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Cloud Communication Concept for Bionic Assembly System

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Abstract

This paper deals with implementation of cloud communication in a hybrid control structure of Bionic Assembly System (BAS). BAS Cloud is a communication interface between subordinating and self organizing subsystems. This concept brings a number of advantages, such as increasing flexibility of interaction between subsystems from the point of view of time and workload, simpler and standardized interface and communication channels between cloud and production facilities, independent storage for complete data records about actual and past system states, independent and constantly updated time measurement system.

Keywords: Bionic Assembly System; Cloud communication; self-organization; scheduling; control structure.

1. Introduction

Globalization brings big changes to the manufacturing industry. One example of this is a change from a high-volume to a customized production strategy. This requires higher production costs [1] and increases the complexity of the control system [2-4].

To answer this requirements Intelligent Manufacturing Systems group from Vienna University of Technology makes constant research and development of a concept of Bionic Assembly System (BAS), which is based on a self-organization - phenomena used in nature. The description of working scenarios and strategies of the system is shown in [5], possible reconfigurations within the system in [6]. A hybrid control structure of BAS is shown in Fig. 1. It combines two basic control structures and principles: centralized control system, based on hierarchy and self-organizing control system, based on heterarchy [5].

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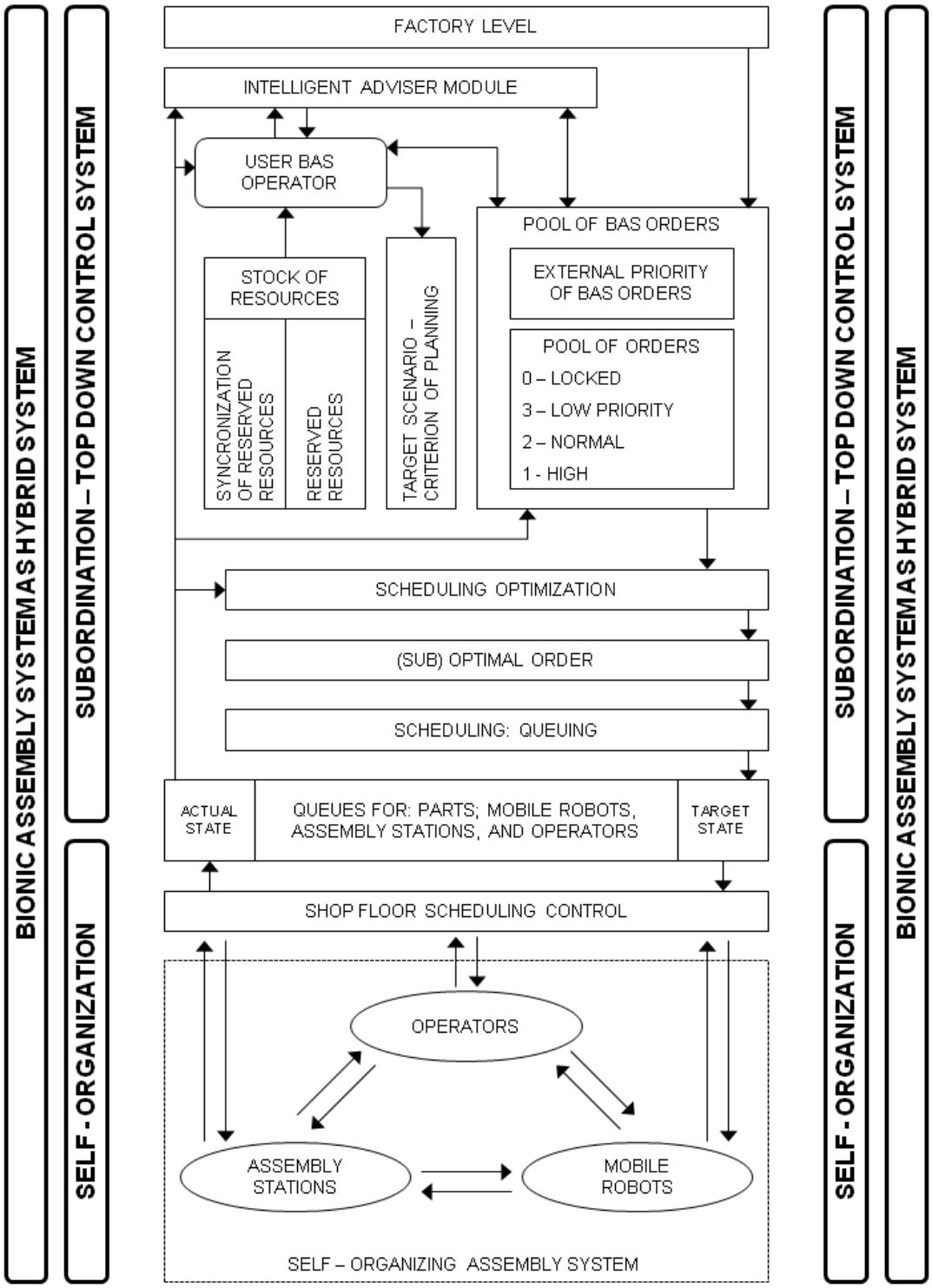

