The 5th International Symposium on Robotics in Construction June 6-8, 1988 Tokyo, Japan

TECHNOLOGIES TO BE DEVELOPED FOR SUCCESSFUL INTRODUCTION OF ROBOTS INTO BUILDING CONSTRUCTION INDUSTRY

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ABSTRACT

Several years have passed since the first robot introduction into building construction sites. Earnest efforts by the involved people developed some types of construction robots in the industry. But the construction industry is understood to be a very difficult area of robotization and there is no integrated robotized building construction system yet. System Science Institute, Waseda University, has started robot research project group since 1982 and the research project was named WASCOR (WASeda COnstruction Robot). As the result of earnest research effort the group has reached a stage to propose a set of extra construction robotics technologies added to the existing ones for manufacturing industry. The author introduces some of the new technologies and suggests a plan of construction robot research laboratory to be installed in the industry.

1. Introduction

Because of serious needs of robotization in constructing industry for promoting safety, improving working conditions, and increasing productivity, people are continuing earnest effort internationally. But it is understood that robot introduction into building construction sites is more difficult than into manufacturing plants because of many discouraging factors. For breakthroughing the hazards against the robotization, we must develop more suitable robot engineering technologies which were not needed for them in manufacturing industry. In this article the author wants to discuss some of the cruicial technologies which are being developed in WASCOR (WASeda COnstruction Robot) research project which is a co-operative research by Waseda University and 11 industrial firms since 1982.

2. A diagram of research themes in robotization of building construction

Figure 1 shows a diagram of research themes made by the author from the title of the papers presended to the past four international symposiums on robotics in building construction since 1984, and two Japanese domestic symposiums on building construction robotics in 1987 and '88.

Themes can be classified into the following major categories;

1) Robot needs survey and authorized significance of robotization
2) Fundamental methodology of the building construction robotization

3) Building design and construction methods for adapting robotization

4) Elemental robot technologies for construction

5) Supporting technologies for designing the construction robot systems

6) Management system for robotized construction sites

7) Construction robot development case studies

8) Education and training of staffs who are involved in the robotization project

As many people have pointed out, difficulties of the construction robot development are brought on the particular feature of building construction work such as location change of the construction site, complexity of the construction system, bigger size of work pieces which need more sophisticated type robots than in the case of manufacturing industry. In Figure 1, (*) indicated items are to be studied in research and development in this area. Some of these technologies can be transferred from closely related area of research as mining, ocean development, space development, defence and so forth, but others have to be developed in building construction industry themselves.

3. Particular technologies needed in development of building construction robots

The relation of important building construction robot technologies from the standpoint of the system structure is shown in Figure 2. For example, in building construction system, three types of catalysts are used for promoting automatized construction process from the system input to the output. Among them physical catalysts are composed of robots, machines, peripheral devices and so forth. Information catalysts consist of rules, manuals, computer softwares and so forth. Human agents include robot operators, maintenance crews, engineers, managers and so forth. For successful development of the robots and the systems, we need to have the reliable catalysts research and development system. The catalysts development system (WASCOR Research Project) is also shown in the figure. As explained in the figure we have to develop new technologies for successfully developing the building construction robots. The development of these new technologies is the most important part in our WASCOR research project. Figure 3 shows concrete item of the technologies related to each step of WASCOR robotized building construction system development procedure.

1) A systematic robot operation system design procedure

A consistent procedure to design the robotized construction system from the beginning to the end must be developed. In the procedure, the following events are included; deciding the area of problems to be solved, forecasting construction and robot technology to be employed, determining reasonable labor saving target of robotization, deciding the area of the construction system design, designing the conceptual robotized construction system, detail design of end effectors, arm joint condifurations, location units, peripheral devices, etc., refining the alternative plan by applying simulation methods, evaluating and selecting the system alternative plans. The WASCOR research group is developing a set of forms and instructions to use the forms based on the procedure.

2) Robotization needs and possibility analysis method

For determining the appropriate area of robotization is very important. The area is decided from the standpoint of operators, the management of subcontractors, the staff of general contractors and robotization work study specialists as shown in Figure 4. The analysis is done by questionaire survey and analysis of operations. As the result of the analysis robotization priority of the operations is decided.

3) Work study method for robotization

New work study method is being developed. Type and accuracy of data collected by the method are much different from those of conventional method for human operation systems design. Automatization of data collection and data processing is possible by applying video and computer technologies.

4) Construction method workability evaluation technology

For reducing operational burden to the robot, at the beginning stage of the robotized operation systems design, we should evaluate construction methods from the robot standpoint and improve the method by modifying connection and fastening method of structural members, introduction of prefabrication system and so forth.

