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BIONIC ASSEMBLY SYSTEM CLOUD: FUNCTIONS, INFORMATION FLOW AND BEHAVIOR

Katalinic, B.; Kukushkin, I. & Haskovic, D.

Abstract: *This paper is focused on further implementation of cloud communication into a control structure concept of Bionic Assembly System (BAS). It presents internal structure of cloud and the information flow between the cloud and active BAS shop floor elements. Investigations are limited on normal working mode. In the comparison to the classical control structures this solution promises improvement of system performances and increase of system robustness. Developed algorithm based on the selection of the best operation for the next assembly step allows real time sequence planning considering system states.*
Key words: Bionic Assembly System; Cloud Communication; scheduling control; interface; Information Flow.

1. INTRODUCTION

Information Technology (IT) is one of the fastest developing fields of technology. IT concepts, solutions and philosophy are disseminating in all fields of science, technology and daily life [1]. The result of this dissemination is an improvement of all affected fields and the development of a new generation of products and systems. All fields of automation are benefiting from this progress. Cloud Computing is one of emerging IT Concepts [2]. This concept can be used for further improvement of internal communication within self-organizing systems.

Intelligent Manufacturing Systems group from Vienna University of Technology makes continuous research and development of a concept of self-organizing system - BAS. The description of BAS working scenarios and strategies is shown in [3], possible reconfigurations within the system in [4]. Current research of IMS group focuses an implementation of cloud communication to BAS control structure [5], [6]. This paper highlights following research results:

- BAS cloud functions
- Information exchange between a cloud and BAS elements
- Cloud Behavior in a BAS normal working scenario

2. BAS CLOUD FUNCTIONS

BAS Cloud is a part of BAS hybrid control structure, as shown in Fig. 1. It is an informational interface between subordinating and self-organizing subsystems. Cloud has the following functions:

1) Connection of self-organizing and sub-ordinating parts.

Exchange of information between a cloud and subsystems goes through communication channels. In this article flow of information from shop-floor scheduling control unit to the cloud is defined as vertical upload and in the opposite way vertical download. Flow of information from self-organizing sub-system components to the cloud is defined as horizontal upload and in the opposite way horizontal download.