Fig. 1. Hybrid Control Structure of Bionic Assembly System (BAS) [5]

System analysis and simulation of BAS working scenarios [7] show following system characteristics:

- Strong interaction between subordinating and self-organizing subsystems
- Shop floor facilities cannot function without permanent and active role of the control system
- Log data is not independent
- Data accessibility is limited on working time of the control system
- Communication between active components follows the concept "Everyone-to-Everyone"
- Communication has no standardized protocol
- If only one element is active, it communicates with nobody. If there are only independent irrelevant active elements, system cannot function. They can communicate, but cannot make progress in production.
- Start of production strongly depends on the shut down sequence (switching off order of the machines). Special problem is when a new start is made by machines, which were not used during the last work period.

Progress in the field of IT has a positive influence on the abilities of computer-based control systems. Cloud Computing is a nice example of this progress. It is a new concept with high potential. This potential could be applied in many different fields. Applications in IT environment are shown in [3]. Google Docs, Dropbox, Skydrive [4], [5], [6], and [7] are examples of cloud computing in home and office usage.

Current research of IMS group is focused on implementation of cloud communication concept to the hybrid control structure of BAS. Preliminary results of this research are presented in this paper.

2. Cloud Communication in BAS

BAS Cloud is introduced between subordinating and self-organizing subsystems as shown in Fig. 2. Functionally it is an informational interface between two subsystems. Exchange of information between a cloud and subsystems goes through communication channels. In this paper, flow of information from any component to the cloud is called upload and in the opposite way download. Cloud has a two way communication with the shop floor scheduling control, one way communication (upload) with the target state module and one way communication (download) with the actual state module.

Examples of data going through the upload channel from the target state module are: orders for mobile robots, orders for assembly stations, orders for operators and orders for transport system.

Examples of data going through the download channel to the actual state module are: states of mobile robots, states of assembly stations, states of operators and states of transport system.

From the other side, following shop floor components have a two way communication with the cloud: assembly stations, mobile robots and operators.

- **Assembly stations** are machines which can complete one or more assembly operations on one or more different products. There can be more alternative assembly stations with different assembly times for the same assembly operation. Also assembly stations are suitable for one or more types of mobile robots. Examples of data going through the upload channel from assembly stations are: station ID, assembly station capabilities (robot, product, operation) and current state (idle, in progress (operation ID/ time to finish), error), product quality state, current order ID, etc. Example of data going through the download channel to assembly stations is the next order ID. This data helps the assembly station to prepare for the next assembly operation.
- **Mobile robots** are responsible for transporting assembly pallets through the assembly system. Each mobile robot gets an assembly order. It means to assemble one piece of one product. During the assembling procedure mobile robot can have alternative ways. It is possible, that one assembly operation can be completed by different assembly stations or workers. During the selection of the most suitable station for the next assembly operation robot follows the criteria of "the shortest completing time" of the next assembly operation. Examples of data going through the upload channel from mobile robots are: mobile robot ID, current order ID,