5) System simulation method

This method is situated in an important position in construction robot system design. Because, generally speaking, the size of work places and robots are far bigger than that of manufacturing industry, and it is more expensive to build prototype model. The simulation methods are composed of the following three types and each type is selected according to the purposes and expected results.

a) Three dimentional computer graphic simulation

By rapid progress of computer technology and reduction of computing cost, the possibility of utilizing the computer graphic technology is increasing. The author anticipates that the computer graphic simulation is applied in these three levels.

(1) Total construction site level

(2) A type of operation level

(3) Robot motion level

b) Scale down solid model

This model is effectively used for checking building design, construction method, material handling system and so forth. Industrial type plastic blocks are conveniently used and scale down ratio of 1/10 and 1/25 are convenient. Figure 5 shows an example of steel beam solid model. The model was used for discussing the beam assembly procedure.

c) Small scale operating model

The model is used for detail examination of the system alternatives. Figure 6 is used for studying the possibility of co-operative motion between a crane and a robot, and also selecting appropriate type of pillar connection.

6) Robot modularization technology

For conquerring a complexity problem of building construction system, we are considering to introduce modularization concept into robot system design and solve the problem by applying easy variable type robots for different operations.

7) System evaluation method

Finally we must develop a traditional important technology for the correct evaluation of the robotized construction system alternatives. In this technology the evaluation is done on two stages. On the first stage an alternative plan is reviewed from the standpoint of feasibility. In this case feasibility means possibility of the alternative plan which can be actually applied to the given purpose and if the plan cannot pass this screening, it has to be abandoned. If it passed the plan receives the second step desirability evaluation. Economic justification is treated as one of the desirability criteria.

4. A suggestion to install a construction robot research laboratory

From the long range standpoint, the author anticipates that an engineering man-power structure of general contractors will be greatly changed for adapting in the innovative age. Today man-power ratio of construction technology research staffs in general contractors is very small. But developing and utilizing robots and advanced automation technologies, we have to enforce construction technology staffs rapidly. In manufacturing industry, Japanese leading electric and electronics manufacturing companies have installed production engineering research laboratories about a quater century ago, and those production engineering research laboratories made big contribution for their productivity and product quality improvement. Figure 7 shows an early stage layout example of construction robot research and development laboratory.

5. Conclusion

The author introduced particular new technologies to be developed for successful introduction of robots and suggested the installation of construction robot research laboratory. The biggest and the most difficult problems in robotization of building construction system are a bigger cost burden of robot development and a smaller size market for paying back the research and development expense compared to the robotization of manufacturing industry. This means more necessity of international company-university-government co-operation promotion for sharing the research and development cost and gathering the robot markets.

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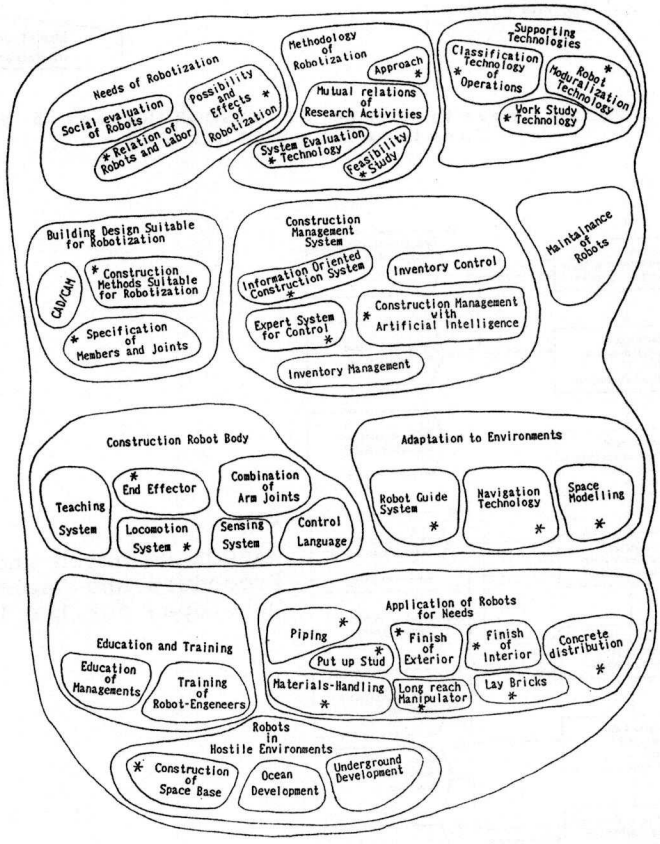

