PARTS AND PACKETS UNIFICATION FOR CONSTRUCTION AUTOMATION AND ROBOTS

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ABSTRACT: This paper proposes a method of configuration of database system for parts oriented construction. In parts oriented construction, robots acquire information related to the tasks from the server through ID attached to the construction components. This system aims (1) simplification in motion planning of the construction robots using information attached to components, (2) reconfiguration of data structure for process of construction tasks. The robot performs the tasks according to local planning based on the local information. The operation server reconfigure parts information based on task result by robots so that the next robot can obtain the required information from the composed components in the next phase. We call the parts integrated information "packets", and call our idea "parts and packets unification." The feasibility of our proposed method is also shown in the preliminary experiments where an RFID tag attached to a component is applied for data exchange.

KEY WORDS: Automatic Construction, Information Integrated Components, Data Collection System and Labeling, Automatic Reconfiguration of Parts Information, RFID Tags

1. INTRODUCTION

The recent advancement of information and communication technologies has brought feasibility of efficient construction automation [1][2][3]. However hard problems of construction automation still exist. In construction site, workspace changes according to a progress of construction works and works are performed in parallel. And a building is one-article production. Therefore, it is difficult to make a global and perfect plan of the construction robots beforehand.

It is reasonable that the parts-oriented construction, where a robot makes a plan using information of parts on site, is applied to the construction automation. For the parts-oriented construction, the server manages a relation between construction components and their information. And the server has to manage the information of working robots. By managing the relationship between the parts and their information, the robot can check the assembled parts and can correct errors caused by disturbances. Therefore, it is expected that the work may not be repeated to cancel the errors and the efficiency may be improved of the work.

In the construction tasks, new components are generated in the progress of construction. We call this newly composed component a "module," since it is used as a part of the building. A module is used as a component in the next phase. Attributes of a module (form, weight, center of gravity, etc.) will change as components are composed to a new module. It is difficult that a robot obtains required information of each component composed in a module. Then parts information about the module should be reconfigured. In order to reconfigure the parts information automatically, it is necessary to match a component (parts) with its accompanying information (packets). We call this state "parts and packets unified state." We propose a parts oriented construc-

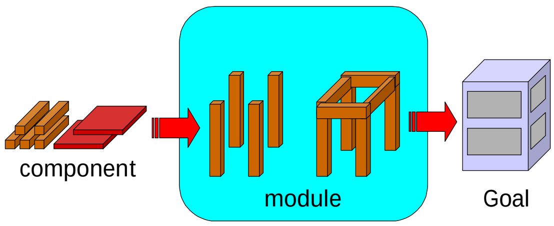


Fig. 1 Change of components in construction

tion system using the concept of "parts and packets unification."

In this study we consider parts and packets unification, where every object, part, module, and structure carries its related information on itself with data carrier such as RFID tags [4][5], bar codes [6], and so on. We are also interested in its effective usage of the construction automation and robots. In the following we will discuss what a feasible database will be, how attributes will be dealt with as construction objects are processed, and what physical and information interactions between objects and robots will be, by citing some example tasks.

2. PARTS ORIENTED CONSTRUCTION

2.1. Unification of Parts and Their Information

We show a construction process of a building in **Fig. 1**. In the construction tasks, information and attributes of each component and those of the completed building are known. And the work procedure is also known. A new module is generated by composing the components. Attributes of a module (form, weight, center of gravity, etc.) will change as the module is composed. But their information is unknown. In a process of construction, attributes of a module should be clear for local planning of the construction robots. We propose a method to clarify the attribute of the module using an ID attached to each component.

