WORK MODULARIZATION FOR BUILDING CONSTRUCTION USE ROBOTS DEVELOPMENT

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ABSTRACT

For breakthroughing difficulty of developing the building construction use robots, the author developed a modularization concept and methodology to cope with the complexity of the operations. In this paper the following iddues are discussed.

1) Fundamental concept of robot modularization
2) Methodology to develop the modules
3) Structure and type of work modules
4) Robot hardware modules
5) New work study method for modularization

INTRODUCTION

In a past decade, averagely speaking in our country, labour productivity in constructing industry has not been increased in spite of double increment in manufacturing industry. This causes increase of price level of buildings and houses on one hand, and on the other hand comparative level-down of workers' working conditions such as salaries, working hours, working environment and so forth.

The main reason why the constructing industry has been left so behind is understood as difficulty of rationalization such as complexity, diversity, multi level vending, mobility of constructing sites and so forth.

For breakthroughing the thick wall to bother productivity increment, we started a research project to introduce robot technology into constructing industry since several years ago under the sponsorship of Japan Industrial Robot Association.

Since a few years ago the research project has been re-organized and extended to the co-operative research project of a university and eleven companies. The research project was named WASCOR (WASeda COnstructing Robot) resrarch project and the research members are eagerly participating in the project. Modularization of the robots is one of the weapons of the project team for attacking the targets systematically.

The authors anticipate that for successfully accomplishing robotization in constructing industry, the introduction a new systematic technology is indispensable and modularization of robots is an imprtant major part of the technology. In this article the authors introduce the outline and direction of the modularization.

1. SIGNIFICANCE OF ROBOT MODULE DEVELOPMENT IN CONSTRUCTION WORK

Operations in building constructing sites are much more varied and complicated than operations in plants of manufacturing industries such as automobile, electric, machine tool and so forth. At constructing sites many processes are done by co-operative group work of operators and about 100 types of technitians' participation are needed for constructing a middle sized office building.

It is not economically feasible to simply apply the conventional limited purpose type of rcbots into those constructing systems. For solving this unexperienced new robotization problem of complexity in constructing industry the authors propose to introduce modularization concept and methodology.

2. FUNDAMENTAL CONCEPT OF ROBOT MODULARIZATION

A fundamental concept of robot modularization is explained in Figure 1. The most important essense of the robot modularization is a concept of work module. It is used for defining constructing operations corresponding to robot hardware module. The role of the work module is a medium to convert the operational function and condition to robot hardware modules.

Work module is developed from analysis of constructing operations under the consideration of robot hardware module development. Also robot hardware modules are systematically developed for fulfilling work module function and conditions. For planning a robotized construction system to be applied to particular constructing site, some of the appropriate robot modules are selected out of robot hardware module arrangements based on the work module model.

By introducing this work module concept serious problem of complexity of constructing robot systems will be systematically solved

3. METHODOLOGY TO DEVELOP THE WORK MODULE IN REINFORCED CONCRETE BUILDING CONSTRUCTION SYSTEM

For developing the work module, authors developed a fundamental approach as shown in Figure 2. In the flow chart several important activities are included as follows:

3-1 Design a new constructing system

The consistent design approach is kept from total constructing site system level to sub systems so far as element motions. In the procedure design of final unit operation, element operation, unit motion and element motion level of models are correspond to each step of work modules.

On the total constructing system design step information of current construction and robot technologies are taken in and referred to.

3-2 New work study for robotization

A new work study method is applied for specifying work modules and their conditions. The method is fundamentally different from human work study, and the other purpose of the study is to collect qualitative and quantitative data for robot hardware modules design.

3-3 Design of robot hardware modules

Based on the data of the work study and referring to the general alternatives of robot hardware modules, a set of robot hardware modules for constructing work are designed. The modules are selected and combined to robotized operation system for particular purpose.

4. A NEW WORK STUDY METHOD FOR ROBOTIZATION

For designing robot work modules authors developed a new method of work study. Figure 3 introduces the outline of the new method. Operations are mainly analysed with a couple of video cameras for collecting three dimentional data and processed by using video analysing systems such as video scaler, position analyser, computer, plotter and so forth.

By using the system we can get dynamic conditions for the robot design such as motion displacement, speed, acceleration speed, time, and some static conditions such as space restriction, motion pattern and so forth. Other data such as environments of construction site, work pieces, tools are taken by using still camera, transit, laser finder and so forth. In Figure 3, a case of steel beam assembly operation is introduced and for specifying work pieces, drawings of them are referred to as shown in the figure.