Fig. 1 Configration of Construction Robot Research And Development Themes

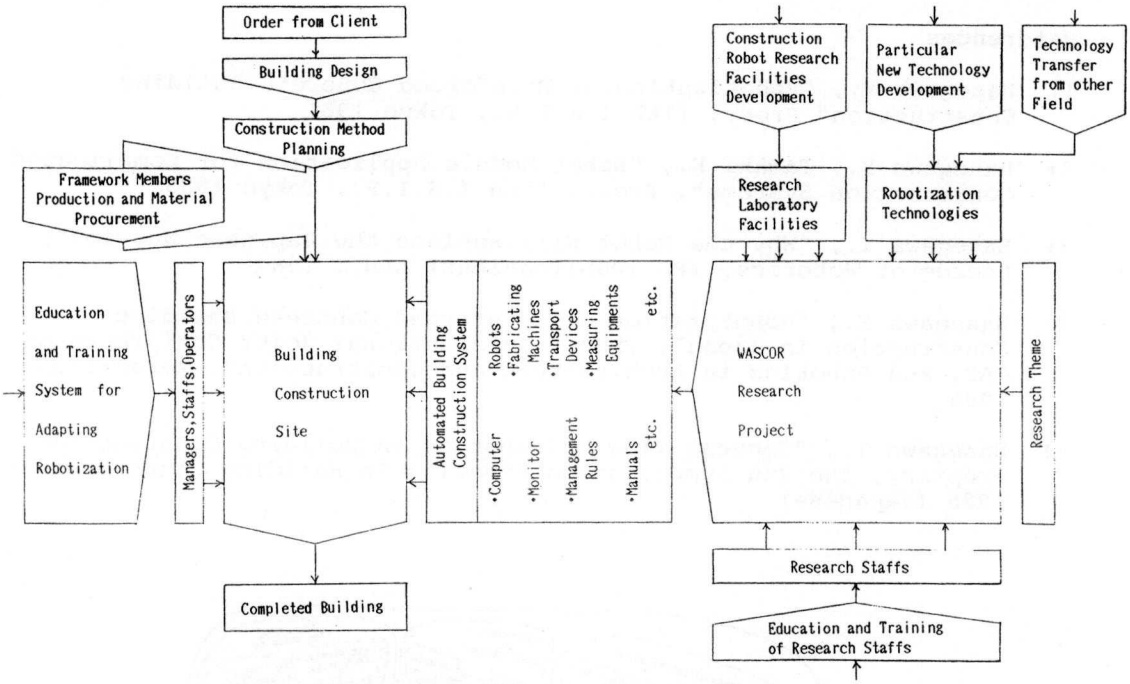

Fig. 2 Reletionship of WASCOR Research and Construction Activities

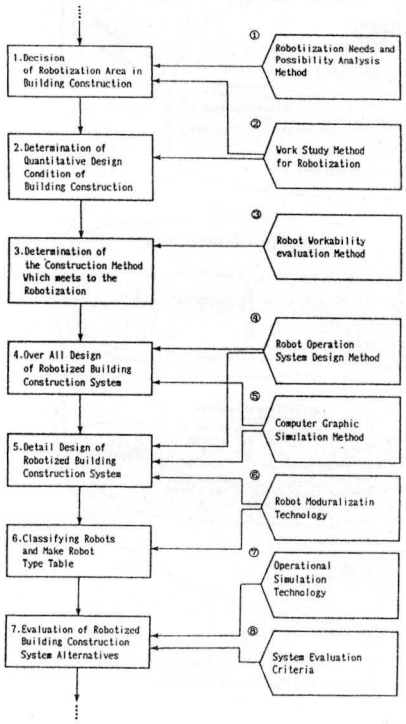

Fig. 3

WASCOR Research and Development Procedure and Technologies to be Developed for the Project

