Automation and Robotics in Construction XI
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A Japanese view on the role of automation and robotics in next generation construction

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Abstract

Productivity is a key issue in the construction industry. It has been forecasted that the labour productivity of the Japanese construction industry should be increased twice in the year 2010, comparing with the present rate. Automation and robotics in next generation construction should try to improve not only productivity but also take humanity into consideration and be harmless to the global environment. To realise automation and robotics in the construction industry, building elements are required to be pre-fabricated and the working space weather protected so that automated systems can be widely applied. This paper introduces some new ideas on the role of automation and robotics in next generation construction and discusses how automation and robotics could be applied.

1. INTRODUCTION

This paper gives an outline of the history, current state and the problems in applying automation and robotics in the Japanese construction industry. The year 1993 can be remarked as an historical year in the area of automation and robotics in construction. Some Japanese general contractors have developed automated building construction systems and applied these to actual construction project. These systems are expected to increase productivity significantly. More than fifteen years have passed since the research and development of automation and robotics in construction started. In spite of R&D efforts, most of the robots would not be widely used because of their high price or low performance. Productivity improvement is limited, when the robot is used for one part of construction process.

2. CURRENT STATE AND PROBLEMS OF AUTOMATION AND ROBOTICS IN CONSTRUCTION

In recent years, research and development in the field of automation and robotics in construction have been carried out very actively. More than ninety types of construction robots, such as a fireproof spraying robot and a concrete floor finishing robot, have been developed. Automated building construction systems have also been developed by some Japanese companies recently. Some research projects in this field have been carried out by government and universities (Figure 1). Automation and robotics in construction can be characterised as follows:

1) Unlike the mass production of manufacturing industry, construction is a mono-product industry. i.e. construction work is less-repetitive work compared to factory work.
2) Building elements are large and robots require to be mobile
3) Robots are required to be usable in all weather conditions.
4)The operation of the robots are required to be easy for workers.
5)The robot should be transportable.

It is necessary to satisfy these conditions. Automation and robotics systems, which are already developed in Japan did not always meet these conditions. Automation and robotics seems to be difficult for construction work which makes substantial demands under items 1 and 2 above. The fact is, in terms of expansion, only a few types among the developed machines are in use. On the other hand, there are another type of problems, which can not be solved by the design of the robotics system. For examples:

1) For effective utilisation of automation and robotics systems in construction, the design of buildings and building elements require the use of standardisation. This is not used at the present.
2) As building design and construction methods are not designed for automation and robotic construction its applicability is limited.
3) There is a question of ownership. Who should own? Who should maintain the automation and robotic systems?
Automation and robotics in construction is still in developing status as a research theme. These problems are required to be solved one by one in the R&D efforts.