5. RELATIONSHIP BETWEEN WORK MODULES AND ROBOT HARDWARE MODULES

The result of the work study is break-down to work modules, and the lowest level of the element motion modules are represented with symbols and signes as shown in Figure 4. These models indicates function of each element motion module and a particular group of the modules are corresponding to robot hardware modules.

For developing work modules from the work study result, whose following items are analysed and defined.

5-1 Motion patterns

Motion locuses, position orientation, constraint of work pieces, hand tools and so forth.

5-2 Dynamic motion conditions

Motion speed, acceleration speed, accuracy and so forth.

5-3 Work pieces and tools

Work pieces' shape, size, weight, material, surface condition, function of tools and other conditions. Robot hardware modules are composed of end effector, wrist, arm, body and locomotion modules. A robot complete is composed of selected robot hardware modules as shown in Figure 4.

6. TYPES OF END EFFECTOR MODULES

In Figure 5 types of end effector modules are shown for example. End effectors are fundamentally classified into two categories such as constraint and process type. Constraint type of end effectors are used for holding work pieces and hand tools. The end effectors are classified by the type of holding, and further classification is done by detailed conditions.

Process type of them are classified by function of processing and further classification is done by the type of processing tools. Those types of end effectors are developed from the result of work study of constructing operations.

7. TYPES OF LOCOMOTION MODULE

Figure 6 shows an example of the locomotion module classification. In this case classification is made by locomoting conditions. Locomotion modules are to be increased by the progress of the mechanisms. In the case of constructing robots the role of the locomotion module is very important and the development of the module is a new field in robotics.

8. A PROCEDURE TO CONVERT WORK MODULE TO ROBOT HARDWARE CONFIGURATION

A procedure was developed by authors as shown in Figure 7. As the result of analysis of constructing operations, motions to be done by robots are indicated by using work modules. On these work module models additional conditions are applied and the information is collated with the list of each robot hardware module. Then the appropriate hardware modules are selected from the module list and combined to a robot hardware complete. In the process of the robot hardware module selection some criteria are applied.

CONCLUSION

The research for construction robot modularization has just started and is in its immatured stage ncw. Even though the introduction of mcdularization concept and methodology will be one of the most reliable tools for breakthroughing thick wall to obstruct robotization of constructing work.

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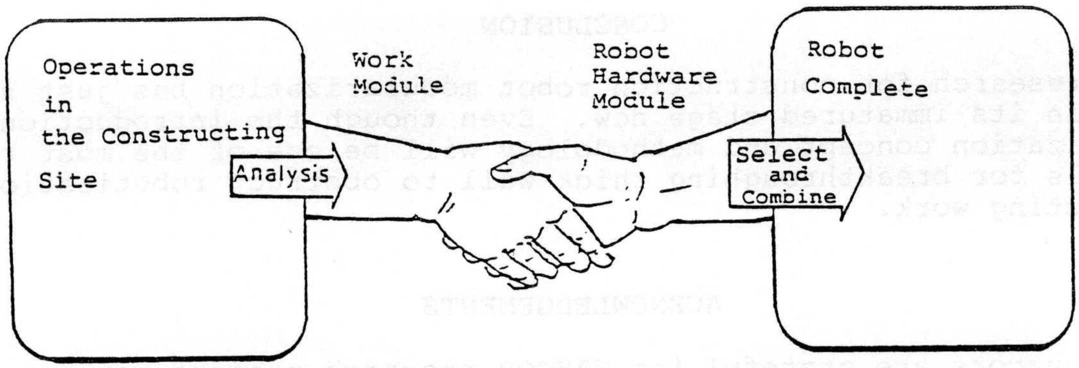