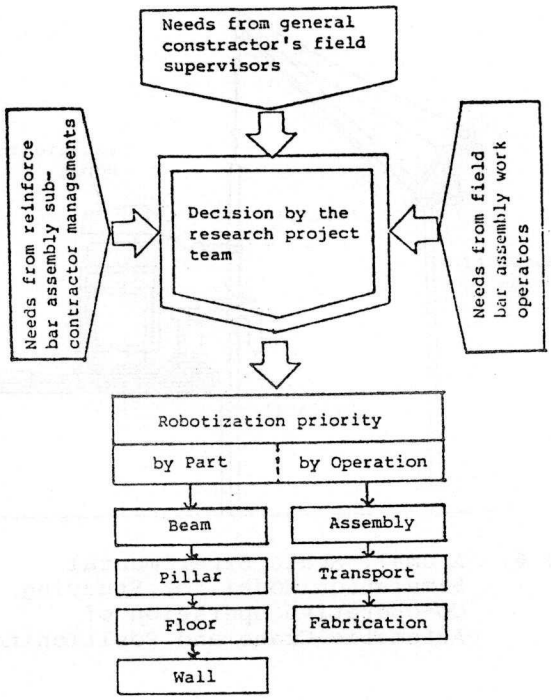

Fig. 4 An Example of Robotization Priority Decision Process and the Result

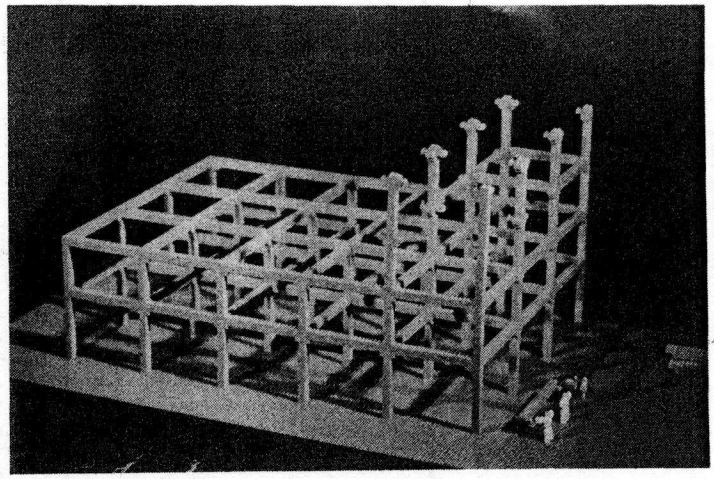

Fig. 5 An Example of Steel Beam Solid Model

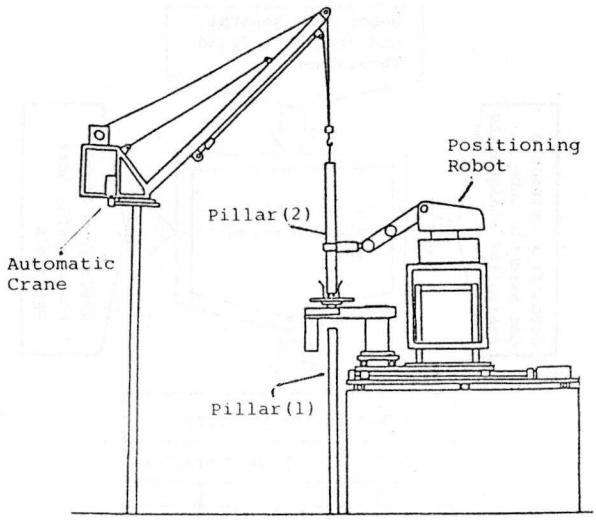

Figure 6. A Small Scale Experimental Simulation Model for Studying Co-operative Operation of Automatic Crane and Positioning Robot

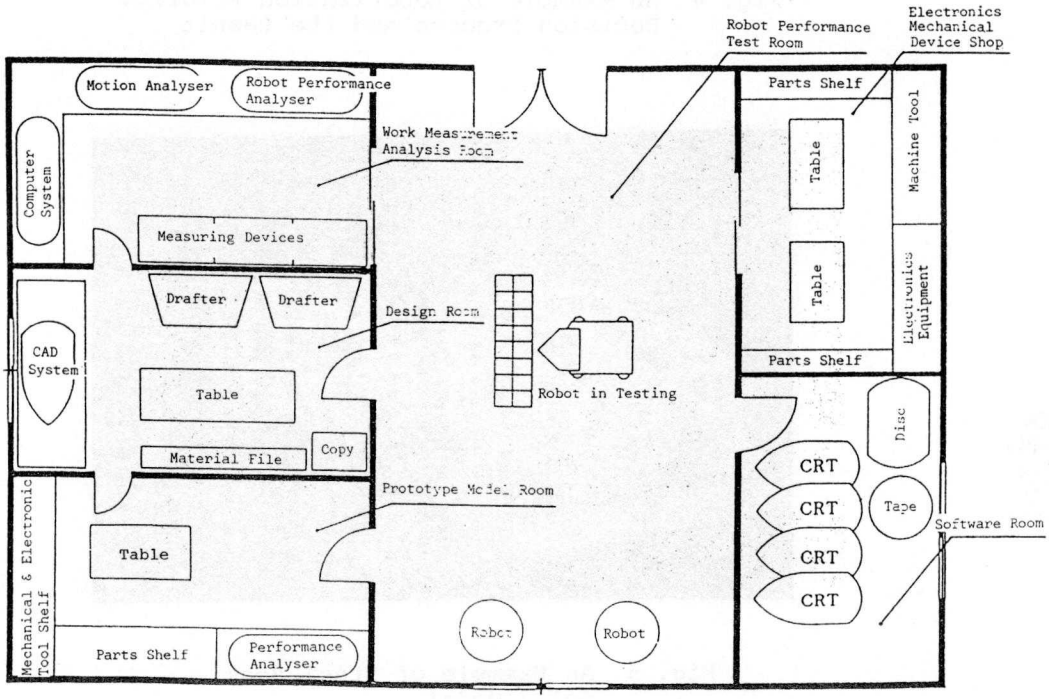

Fig. 7 An Example of Construction Robotization Research Laboratory Layout