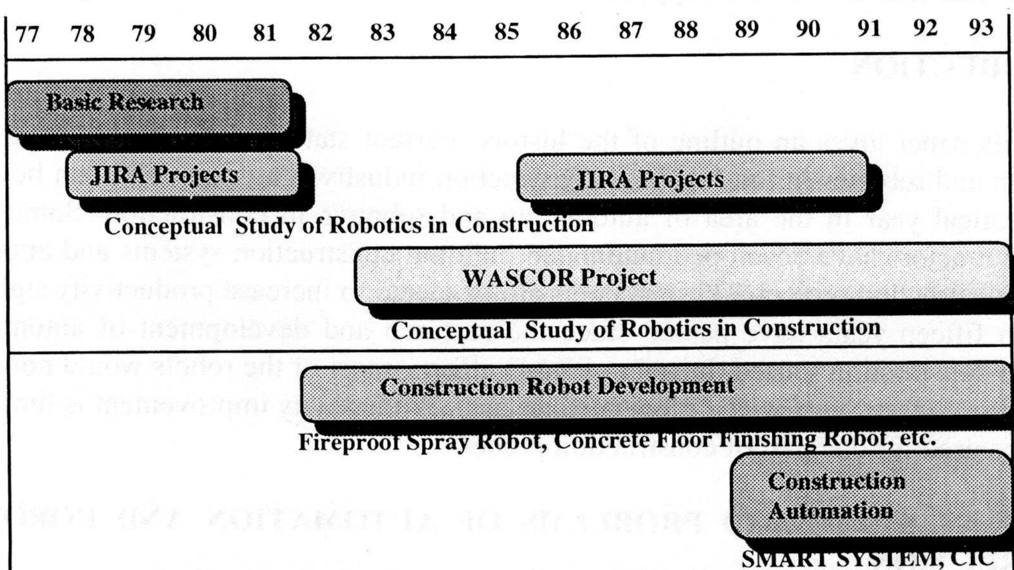

Figure 1. History of Automation and Robotics in Japan

3. NEXT GENERATION CONSTRUCTION

Since the days of the Egyptian Pyramids, large scale construction has played an important role in the image of a nation. Construction systems are influenced by the materials mainly used in that system. For example, the architectural culture based on the use of stone grew in Egypt and Europe. Architectural culture based on the use of wood grew in Japan. In the modern age, concrete and steel are used as the main materials in construction. Various kinds of machinery and equipment have been used for construction works since their development. The extensive utilisation of machinery such as the bulldozer, crane and lift with fuel engines and electric motors have increased the speed of the construction works and improved productivity. On the other hand, the manufacturing industry, a relatively young industry compared to construction has introduced mechanised production systems to improve productivity. They introduced robots in their factory and achieved great progress in productivity improvements. In this chapter, the social background and functions of next generation construction is discussed.

Construction investment in Japan will increase, improving the insufficient infrastructures. However, the numbers of workers in the construction industry is estimated to decrease year by year. The estimated number and required number of construction industry employees are shown in Figure 2., these based on the assumption of 2.3% to 3% growth in the GNP. The shortage of construction employees will be more than two million in 2010. To overcome this gap, the productivity of the construction industry should be doubled over the next ten or twenty years. However, is it enough to improve only the productivity of the construction industry in the next generation? The average age of construction workers is getting higher. It was 44.3 years old, according to a survey in 1991. One of the reason why ageing of the labour has occurred is that the construction work has an image of being a hard, dirty and risky working environment. The industry is widely considered by young people as a "3K business", where the 3K represents three Japanese words, "Kitsui" (hard), "Kitanai" (dirty), and "Kiken" (dangerous). It is necessary to change this image of the industry for the next generation construction. Environment is another key issue in the construction industry. Along with, saving the global environment, noise, vibration and dust reduction are key issues. The treatment of construction waste should be harmless to the environment. From these discussions, the next generation construction can be characterised by three key words "Productivity", "Humanity", "Environment". The system which has best balanced combination of these three items can be called next generation construction system.

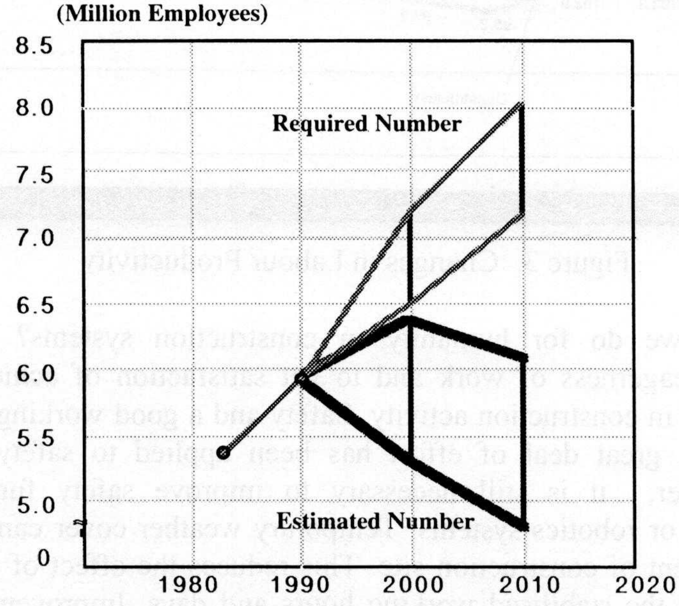

Figure 2. Number of Construction Industry Employees

3.1. Productivity

Productivity can be defined as Output/Input, however, there are many views on productivity. It depends on what kind of index is used for input and output. Labour productivity is normally used to compare the productivity of construction operation. Figure 3 shows the changes in labour productivity in manufacturing and construction industry of Japan. In comparison with the manufacturing industry, the labour productivity increase in construction industry remained slow. This figure also shows that the increase in labour productivity was very slow until 1985, where after it started to improve 1986.