Fig.1 Fundamental Concept of Robot Modularization

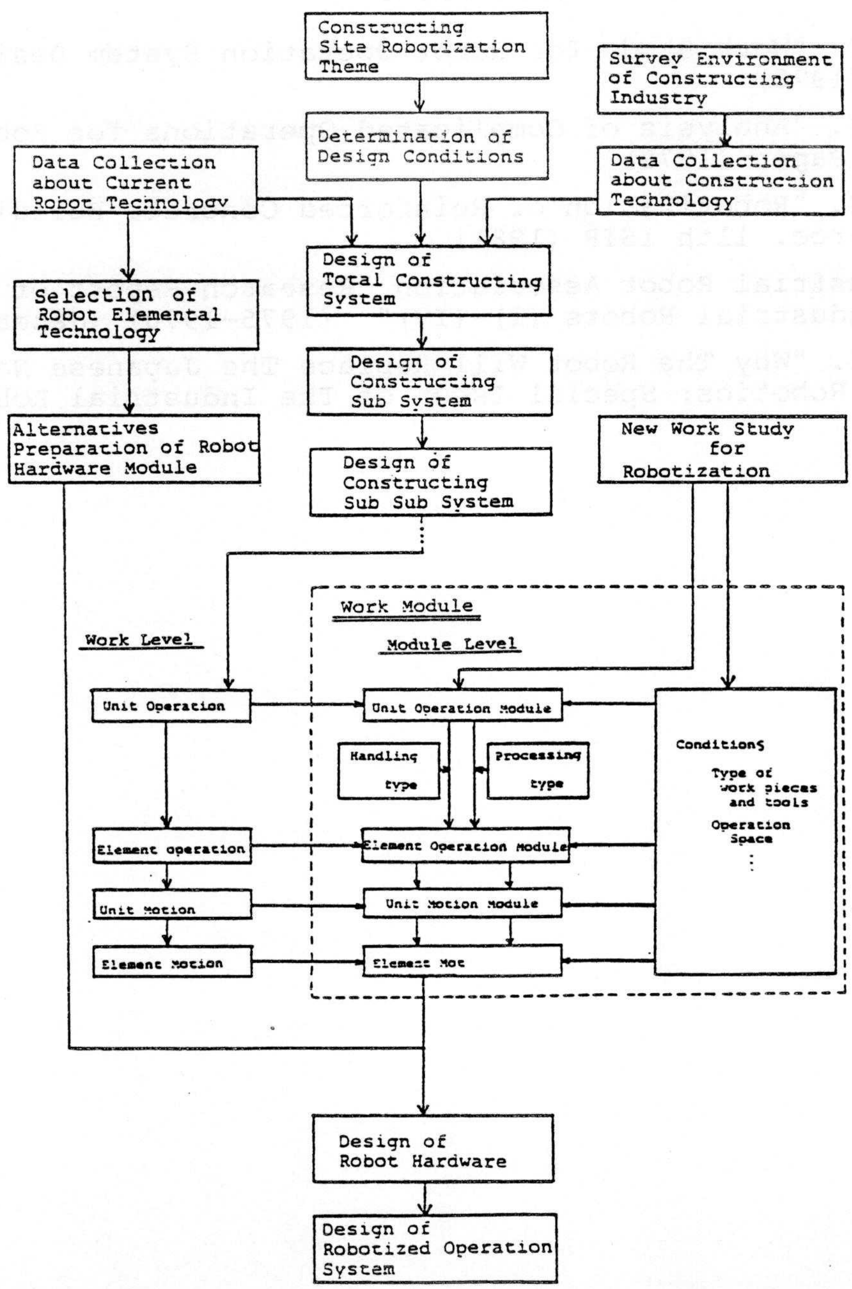

Fig.2 An Approach to Develop Robot Modules

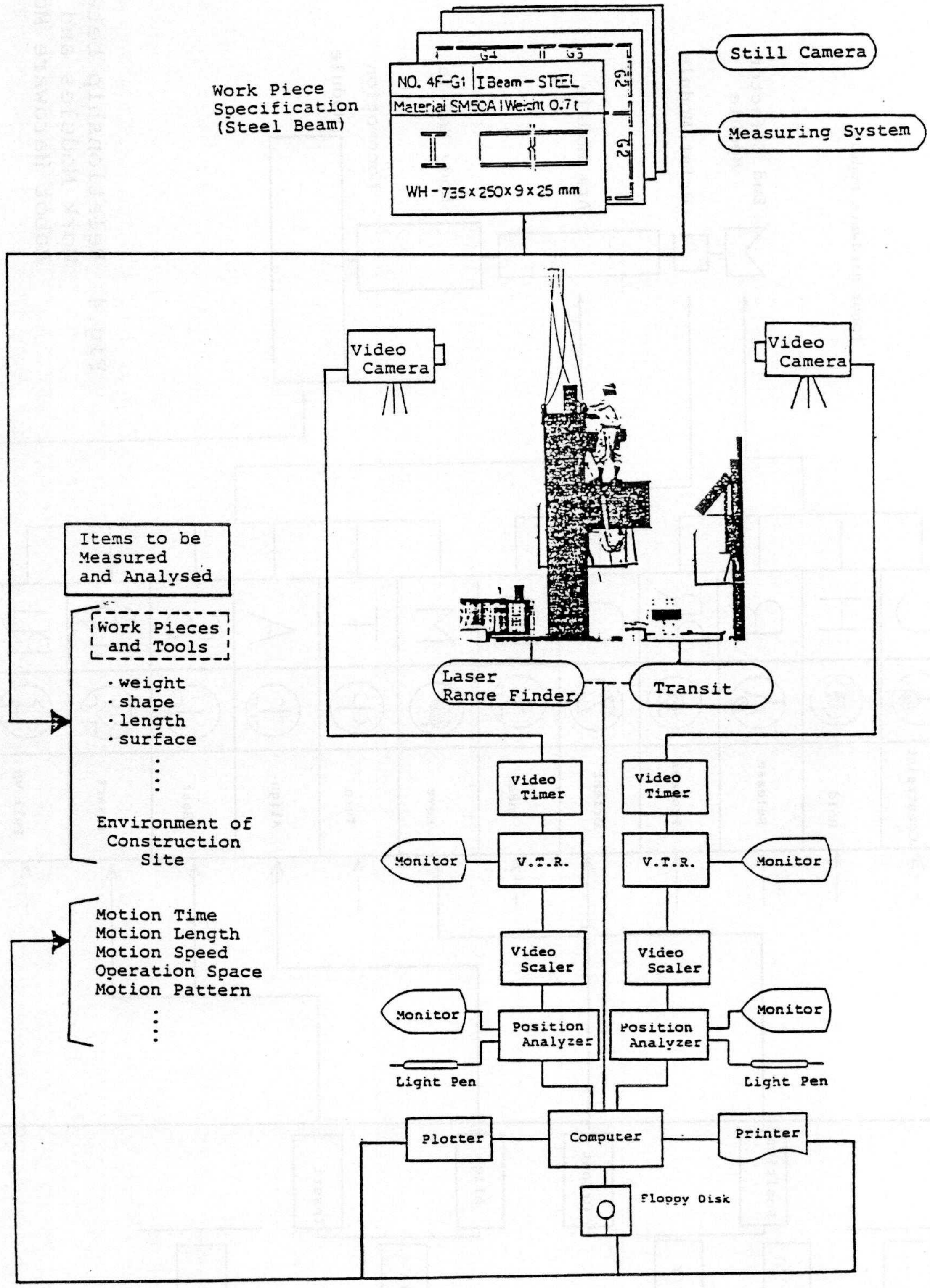

Fig.3 A New Work Study Method for Robotization

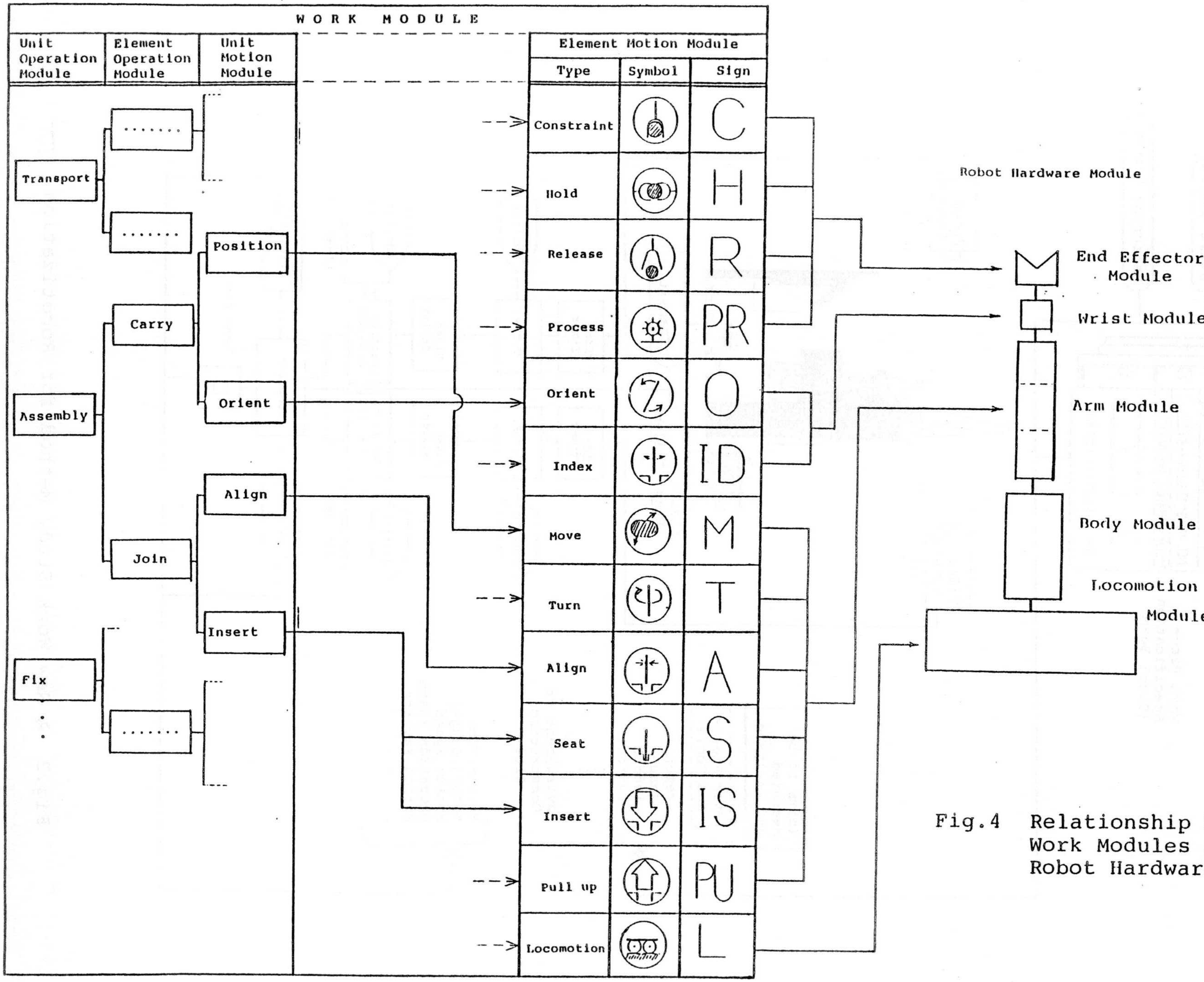

Fig.4 Relationship between Work Modules and Robot Hardware Modules

End Effector Module

Contraint Type					
Type			Symbol: Standard	Symbol: Variation	Work Pieces
Hold	Expand	Squeeze (Inside/ Out)			
Hold	Expand	Inside Out			•Form Panel