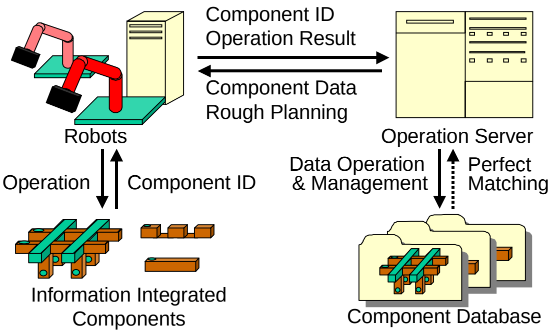


Fig. 2 Diagram of parts oriented construction

2.2. Parts Oriented Construction

We consider a method of realization of the parts oriented construction system using information-integrated components. In **Fig. 2**, we show a relation between construction robots, components, and their information. A Robot acquires the parts information via ID attached to the components, and operates the components. The robot sends the components ID and the task results to the operating server while achieving the tasks. The server sends the parts information to the robot by the components ID. There are several methods to obtain the components ID in this system, for example, RFID tags, bar code, and so on. And there are several ways to communicate between the robots and the server, for example, a private network, LAN, and so on.

A method of informational operation by the server and acquisition of the parts information by the robots are serious problems to the settle of the construction system. Thus we discuss the method of the informational operation and management of the parts information in section 3. And in section 4, we carry out experiments of the acquisition of the parts information using RFID tags. We discuss the problem in the parts oriented construction system.

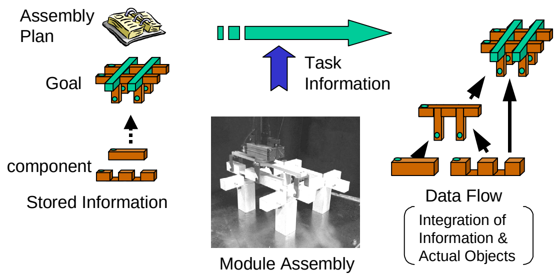


Fig. 3 Example of parts and packets unification

3. MANAGEMENT OF STRUCTURE OF PARTS INFORMATION

3.1. Autonomous Data Acquisition

Fig. 3 shows a concept of autonomous composition of parts information. Robots achieve a construction task based on the task plan. The parts information is also composed from the task results. Thus the parts information of the modules is also composed. Fig. 3 shows an example of how a module and its attributes are reconfigured through an assembly task. The attributes of a real module and those stored as parts information of the module in the server are matched by autonomous reconfiguration of the parts information. Thus, the robot can determine the detail motion plan using the rough motion plan and the stored information of the modules.

We show the merits of the autonomous data reconfiguration. If the attributes of modules are stored as the accompanied parts information, the robot can obtain the information of the modules easily by local information acquisition through the ID.

3.2. Properties of Parts Information

Attributes of a module, for example, weight, center of the gravity, posture, and so on, change in robots and machine acting on a module. It is expected that recognition of the stored attribute utilizing the task result of robots lead to consumption of lower energy and safety of the construction site for workers, machine, and robots.

In this section, we describe the property of the attributes of modules. The attributes of modules change in a progress of tasks. Some attributes inherit the former attributes before the change (dependent), and others do not inherit the former attributes (independent). For example, form, moment, and the properties of a module depend on those of a former module. On the other hand, appearance and accuracy of a module do not depend on those of a former module. Accuracy of attachment and processing of modules are different since abilities of workers or robots are different. And new attributes are added when a module is processed, i.e. welding and cutting.

The attributes of each module should be reconfigured during construction. A large module consists of many modules.

3.3. Reconfiguration of Parts Information

Fig. 4 shows the change of the parts information stored in the database in the process of module assembly. The top of the figure shows an example of the process and how each component is composed is shown. The bottom of the figure shows the parts information of the composed module. In this figure, module C is composed from component A and B. And module E is composed from module C and element D. The code “xxxx” indicates the ID code of each tag or information. In this example, the module is composed so that the parts information is also reconfigured. It is desired that the database should be set up in order that the robot can refer the same information of the

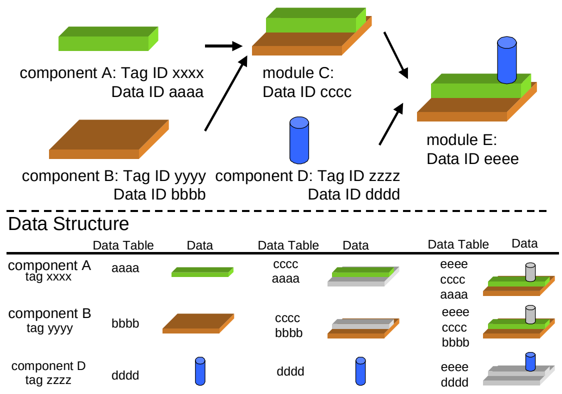


Fig. 4 Autonomous data renewal process in module assembly

module via each tag attached to the module. We will discuss the structure of the parts information and the method of reconfiguration of reference of the parts information.

