Robotics Construction in the 21st Century In Japan- IF7II

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ABSTRACT: In construction production field, since various type of disturbance factor is existed, it is difficult to manage related information by using conventional model. In this paper, a new concept of "Parts and Packets unified architecture" is proposed. Data or information related to a product are carried by product itself and can be handled to manage whole system. It is a unified controller system which operates parts and packets together.

KEYWORDS: Glue Logic, Parts and Packets, Active Data Base, RFID, Automated Handling, Dynamic Scheduling

1. INTRODUCTION

It can be said in general that the construction industry is, regardless of its nations it belongs to, advanced or otherwise, of local character bounded to the narrower view on its marketplace, supply chain, and technology advancement. So fragmented are they, albeit of its huge market-size and opportunities, that it has been, in the aspects above, far behind the manufacturing industry like the automobile, aerospace, and many other manufacturers, lest to mention the IT industry. A major new initiative is underway here in Japan, aimed for breaking this socio-economical stillness and prejudice, stepping forwards to create a new industrial formation worldwide in this century. It is integration of "parts and packets" with a control mechanism of their dynamic flow throughout a perplexedly complex network of production in construction. we all realize this adventure may lead us to further advancement in incorporation of the manufacturing mechanism in our industry.

We all notice that the Internet has driven forcefully the way we do business and will continue to do so in the coming decades. It is the information network that has changed the surface of the globe permanently so that nobody can dream up even reversing it. However, what is flowing in the business of manufacturers and construction alike is not merely information, but more importantly the material flow. The supply chain network, in its broadest sense, is indeed the primary concern of our time that needs some paradigm shift as the Internet brought about for information. If there is a way where the information packets and material parts go around in hand with hand over the production network, and the information network and its material counterpart will be no longer considered distinguishable. If every one of the parts for assembly has a chip with antenna implanted which contains a unique address "Product URL", it alone opens up a new horizon over which the two networks work together synchronically. The idea along this line is already intensively being studied by several research organizations over the world. It is as simple as the Internet, and yet it reaches the scope as wide and as deep as the Internet.

Coming around the corner is the technology that brings about another major impact on our way of construction business to some degree comparable as the Internet did. Given the new technology, we are most likely to be forced to restructure our product model of buildings, process model of construction, data model, construction management and the supply chain model, in short, overall business model for our construction industry. It will above all provide us with chance and opportunities to be able to solve the long-standing problems that have confronted us so long – implementation of manufacturing mechanism in construction.

2. SCOPE OF IMPACT

Of course even one large project cannot solve all the problems related to implementation of parts and packets integration mechanism in construction. We thus propose here for an International Platform of IT based reformation in construction under the banner of "Product URL-attached Parts Oriented Construction ". For the purpose to clarify and extend its unique characteristics further, here we describe some of many possible applications at construction sites, not to restrict its much broader scope.

(1) ***Quality Engineering***

Construction parts (building materials, components and parts) and design information are currently supplied to the construction workers separately. The skilled workers then interpret the drawings to map its graphic information to the construction parts available at hand. The current practice thus heavily relies on the interpretation skill of the workers, that induce uncontrollable randomness in quality achievement. If each part carries the relevant design information or can access to the remote servers swiftly via its address, the workers can retrieve only the relevant procedures necessary for its implementation. So that way an even unskilled worker can achieve precision works comparable to the manufacturing workers.

(2) ***Life-cycle Engineering***

Two to three million parts needed for a building, depending on how to count, and yet the vast bulk of construction parts can easily be registered in and retrieved from D/B by this system. We thus can keep all the information of parts and their history in log. 80 –90 per cent of the life cycle engineering can be solved by this bulk of D/B. Parts comparability with this parts-level information retrieval will make possible replacement of parts in a building to its full extent, even perhaps structural modules, not to mention the infill. It will eventually erase the current dichotomy between renovation and newly-build in its entirety.

(3) ***Supply Chain Engineering***

One can easily see the impact on the supply chain is far vast than ever achieved, for parts and packets (i.e. material and information) are no longer separable.