Hold	Close	Gathering			•Reinforce Bar
Hold	Close	Squeeze (Outside/ In)			
Hold	Close	Parallel			•Pipe
Hold	Close	Regular Grasp		⋮	
Hold	Close	Pinch			•Form Separator
Hold	Touch	under-neath			
Hold	Touch	Push			
Hold	Suc-tion	Vacuum			•Wood Plate
Hold	Suc-tion	Magnet		Soft Magnet	•Steel Frame

Process Type			
Type		Symbol	Example of Processing Tool
Fabricate	Scrape		Scriber
Fabricate	Chip		Chisel Chipping Hammer
Fabricate	Plane		Planing Machine
Fabricate	Drill		Drill
Fabricate	⋮	⋮	⋮
Joint	Screw Drive		Screw Driver
Joint	Rivet		Riveting Head
Joint	Bolt Setting		Bolt Driver
Joint	⋮	⋮	⋮
Welding ⋮			

Fig.5 Types of End Effector Module

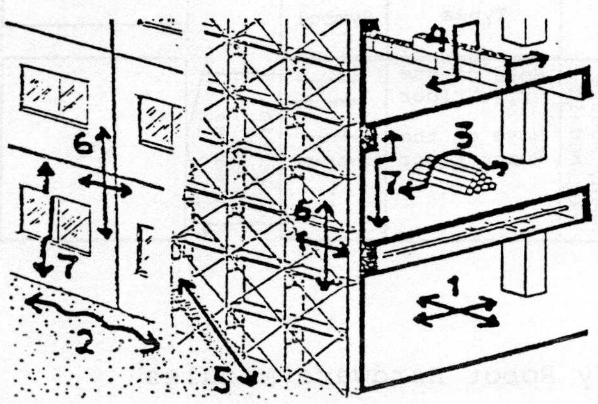

Fig.6 Types of Locomotion Module

No.	Symbol	Type	Examples
1		Move on the Flat Floor	Wheel
2		Move on the Rough Floor	Off Road Type Wheel
3		Climb and Down Obstacle	Caterpillar
4		Stride over	Limb
5		Up and down stairs	Limb
6		Vertical Move on the Wall	Suction Legs
7		Vertical Move on the Wall with Gap	Be Developed in the Future