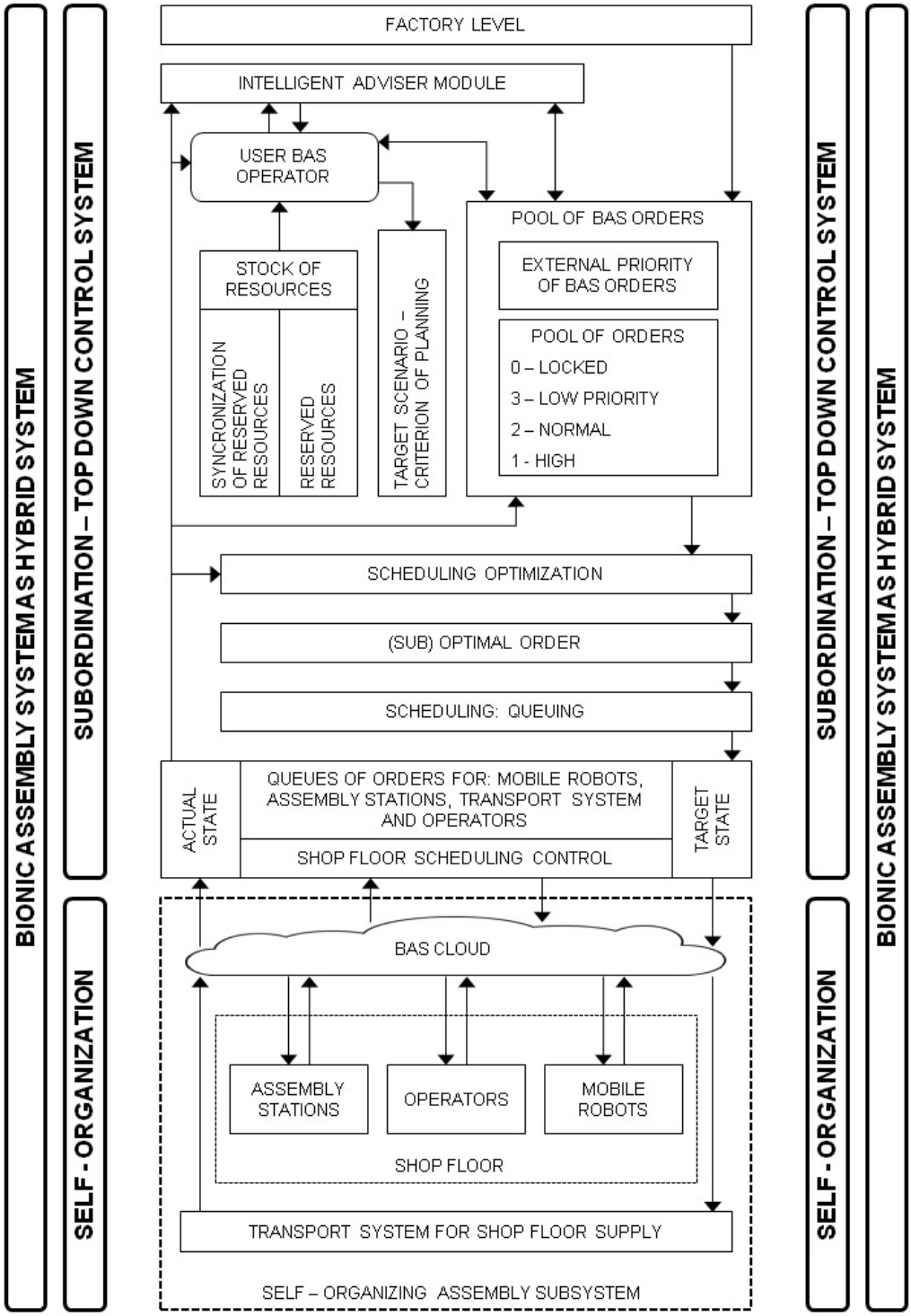

Fig. 2. Cloud-based Hybrid Control Structure of BAS

current assembly step, current station, own shop floor position, current state (idle, moving, in a queue, assembly operation, quality error, error, battery level), etc. Examples of data going through the download channel to mobile robots are: next order ID, list of available stations, waiting time in front of the stations, etc.

- **Operators** are responsible for assembly stations set ups, ensuring and supporting the material flow in the system and correction of interruptions during production. They get the orders through the download channel and send the results of the work through the upload channel.

Cloud communication opens a new possibility to include a transport system for shop floor supply with parts and other means into the self organizing subsystem. Supply orders come through the download channel. After the completion of the orders, the results are sent to the cloud through the upload channel.