(4) ***Construction Management***

This IT-based Parts Oriented Construction will allow the Cost Management to achieve its full transparency due to its accessibility to the parts-level information. For the design and execution are far more closely linked than ever achieved, controllability in Construction Management will increase drastically in result.

(5) ***Inverse Manufacturing***

The Inverse Manufacturing is reverse processing from the artifacts to their components for the purpose of recycle and reuse. It moreover represents creation of a new industry to close the loop of industrial activities from the sold artifacts to the re-fabricated artifacts by reuse. The implementation of the Inverse Manufacturing however presumes the accessibility to the parts-level information of their material characteristics for recycle and reuse.

(6) ***Standardization of Product Model, Process Model, and Parts Specification***

Though standardization of product model and process model is moving forward elsewhere, it is necessary to accelerate it and to incorporate parts oriented view. The IT-based Parts Oriented Construction and standardization activities of modeling will promote each other and provide each with solid basis. Standardization of parts specification will make it possible that parts can go around freely over the net and across the borders.

Though only a few of the possible applications were listed above, one may be able to see already the vast scope of its impact, only comparable to the Internet revolution. It is not a mere replacement of the existing technology by a new one, but a paradigm change, that requires or induces the industrial rearrangement across the world. This depth it can reach to and this scope it can span over may require an international collaboration program.

3. DYNAMIC CONSTRUCTION BY INTEGRATED PARTS AND PACKETS

Control of construction process must deal with a bulk of scheduling elements that are produced by multiple heterogeneous players, contractors, sub-contractors, and parts makers. Their scheduling elements are necessarily intermingled and linked with each other. The whole schedule is managed and adjusted as one giant flow of processes. One small change in a tiny part of the whole schedule may possibly propagate its influence into the whole [1]. Every such complex system which is non-linearly linked often shows some chaotic behavior at worst, and leads to a catastrophe. Upon this peculiar condition, construction process management is conducted on site holistically at every moment from the commencement and completion of a project.

There are variety of causes that force scheduling change. It is of critical issue when a signal of change is dispatched within a complex system. If timing gets lost, disastrous consequence may result with severe cost loss. It is also critical where a change occurs among multiple players, as well as what happens. The Parts and Packets Unification System (hereafter called PPUS) allows parts or units to signal change in their attributes, as they go through the complex production system (Fig.1).

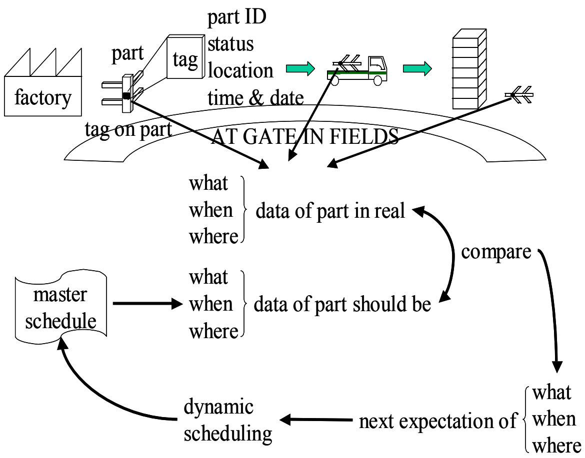

Figure 1. Dynamic Scheduling in a Frame of PPUS (Parts and Packets Unification System)

In a factory, production facilities like cells and stations are positioned at rather fixed location and are linked by information network. Whereas, at a construction site, most of facilities are temporary, mantled and dismantled cyclically, and are changing their locations continuously. It is not a trivial matter to link these temporary facilities by information network. In a factory, a pre-processed product is gradually processed in sequence as it passes through cells, stations, and lines. In another word, the frame of coordinate to detect the current status, position, and timing of parts is fixed, while the frame of coordinate itself is changing in the case of construction, for the production environment is metamorphosed as a building is being built. What was built till now interferes with what to be done. This dynamic linkage between the production environment and processing makes it subtle to network product, process, and its environment.

An intelligent construction method is not perhaps possible to its full realization, unless it succeeds to adapt these inherent non-linear coupling within the system, either in scheduling or in actual processing. PPUS is one possible solution, for chip-implanted parts behave as if they spontaneously send messages to their proper addresses, whenever their state are changed, and move around freely within the production system as if each of them provides its local coordinate of reference.