We show the method of the configuration of the parts information in the following. It is supposed that a tag is attached to component A, B, and D. The parts information referred to each tag is stored in the server. When the robot composes component A and B, the robot acquires the parts information using the reference from the tag xxxx attached to component A and tag yyyy attached to component B, and the robot achieves the task. Then both attributes of component A and B change so that the newly reconfigured information of module C is generated. And the attribute of module C is referred to the tags attached to component A and B. Therefore the robot can acquire the information of the module via any tags attached.

Fig. 5 shows the reconfiguration of data reference from tag xxxx, yyyy in the composition process. The left side of Fig. 5 shows the ranking of the parts information references. For the first time, the reference of parts information about each element is stored in the reference map. In the process of the module composition, the ranking of the reference changes in order that the robot refers to the information of the composed module via each tag attached to the module. Through the data operation, the robot can refer to the present information of the module via any tags attached to the module. On the other hand, the robot reaches the information of each element using the list of the reference map for each tag.

We make a simple program of reconfiguration of the database, so that the robot can reconfigure the parts information of the module.

4. EXPERIMENT OF ACQUISITION OF PARTS INFORMATION

4.1. Acquisition of Parts Information by Robot

We describe a method of acquiring parts information by a robot. To obtain the information attached to the parts, a robot recognizes letters or markers printed on the parts in a

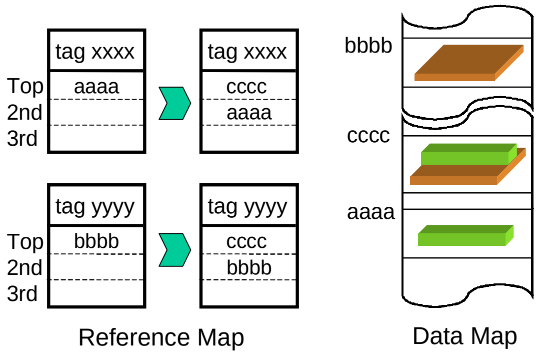


Fig. 5 Reconfiguration of data reference in module assembly

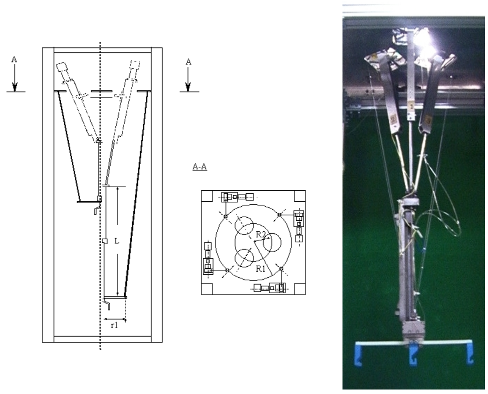


Fig. 6 Prototype of hybrid arm

method [7]. But a vision sensing has a difficulty to acquire the information, since a vision sensor is strongly influenced by conditions, the surface status of parts and a light source.

We adopt an RFID tag as a medium for acquisition of the information. An RFID tag is robust against a change of environmental conditions, e.g. temperature and light sources. However it is influenced by a metal that is frequently used as parts in construction site, since they are communicated by radio signal. Here we try to carry out experiments of acquiring parts information using RFID tags to ascertain the feasibility. Through the experiment, we discuss possibility of autonomous construction using RFID tags.

The experiment setup includes using an antenna, RFID tags, parts models, and the prototype hybrid parallel arm for autonomous construction (see **Fig. 6**). We consider the conditions about a robot that acquire parts in-

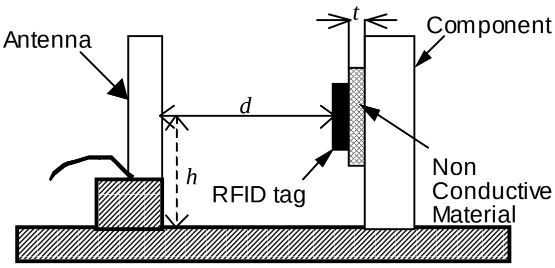


Fig. 7 Experimental environment

formation from the parts by RFID tags, and also discuss how the tags should be attached.