Nowadays, structural systems for building have been changed to improve productivity. Instead of reinforced concrete buildings, steel structured building or pre-cast concrete building elements were widely used. The introduction of large sized construction machines such as tower cranes and lifts have also improved the productivity of construction industry. In civil works, such as tunnelling works, the introduction of new construction method and equipment has led to productivity at twice than that of 1970. For the next generation construction system this will need to be increased twice again.

The strong need for improvement of productivity will propel automation and robotics in the construction industry of Japan. Pre-fabrication will be widely adopted as it reduces the processing of materials at the construction site. Productivity of construction design and management should also be improved by the use of computer and communication systems. Many types of data for design, construction and management can be handled efficiently by computer integrated construction systems.

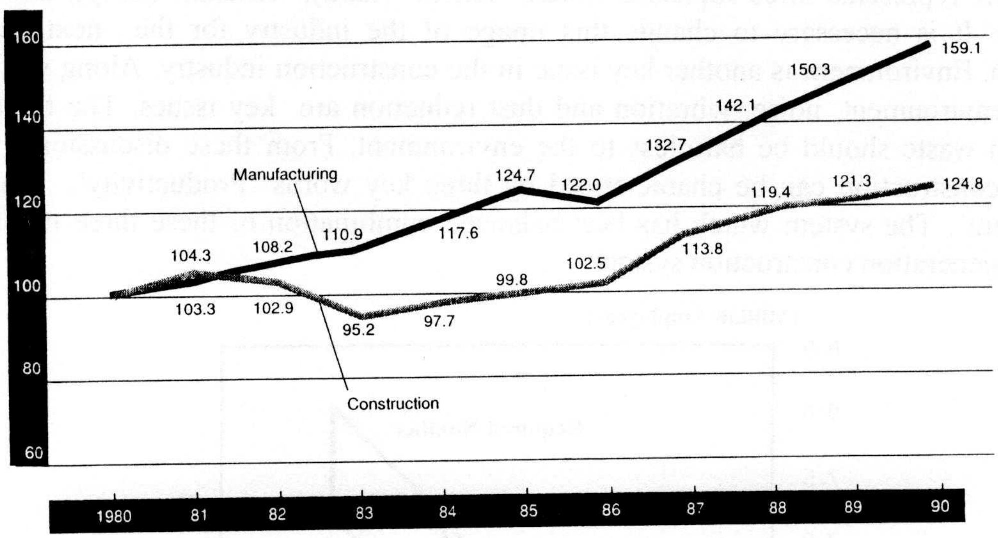

Figure 3. Changes in Labour Productivity

3.2. Humanity

What should we do for humanity in construction systems? To work safe and comfortable, to have eagerness of work and to get satisfaction of achievement will be the humane considerations in construction activity. Safety and a good working environment should be considered first. A great deal of effort has been applied to safety issues in Japanese construction. However, it is still necessary to improve safety further by introducing construction machines or robotics systems. Temporary weather cover can be used to improve the working environment of construction site. This reduces the effect of weather such as rain and wind, and realises the stabilised working hours and days. Improvement of site facilities such as temporary house and office is also important. Furthermore, construction operations are supported by skilled workers. They have pride and confidence for their skill, but the introduction of prefabrication, automation and robotics systems will cause changes in their work. It will require new knowledge and techniques for proper use of new methods. In this situation, it is necessary to keep working motivations and satisfaction of achievement for construction workers.

3.3. Environment

Global warming by the green house effect, ozone hole, desertification and treatment of waste disposal are serious problems for the earth. Environmental issues are becoming more and more important for the future. When we consider the next generation construction, environmental protection will be essential. Disposal of construction waste disposal such as crushed concrete and excavated wet soil will be a big problems for small countries like Japan.

In the automobile industry, recycling of material is already considered to cope with the environmental problems. The German automobile car, Golf, uses plastic bumpers that can be recycled. In the design of this car, "Design for Disassembly" is introduced. Furthermore, design methods that considers the effect to environment in its life cycle, from production to scrap of the car are developed. When such idea are adopted in the construction industry, the effects of construction operations on the environment will need to be analysed from the design of the building to the demolish of the building. It is necessary to determine a design methodology for recycling in construction for the purpose of environment protection and effective use of natural resources.

