization suitable for construction production

Information sharing and collaborative operation are important for overall optimization such as modularization of design, linking of orders and procurement/ plant, linking of transportation/ assembly/ construction.

3.2.3 Strategies for effective factory processing

The method of reducing on-site processing, bringing it into the factory after processing, and then assembling on-site may be effective even in a small scale. Especially, it would be desirable to be able to assemble and install by a machine for small scale.

3.2.4 Process control to ensure productive quality

In order to estimate the degree of quality variation in process confirmation, elucidate the relationship when and what should be measured, and incorporate it into the process.

Particularly in the field of civil engineering, it is expected to utilize ICT such as automatic measurement recording/evaluation and remote attendance, which enables flexible process management and setup adjustment.

It is necessary to discuss how to rationalize the involvement of people, such as the centralized management of a wide area by several people.

3.2.5 Optimization of logistics such as soil

It has been said that the bottleneck of earthworks is the uncertainty of the time, amount and quality of soil. Coordination of excess and deficient soil transportation in construction involves many owners in a wide area, and there are cases in which stockyards and soil improvement are used. It may also be a consideration for the government's construction order plan.

Currently, visualization of transportation is being promoted, and we expect that awareness of issues will be shared.

3.2.6 Improvement of quality/quantity confirmation

Level 4 (L4) is a unit of contract modification (MLIT(Ministry of Land, Infrastructure and Transport) estimation standard in Japan), and the quality/quantity confirmation method is determined. It is easy to improve if this is digitized from the time of occurrence and incorporated into the construction process management in a way that requires as few human hands as possible.

3.2.7 Hierarchical structure of construction/work status

The unit of the state of what you are doing now becomes the unit of motion analysis and the unit of learning (preparation unit of teacher data), and has a hierarchical structure.

"Which state can be changed next?" is an internal description of the state transition in the autonomous case.

3.2.8 Command system of instruction and simulation

Even if both remote and autonomous are used, a command system for construction/work instructions from the control is required.

Construction/work instructions are assumed to have a granularity (unit in a hierarchical structure) that is commensurate with the work unit utilizing autonomy.

It is convenient to use this hierarchical command system for construction simulation.

3.2.9 Blasting machines expected to improve work environment

In the case of improving LCC of steel bridges, it is desirable to repaint with high durability at least at the girder end. For this reason, use of blasting as the substrate adjustment is preferred

For that purpose, it is good to use a blast machine system with few scaffolds and enclosures, less scattering of dust and sewage, a light load on workers' protective clothing and dust masks, and high availability.

4 Transformation of safety philosophy

4.1 Safety philosophy

The number of deaths from construction labor in recent years is about four times the average of other industries on a working population basis. From the standpoint of utilizing robot technology, the safety concept that "unsafety condition should not be allowed. People do not do it" should be rigorously pursued.

In example in Photo 1, this person should not be nearby a hydraulic excavator in the first place. He should not measure the depth of the ditch. The depth of the ditch should be measured by hydraulic excavator.

Again, the points of thinking are shown below.

1. Unsafe condition is not allowed. People should not do unsafe operations.
2. The basic idea is to solve by technology.
3. Some extent of human error is always assumed to occur.

Photo. 1. Simulate close work (by PWRI2003)

The technical points to be pursued are as follows.

1. Substitute by machine
2. Machine/person separation
3. AI avoidance, etc.

4.2 Keeping people away from dangerous work

If area near the machine is dangerous (Photo 1), no one should be present. By using MC/MG (machine control/machine guidance), it is possible to assign the measuring task to machine. (Photo. 2) It is no longer necessary for worker to stand a stick in the ditch to measure ditch depth.

In the future, it is expected that in many situations, people will achieve what they do not need do.

Photo. 2. Depth setting MC

5 Towards an object-oriented construction plan

5.1 Object-oriented CAD

3D CAD design data is composed of parts, and the data structure of parts can be object-oriented. (Fig. 1) In recent years, it has been studied in algorithmic design [2] and parametric model design [3]. The image is as follows. [4]

1. Object modules in Library
2. Object modules make up a structure
3. Object modules link Working standards
4. Design with a combination of Object modules (parts and expansion parametric model).
5. Object modules link Design and Analysis tools
6. Object modules (Parts/group) are written with the context of construction.
7. Object modules link Estimates
8. Object modules link Supply chain management

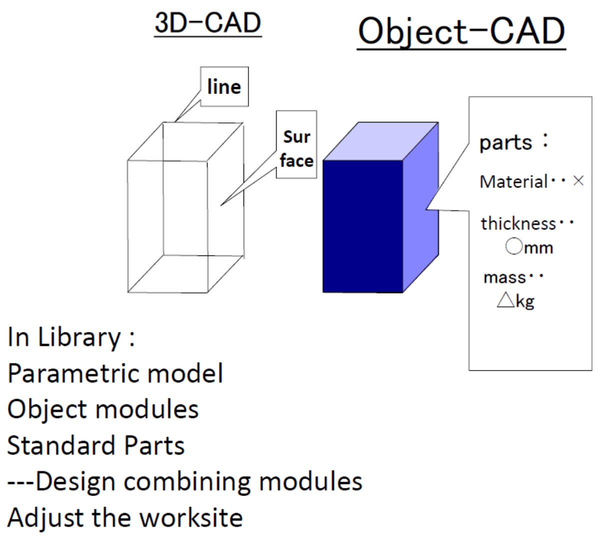

Figure 1. Image of Object oriented CAD

5.2 Expected functional requirements

The evaluation index to be optimized and functions expected from object-oriented CAD are as follows.

1. Object modules in Library
2. Object modules make up a structure
3. Object modules link Working standards
4. It can be solved that construction (/temporary construction) is cheap and quick.
5. It is possible to make a trial design when it consists of only standard parts.
6. It can be solved using environmental evaluation indicators such as energy consumption.
7. Support optimization of setup change
8. Simulation can be performed according to work standard and order.
9. Construction improvement can be described by work standard improvement.
10. Earthwork site rub module can be used.
11. Object modules must Adjust the worksite

6 Conclusion

The author's view on desirable goal and approaches towards the goals was described. In particular, the author presented hypotheses that should be addressed with high priority, with some hypotheses not being discussed for more than 10 years.

This paper lists followings as important aspects to be considered:

1. To share ideas on future construction sites with others.
2. To place high priority and respect on human time, safety and purpose of life.
3. To continue improvement and PDCA on site.
4. To support robust optimization for changes in construction plans and setup changes.
5. Ease of making and ease of maintenance are key indicators in optimization.
6. To set measurement indicators in life cycle
7. To promote digitization in the real world
8. To set rules and system design for optimization
9. To increase production in factory and reduce on-site work
10. Factory products to be handled by machines, not by humans.
11. Monitor process control to ensure productive quality
12. Optimize logistics such as soil
13. Digitization of quantity and quality for each contracted minimum unit
14. To aim for a hierarchical structure of construction/work status
15. To aim for a hierarchical command system of instruction and simulation
16. Unsafe condition should not be allowed.
17. Object-oriented construction plan
18. Object oriented CAD for construction sites
19. How work standard improvements can be diverted and reused

In this paper, author's image, goals, and various hypotheses were presented. It is the author's intention that such information will lead to discussion and promotion in the field of construction production engineering.

The author hopes that further discussions will be deepened and research and development and social implementation will progress toward the future of construction production engineering and robot technology utilization.

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