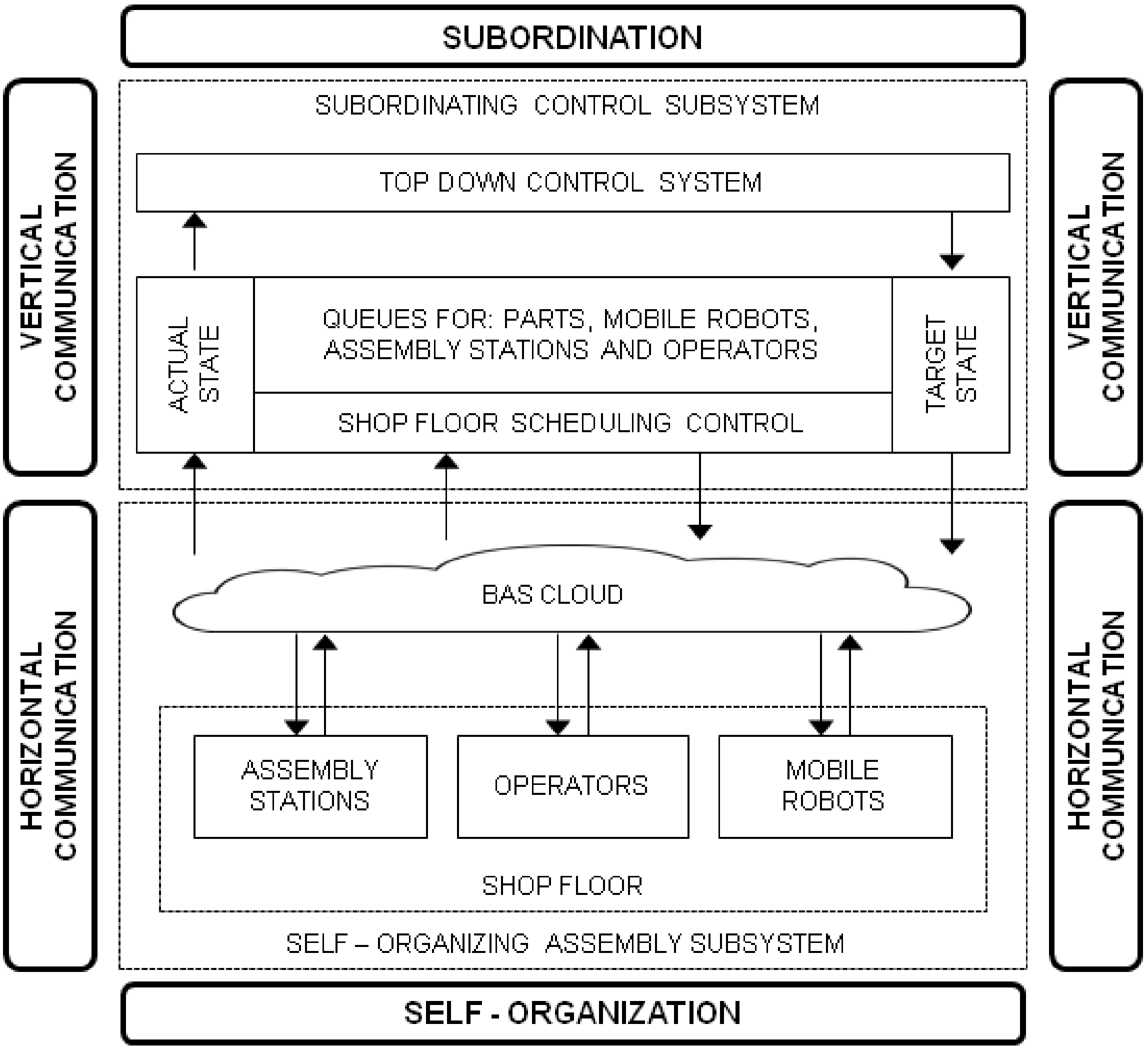

Fig. 1. Cloud-based Hybrid Control Structure of BAS

2) Internal horizontal communication organization.

Cloud has a two way communication with the shop floor elements: assembly stations, operators and mobile robots (Fig. 1.). Introduction of a cloud changes the “everyone to everyone” communication to a direct “element - cloud” interactions.

3) Memory storage.

Cloud is a passive storage element. It only stores the data, which comes from other active elements and doesn't react on system changes. It contains technological, control and system state data.

2. BAS "NORMAL" WORKING SCENARIO

This paper is limited on investigation of BAS normal working scenario. It means execution of uninterrupted sequence of assembly orders. System start-ups, shut-downs and interruptions are not considered.

A sequence of system orders is formed by sub-ordinated subsystem according to the logic of working cycles [6]. As a result of this process queues of orders for mobile robots, assembly stations, transport system and operators come to the target state module of the shop floor scheduling control unit. An order for mobile robot is

called robot assembly order (RAO). Each of these orders has a unique order ID, which consists of two parts.
The first part indicates an order number according to the logic of working cycles [6] *(l-th example of k-th Run of h-th product type with j-th priority of i-th system order)*. The second part contains timestamp (YYMMDDHHMMSS). Shop Floor Scheduling Control vertically uploads robot assembly orders to a cloud according to the first-in-first-out principle. For each RAO data file is created, as shown in Table. 1.
This file contains RAO ID and Product Type.
According to this data, pallet type and number of assembly steps for this product are uploaded from the Product Technological Data File. After this, RAO is ready to be processed.

Robot Assembly Order Data				
Timestamp	**Data**	**Value**		
YYMMDDHHMMSS	AO ID	lkhji-YYMMDDHHMMSS		
YYMMDDHHMMSS	Product Type	Catalog number		
YYMMDDHHMMSS	Pallet Type	Catalog number		
YYMMDDHHMMSS	Number of assembly steps(NAS)	According to technological data		
YYMMDDHHMMSS	Robot ID	Catalog number		
YYMMDDHHMMSS	Pallet ID	Catalog number (Type-ID)		
YYMMDDHHMMSS	Pallet Quality State	Positive / Negative		
YYMMDDHHMMSS	Product Quality State	Positive / Negative		
Assembly sequence				
Timestamp	**Step (1...NAS)**	**Station ID**	**Operation**	**Status**
YYMMDDHHMMSS	1	AS ID	OP ID	Waiting / In Transport - Comes from a robot
YYMMDDHHMMSS	2	AS ID	OP ID	Completed / In Process / Failed / Repair - Comes from assembly station
YYMMDDHHMMSS	...	...	...	
YYMMDDHHMMSS	NAS	AS ID	OP ID	

Table. 1. Cloud-stored Robot Assembly Order Data File

Mobile robots are located in pool of robots. There are three possible robot states:

- Switched-off - robot is not participating in assembly operations before it is switched on by shop floor scheduling control unit.
- Stand-by - robot is participating in assembly operations, but has no active RAO.
- Active - robot has active RAO.