4. THE ROLE OF AUTOMATION AND ROBOTICS IN NEXT GENERATION CONSTRUCTION

Figure 4 shows the trend of automation and robotics in construction in Japan. At the beginning, that part of construction work which was suitable for applying robotics were surveyed and this easily achieved. These were single task robots. After that, the trends of automation and robotics in construction were divided into three streams.

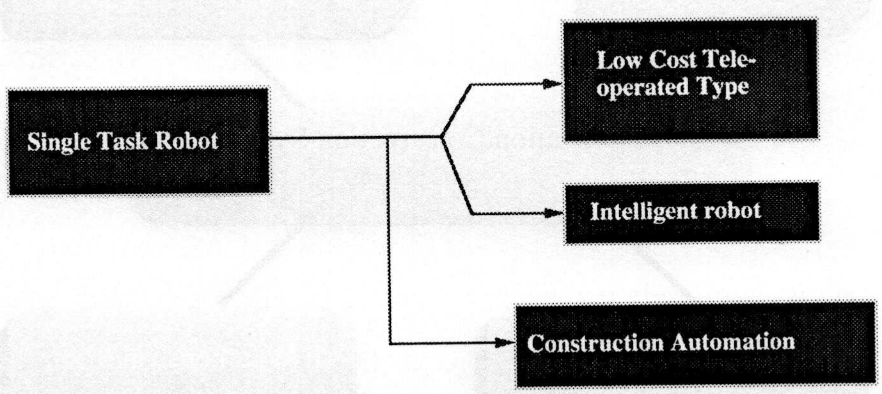

Figure 4. R&D Trends of Automation and Robotics in Construction

Construction automation is trying to automate assembly of building elements such as column, and beam, and management system of the construction site. R&D of construction automation started around 1988 and the application to actual building construction projects started at the end of 1992 by some Japanese general contractors. As these projects are first trials of their system, these systems will be improved by the data that is corrected from the trials. Even though there remain problems to be solved, this gives some direction to the next generation construction.

The trend of single task robots is divided two streams, one being the low cost tele-operated type. As construction work is less-repetitive, the alternative teach-playback type robot does not fit for construction applications. Another reason is that practical, low cost, robots at low cost. robots need to be developed. Most of the single task robot in Japan are of the tele-operated kind. On the other hand, dramatic labour saving can not be achieved by tele-operated type robots because these require operators.

The second stream is the fully automated system. Recently, automatic welding systems have been developed, for example. This robot has laser sensors and a CPU which enables teaching-less operation. The robot measures the portion to be welded by its laser sensor.

The role of automation and robotics in construction can be shown in figure 5. Prefabrication, information integration, all-weather working condition, and automation and robotics are the four major items to realise the next generation construction system. Productivity improvement, humanity enhancement, environment protection are also to be considered as basic philosophy of the next generation construction. Automation and robotic systems will play an important role in next generation construction. However, this does not mean fully automated or robotized systems. When we upgrade the level of automation, the cost of its system will increase in a relative ratio. As in the automobile industry, when they construct new factory, they adopt full automation line for the process that is easy to automate, but they do not automate the process that are difficult to automate. For this process, they consider working conditions and motivation first. This strategy is practical and fits for automation and robotization in construction.