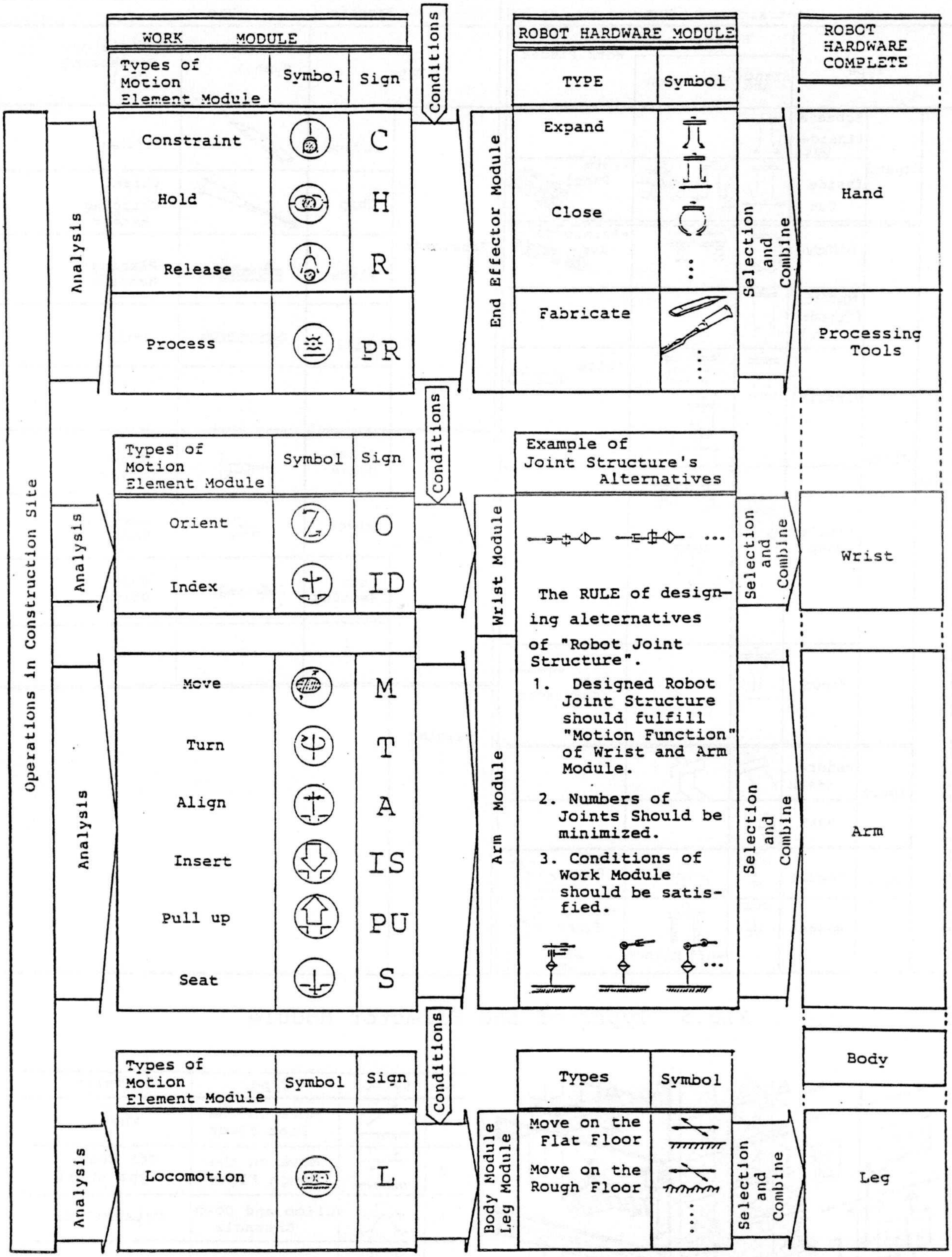

Fig.7 A Procedure to Specify Robot Hardware Modules from Work Modules