A number of stand-by robots in a system are regulated by shop floor scheduling control unit.
A robot working algorithm is shown in Fig. 3. It consists of 5 sections. These sections describe following functions of mobile robot:

1. Search of RAO
2. Reservation and preparation of RAO
3. Assembly sequence loop
4. "Best operation" search loop
5. Post-assembly actions

Section 1. All Stand-by robots check if there are any available orders on the cloud. If there is an order waiting, it proceeds to section 2. If not, it repeats the procedure.

Section 2. When an order is found, robot reserves it by horizontally uploading its own ID number into the cloud. This data comes to Robot ID field of the RAO data file (Table 1).
From this file robot downloads the required pallet type and number of assembly steps. After that it goes to the pool of pallets and gets a pallet of the specified type. Each pallet has an information tag, containing ID and quality state of Pallet. When the palette is loaded on the robot, the tag gets scanned. Robot gets Pallet ID and quality state information from this tag and uploads it to the cloud. This data comes to Pallet ID and Pallet Quality State fields of the RAO data file (Fig. 2). After this section the robot is ready to start the assembly sequence according to the AO data.

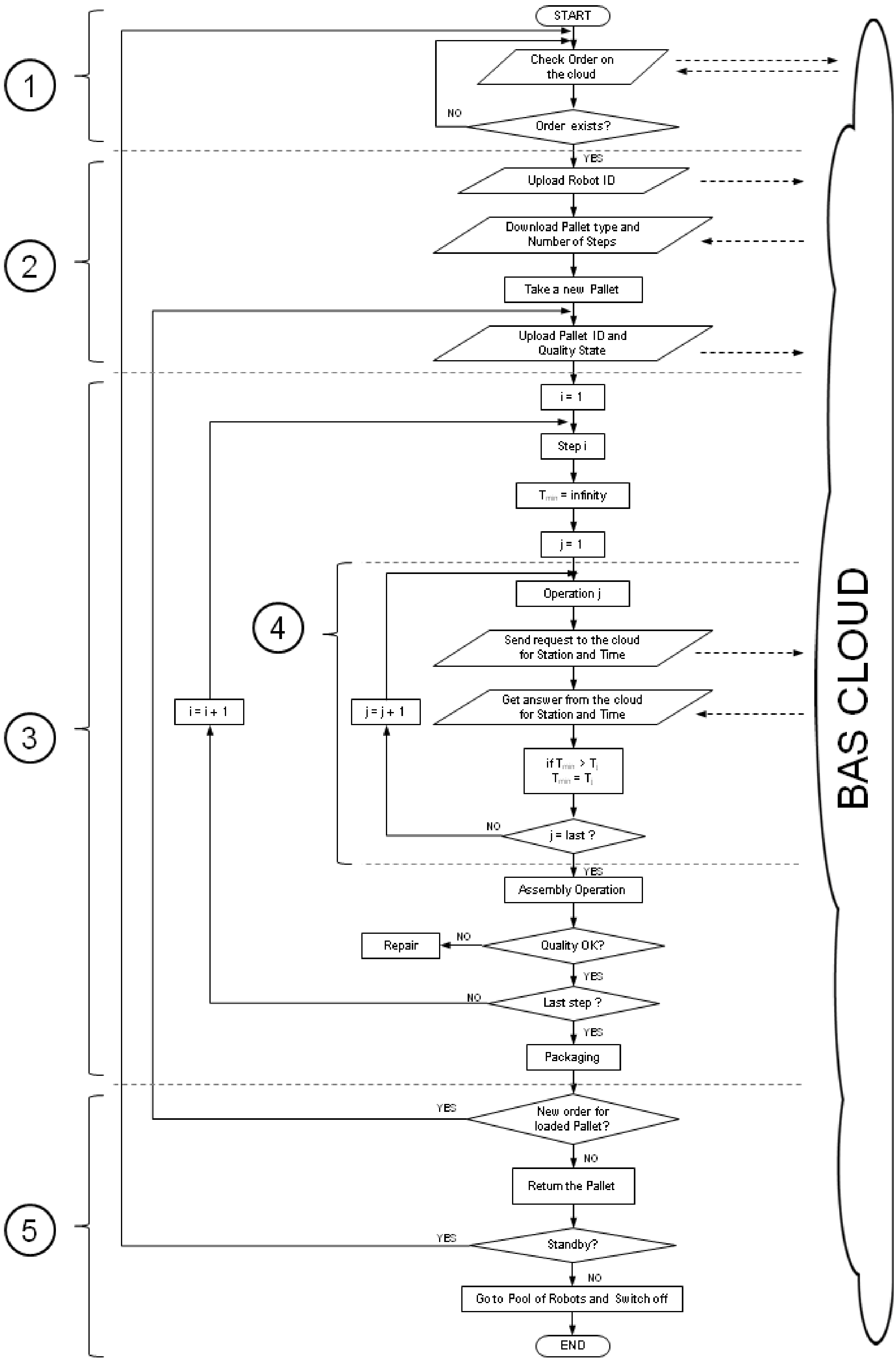

Fig. 2. Mobile robot working algorithm

Section 3. To assemble one product robot has to make a number of assembly operations. Some of these operations depend on an assembly state of the product, some could be done only in strict order. This number of assembly operations is called assembly sequence. To complete an assembly sequence, robot has to make a fixed number of assembly steps (NAS), one operation per step. NAS is stored in RAO Data File in the cloud. Efficiency of assembly system depends directly on ability to choose an assembly sequence based on the best operation for the next assembly step. A process of the search of assembly operation is described in Section 4. When assembly station for the next assembly step is chosen, robot horizontally uploads station and operation ID to the corresponding assembly step field in RAO Data File. During an assembly sequence the RAO could have six states:

1. *In Transport* - when assembly pallet is transported by robot to a chosen assembly station.
2. *Waiting* - robot waits an assembly operation in a queue in front of chosen assembly station.
3. *In Process* - Assembly pallet is on a station for an assembly operation
4. *Completed* - Assembly operation succesfully completed, quality states of product and pallet are positive
5. *Failed* - Assembly operation is not succesfully completed or quality states of product / pallet is negative. Robot has to drive this pallet to a repair station.
6. *Repair* - Pallet is on a pallet station, waiting for an operator.

The last operation of an assembly sequence is packaging. Robot drives to a packing station and leaves a product on it. When assembly sequence is completed, robot starts post-assembly actions (Section 5).

Section 4. For each assembly step robot has to find the best station from available ones.