4.2. Experimental Setup

The experimental setup is shown in **Fig. 7**. The center of the antenna is set at the same level, h, as the RFID tag, and the distance between the antenna and the RFID tag is *d*. and the distance between the RFID tag and the component is *t*. The RFID tag is OMRON V700-D13P21. The antenna is OMRON V700-H01. In this setup, the height *h* is 215[mm]. The component is 60[mm] by 60[mm] by 130[mm], and it is made of iron. There are two pins on a pair of the parallel surface. The length of each pin is 15[mm]. The floor is made of metal.

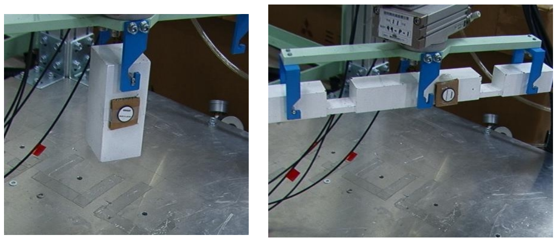
We examine what the maximum distance between the antenna and the RFID tag attached to the component where no antenna can communicate with the tag. And we measure the thickness between the RFID tag and the component to obtain the reasonable communicable distance. A nonconductive material is introduced to cancel the metal influence on radio signal. Its thickness will be varied. To compare the ability of the communicable distance, we measure the communicable distance between the antenna and the RFID tag attached to the nonconductive object.

4.3. Measurement Results

We measure the communicable distance by changes of the distance *d* between the RFID tag and the antenna. We wrote small-size data to the RFID tag, and read the data from the tag using the antenna. We regard that the trial succeeds if both writing and reading tests are succeeded. For each distance *d*, 10 trials are carried out, and we set distance *d* by 5[mm]. We regard the distance that all trial at the distance succeeds as the communicable distance. The thickness of the nonconductive material *t* is set 0, 3, 6, and 9[mm].

Table 1 Communicable distance between antenna an RFID tags

t [mm]	0	3	6	9
Maximum Distance [mm]	Failure	90	125	130



(a) Pillar (b) Beam

Fig. 8 Information integrated components handled by the hybrid arm

The communicable distance between the antenna and the RFID tag is shown in **Table 1**. The table shows, a reasonable communicable distance can be defined if the RFID tag is attached to the component with the nonconductive material, but not directly. In the comparison, the communicable distance in the case the tag attached to the nonconductive material is 180[mm].

4.4. Acquisition of Parts Information in Manipulation

We examine acquisition of parts information while the hybrid arm shown in **Fig. 8**. The hybrid arm manipulates the parts and the experimental setups are carried out in the same conditions as in section 4.2. The height *h* from the ground to an RFID tag is set 190[mm] so that the hook or the end-effector of the hybrid arm might not become obstructive on manipulating a component. We attach an RFID tag to a beam component at 40[mm] shifted from the center since the end-effector has the hook at the center. In manipulating the beam component, the height *h* is set 230[mm]. We set the thickness between the component and the tag *t* is set 6[mm] from the measurement results in section 4.3. Fig. 8 shows how the arm can handle the component.

We tried the communication test with the distance 80[mm]. From this examination, the robot can acquire the parts information via the RFID tag attached to the component using the antenna. But, when we shift more 10[mm] from the center of the arm or set the communicable distance *d* more 20[mm], the antenna cannot communicate with the RFID tag. Therefore, the distance should be carefully selected in the actual application.

5. CONCLUSIONS

This paper proposes a parts oriented construction system using the concept of “parts and packets unification.” We propose an autonomous data reconfiguration using the change of attributes of modules that a robot acts. We discussed the data structure of the parts database, reconfiguration of the parts information changes on task procedures, and the property of parts information. And we showed the autonomous data acquisition using RFID tags attached to components. Through the experiment, we assured the feasibility of the proposed parts oriented construction system.

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