4. GLUE LOGIC AS CONTROLLER FOR BUILDING WORKS

Millions of chip implanted parts move around in a complex production system of construction under the scheme of PPUS. As they are assembled, their attributes may be altered. Some controller is required to orchestrate their movement.

The controller system named ``Glue Logic" is an infrastructure system which is designed to make building manufacturing work control easy and flexible [2]. This system binds multiple application software modules, referred as “agents”, developed and compiled separately, and coordinates those agents by means of inter-process massage passing. As the Glue Logic supports event notification and condition monitoring features based on active data base scheme [3], users can easily build real-time event-driven application agents. Each agent is free from polling shared data, waiting for notification messages from the Glue Logic.

As all of the data and agents in a system are abstracted, and are handled with symbolic names defined in the Glue Logic, agents can be built without any knowledge on implementation of others. Each agent in an application system can be developed concurrently, and can be added, deleted or changed freely without modifying other existing agents. As the result of these, the Glue Logic compliant agents are easy to re-use, and the users can build large libraries of application agents. Some agents having rather general purpose may be shared among various users, the life cycle and the reliability of such agents are extended, and the cost for software development is greatly reduced. Above all told, the Glue Logic can be realistic controller of a complex system of PPUS.

As shown in Figure2, the Glue Logic consists of two major parts: the communication interface subsystem and the data management subsystem [4].The communication interface exchanges information with agents running in both the same work-cell controller and remote work-cell controllers connected with the network system. The data management subsystem consists of also two parts: the data change monitor subsystem and the data storage subsystem. The data storage subsystem manages the association pair of the *name* and the *value* of the object. The data change monitor subsystem monitors the changes in the data storage subsystem and sends out the data change notification messages, and executes depending data evaluation.

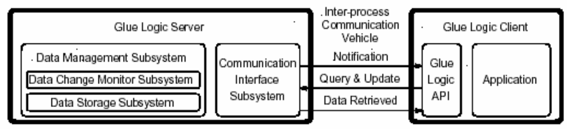

Figure 2. Configuration of Glue Logic

5. IF7II PROJECT

IF7II project started two years ago in the framework of IMS (Intelligent Manufacturing System) program. The objective is to develop the PPUS system and implement it in actual practice. Figure 3 shows the scope of research.

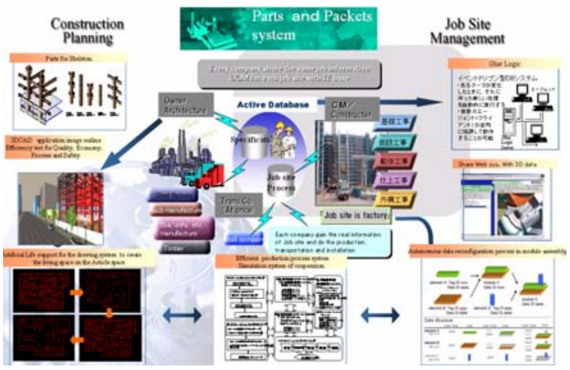

Figure 3. IF7II IMS Project and Its Scope

Three companies are involved in its implementation, Shimizu as general contractor, Tostem as sub-contractor and maker, Hitachi Zosen Information System as solution business. Figure 4 exemplifies its partial system developed and analysis conducted.

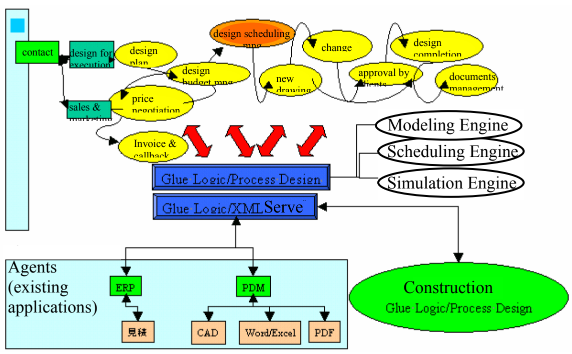

Figure 4. System Development (example)

5.1 Construction Management via Gates

It is adequate initially to implement PPUS from bottom-up as it is an extremely distributed system for building production. First, PPUS is viewed from a parts-maker's point of view. Activities of building parts maker are engulfed in a much larger complex whole of activity network on site. A maker manages its production process, and responds to changes required from the larger flow. Some change often propagates its influence on multiple subcontractors who are linked each other, and causes loss of cost among them, potentially, at worst, resulting in exponential blowout.