Availability of an assembly operation depends on two factors: physical presence of the station for this operation and technological possibility to make this operation on this stage of assembly. A number of previously completed operations, required for the processing of the next one are called preconditions set. This set is available for each operation and stored in technological data file of each product.

For each of assembly operations robot checks its availability by comparing preconditions set with an own list of completed operations. If all preconditions are satisfied and this operation was not completed yet, robot requires station numbers and operation times suitable for this assembly operation. A process of the best station search is based on the smallest time resistance criteria. That means that from all suitable stations robot would choose the one with the smallest assembly time (*Tas*). This time sums from the transport time, waiting time and operation time.

Before the "Best operation" search loop *Tasmin* is set to infinity. On each iteration of a loop, if operation time of a chosen station is smaller than *Tasmin*, the current value of *Tasmin* would be replaced with *Tas*. After the loop robot gets a number of the required station.

Section 5. Robot gets an empty pallet from the packing station and checks if there is any available order for this pallet type on a cloud. If yes, robot reserves it by horizontally uploading its own ID number to the cloud. Then it horizontally uploads Pallet ID and Pallet Quality State fields of the RAO data file.

If there are no available orders for this pallet, robot brings the pallet back to the pool of pallets. After that it gets a new state from the shop floor scheduling control unit. If it stays Standby, it goes to Section 1. If it gets Switched-off state, it drives to the pool of robots and shuts-down automatically.

CONCLUSION

Introduction of cloud communication opens new possibilities for further improvement of internal communication within self-organizing systems.
Implementation of cloud communication into the control structure of Bionic Assembly System (BAS) concept brings a number of advantages. In the comparison to the classical control structures this solution promises improvement of system performances and increase of system robustness.
Introduction of a cloud helps to organize horizontal communication on BAS Shop-Floor in a direct and simple way. It changes the “everyone to everyone” communication to a direct “element - cloud” interactions.
Developed algorithm based on the selection of the best operation for the next assembly step allows real time sequence planning considering system states.
Research is limited to a normal working mode of assembly. Future research will cover communication of other elements of self-organizing sub-system, as well as analysis of cloud behaviour in system start-ups, shut-downs and working scenarios including interruptions.

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AUTHORS’ ADDITIONAL DATA

All Authors are coming from: Vienna University of Technology, IFT-IMS Group, Karlsplatz 13/311, 1040 Wien, Austria, Europe.
Professor Dr. sc. Dr. mult. h.c. Bra nko Katalinic, President of DAAAM International, president@daaam.com, branko.katalinic@tuwien.ac.at
Dipl.-Ing. Ilya Kukushkin, PhD Student, Senior Assistant of DAAAM International, kukushkin@ift.at
Mag. ing. mech. Damir Haskovic, PhD Student, General Secretary of DAAAM International, damir.haskovic@ift.at

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