3. Working scenario

System orders are coming from a high level of the top - down control system of a factory. A process of assembly orders forming and logic of BAS working cycles is described in [5]. 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. From this module the orders are going to the corresponding component of the self organizing subsystem. After the completion of orders a feedback from self organizing assembly subsystem components comes to the actual state module. Shop floor control unit is responsible to feed the orders to the components in the right way: one order in time for one component.

This orders come to the BAS cloud through the upload channel. Shop Floor Scheduling Control starts to generate pallets and tags for assembly orders. Tag includes information about assembly order, number of assembly steps and ID of operation required for each step. Operator receives this information and prepares the pallet accordingly. When a pallet is prepared, operator uploads the Pallet ID and Status: New to the cloud.

If there are suitable mobile robots without a pallet in the system, they send a status update to the cloud and drive to a pool of pallets. If all robots are busy, the first suitable one who is finished gets this assembly pallet.

When the robot gets a pallet, it sends the following data to the cloud through the upload channel: mobile robot ID, current order ID, current assembly step, current station and own position (X,Y). After that the mobile robot gets the following data from the cloud through the download channel: list of available stations and waiting time in front of the stations. A list of available stations would be sorted according to the robot ID, product ID and current assembly operation. Waiting Time in front of the stations is calculated according to (1)

$$T_w = \sum_{i=1}^{n} N_i^{Rt} * T_{op} \quad (1)$$

T_w - waiting time is calculated as a sum of times of assembly operation (T_{op}) multiplied with N_i^{Rt} - number of robots of type *i*, where *i* is changed from the first till the last robot type.

After all information from the cloud is received, the robot calculates the best decision with an algorithm described in [7]. When the decision is made, robot sends his updated Next station and Current state (moving) to the cloud and starts moving. While moving, robot reads the QR-codes grid on the floor and sends his position to the cloud. This helps to track the robot constantly on the shop floor.

When the robot arrives to a station, it updates his Current Station field in the cloud. Then it waits in a queue, docs with the station and waits for the finish of the assembly operation. When the assembly operation is finished, assembly station updates the Product Quality State to a positive or negative, brings an assembly pallet back to the robot, reads Next Order ID from the cloud and prepares for the next assembly operation.

Mobile robot gets a pallet and checks the Product Quality State. If it is negative, robot updates Next Station field to Repair Station and drives to it. If Product Quality State is positive it updates the Current Assembly Step and repeats the assembly procedure. When a product is assembled, robot updates the Current Assembly Step to Packaging and brings a pallet to the packing station. As a last step it brings an empty pallet to the Pool of Pallets and gets a new one. If there are no pallets available, it drives to the pool of robots and hibernates.

4. System Start and Finish

Log data and history of production and states of BAS elements is very important for system functionality. BAS Cloud allows organizing this procedure in the following way.

Architecture of BAS Cloud includes an internal clock, which is used as a central clock in BAS. Every second BAS Cloud writes an integer number to its time cell in a special format (YYYY-MM-DD-HH-MM-SS). This timestamp is added, when any data in the cloud is changed. All the system states are stored in the cloud and at the beginning of a shift all the elements take the current system state from there. Cloud connects real shop-floor elements with the top-down control system, which performs virtual planning and gives target states. This opens an opportunity for real time re-planning and control of the whole production in all its phases. This feature is unique and absent in traditional assembly systems.

When a new element is introduced into the system, it will be included to the cloud automatically with its own ID number and a timestamp. After that, all the relevant system elements receive the information that a new BAS element (station, robot, operator) is introduced to the system. Removal of an element or switching off the system follows a similar scenario. Time and state of an element is saved to the cloud, and then an element hibernates.

5. Conclusion

Implementation of cloud communication in a hybrid control structure of BAS is a logical result of the further development of flexible assembly systems. BAS Cloud is a communication interface between centralized control system based on the hierarchy and self-organizing control system based on the heterarchy. This concept brings a number of advantages, such as:

- Increased flexibility of interaction between subsystems from the point of view of time and workload
- Simple and standardized interface and communication channels between cloud and production facilities
- Possibility to include a transport system for shop floor supply into the self organizing subsystem
- Independent storage for complete data records about actual and past system states
- Independent and constantly updated time measurement system
- Fast and simple system set-up and shut-down

The future research will be focused on assigning functions, organization and responsibilities between BAS cloud, subordinating and self organizing subsystems. This would be realized through analysis and simulation of BAS working scenarios and algorithms.

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