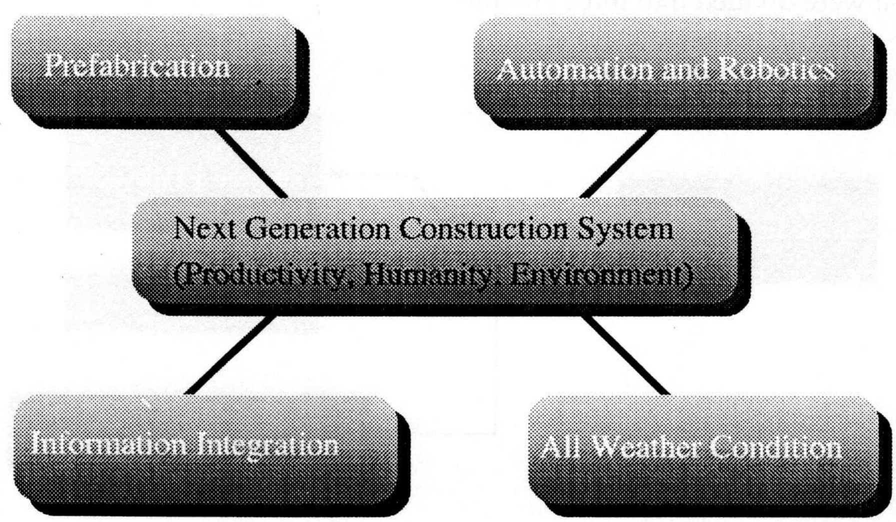

Figure 5. Next Generation Construction System

5. FUTURE THEMES FOR RESEARCH AND DEVELOPMENT

R&D themes to realise next generation construction systems are as follows:

1)New structural system or construction method: Prefabrication, modularization
2)New materials: High strength concrete, fibre reinforced concrete, FRP
3)Design technology: 3D-CAD, CAD/CAM, virtual reality
4)Production design technology: Estimation method for assemble easiness, connection design for automatic assembly and construction planning simulation technology
5)Integration technology: Computer, database, telecommunication technology
6)Mechatronics technology: Robotics, control technology, sensor

Future R&D themes on automation and robotization in construction should focus on the enlargement of the application areas. Many things should have done to improve the applicability of the systems. For example, the size of building elements should be standardised and connection systems should be designed for automatic assembly. Structural design requires to be redesigned from the production design point of view. Construction methods are required to be simulated and the results of this are required to feed back into the original design. These themes also focus on the upgrading of the level of basic technologies. As it is more difficult to realise automation or robotization in construction than manufacturing industry, it is essential to make research and development efforts for basic technology for automation and robotics in construction. (Figure 6)

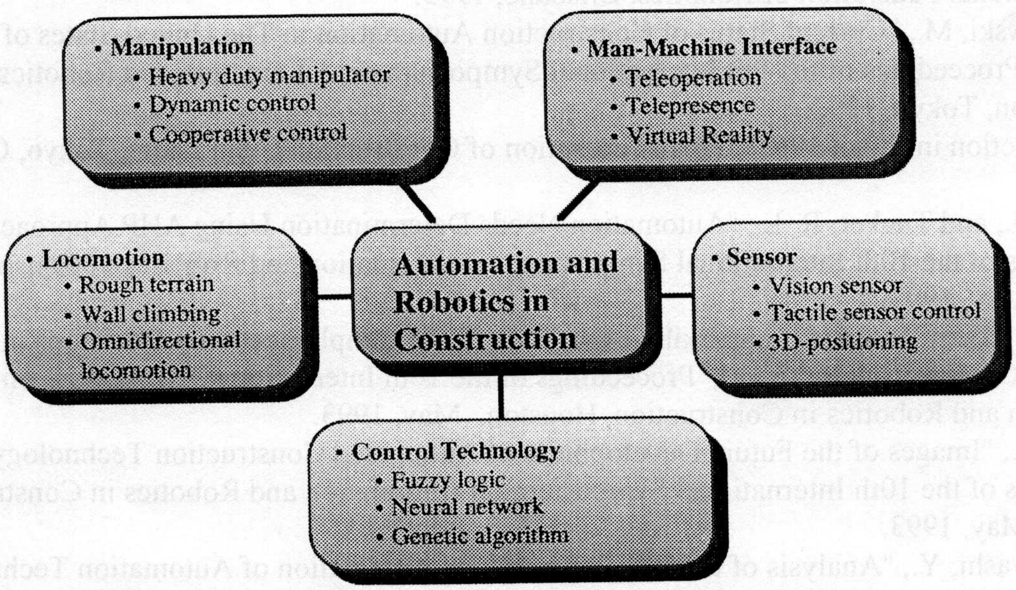

Figure 6. Basic Technology for Automation and Robotics in Construction

6. CONCLUSION

To get dramatic improvements in productivity in next generation construction, automation and robotics systems, which can be widely applied to any kind of projects, should be developed. Furthermore, construction systems for automation and robotics should be developed with the co-operation of government, universities, construction industry and other related industries. The role of automation and robotics is very important to realise next generation construction. It is believed that the fruit is not only the improvement of productivity, safety and better working environment but also the upgrading of the status and image of the construction industry.

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