We identify the points in process where outbreak of cost increase is likely, and then set them as gates. The main stream of a maker's process comprises of "Contract", "Design Approval", "Manufacturing Preparation", "Product Drawing", "Production Plan", "Manufacturing" (cut, fabricate, assembly, curing), "Shipment", "Installation", and "Delivery". The sub-process from "Design Approval" to "Shipment" is solely within the maker's process which remains a black-box for the construction site. However, this sub-process is one of primary sources of cost increase. The Glue Logic system monitors and supervises the sub-process by checking the gates, even though parts are not yet formed. In another word, the gates are virtual entity that sends message about not-yet-formed conceptual parts, when they pass the gates.

Once parts are manufactured, chip-implanted parts are shipped to a construction site, assembled, and installed on site. As parts are dislocated in space and time, and/or reconfigured as integral part of a building under construction, simple act of reading the product URL on chip triggers to change the attributes of these parts in the data management sub-system of the Glue Logic. Once the parts' attributes are changed, that triggers to send message to the pre-assigned addresses if a simple logic attached to the data point is satisfied. Each data point therefore contains attribute, simple logic, and address. Millions of data points are passing information each other. This very bulk of acts of passing and receiving dynamically change the state of the whole data base. Hence the data base behaves like an autonomous giant controller.

5.2 Construction Management via RFID

<Parts Management>

Figure 5 shows one type of chip made by Hitachi, called μ-chip. Its size is quite tiny of a micron. Attached to it is electromagnetic induction coil or antenna. When a chip-implanted part passes through a gate, the gate reads the Product URL of the part. It determines what it is, where it is, when it is as well as in what state it is. The corresponding data point in the Glue Logic is then altered, which generates an event and a chain of succeeding actions.

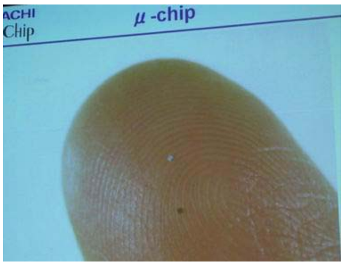

Figure 5. Hitachi μ -chip of a micron

It is expected that the size will soon be reduced down to nano dimension, given the recent quick development of Nano Technology.

<PDA Reader>

The construction workers carry a PDA which is capable of read/ write on a chip attached to parts (Fig.6). They can retrieve handling manuals, drawings, installation sequence, and other relevant information about parts, when needed. This handy digital equipment allows even an unskilled worker to perform a quality work. Upon completion of installation, workers dispatch a message of completion to the Glue Logic. This allows concurrent management of completion of works. Moreover, if a worker read the chip both at the commencement and completion of work, the exact work period is automatically calculated and recorded in log. This simple mechanism leads to a vast consequence such that we automatically obtain a work period of every construction work, and the resultant data enables a scientific approach to construction work.

Figure 6. PDA Reader

<Assignment and Inspection>

The required points of contact are attached to each data point in the Glue Logic Controller. As the state of a building part within the data sub-system of the Glue Logic is altered at each stage of construction process, the point of contacts are altered as well. In this way, it seems as if every building part were of autonomy to choose then-appropriate addresses and send signals to them to which its assignment is informed, as it passes through consecutive construction stages.

These assignments are sent to parts makers, telling when building parts are needed, how many of them must be delivered, at where they are installed. These autonomous assignments reduce excess inventory for the makers, and superfluous temporary storage on site.

Upon completion of installation of parts, acceptance inspection is conducted. A worker carries a PDF reader on whose screen page a standardized checklist pops up when it reads the Product URL from the chip. The inspection result is remotely informed to the maker via the Glue Logic Controller. This un-necessitates inspectors from the maker to come to the site.

<Scheduling Management>

Construction scheduling is an integral complex whole of sub-schedules for contractors, sub-contractors, and makers [5][6].A master schedule is made for on-site schedule as a global schedule.

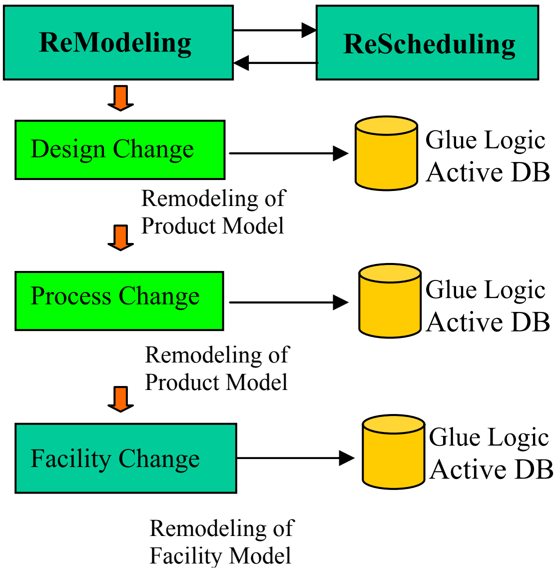

Figure 7. Rescheduling and Remodeling

Source of change in scheduling exists everywhere among the multiplex of schedules, lying layers upon layers. Dynamic scheduling becomes possible in the Glue Logic architecture, for the component schedulers are considered independent objects of time management which send messages of requirements of schedule change to each other and respond to the others' requirements.

However, it is not always possible to satisfy all the requirements of schedule change, because of possible conflict among these requirements [7]. Unsolvable conflicts may demand remodeling of product, process, or facility (Fig.7). Switch to remodeling from rescheduling is automatically done by the Glue Logic controller.

<Automated Handling of Components>

Figure 8 shows a relation between construction robots, construction components, and their information. A robot can acquire information about the required task and about the component via RFID attached to the component. Then it accomplishes the task in compliance with the retrieved information: First, the robot acquires an ID from RFID device attached to the component. The robot sends the acquired ID and the required task to the operation server, while achieving the task. The operation server creates required information for achieving the next task using the ID and sends the resultant information to the robot. Meanwhile, the operation server updates the component data according to the task results. The communication between the robots and the server is a LAN network or the Internet.

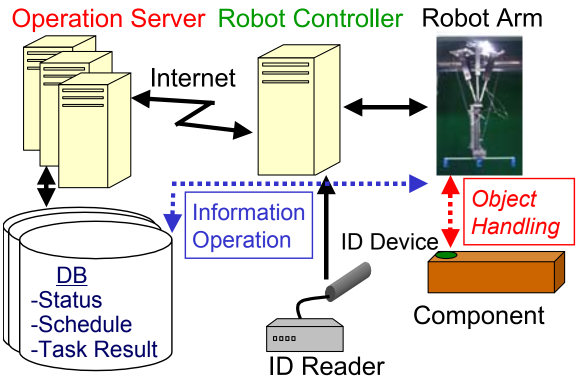

Figure 8. Relation between components and their information under the parts and packets unification

As shown at Fig.9, the robot obtains the ID from RFID device attached to the component if the ID device is within the communication area of the ID reader.

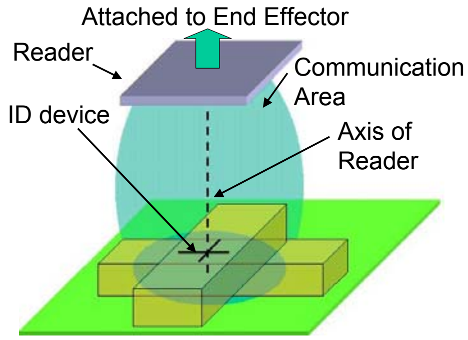

Figure 9. Communication area of ID reader

6. CONCLUSIONS

Robotics Construction in this century may be transformed into more subtle form. The whole construction process is regarded as virtual "Robotics" which is controlled by a giant controller. Parts and packets are unified. The components to be controlled have both information and physical aspects within their integrity. The controller is a transmuted "OS" (operating system), which operates both packets and parts.

Acknowledgement

This work is supported by IMS International Program IF7-II.

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