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Control structure and scheduling of a hybrid assembly system

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Abstract. This paper describes a hybrid control structure, working scenarios and logic of working cycles during the assembly of an unlimited sequence of assembly orders in a bionic assembly system (BAS). Focus is given on the realization of the communication between subsystems, different modes of the assembly process and scheduling strategies and basic tasks of mobile robots during assembly. BAS is a new concept in advanced assembling systems, which combines two basic control structures and principles: a centralized control system, based on the hierarchy, and a self-organizing control system, based on the heterarchy.

Key words: hybrid control structure, scheduling, bionic assembly system, self-organization, assembling.

1. INTRODUCTION

Actual design results of continuous research, focused on the development and implementation of the next generation of assembling systems, will be presented. The next generation of assembling systems is of hybrid type, which combines two basic control structures and principles: a centralized control system, based on the hierarchy, and a self-organizing control system, based on the heterarchy.

The first concept is well-known and it is the most used control concept in the industry till now. The other one is present in the nature, but almost not used in the industry [1,2].

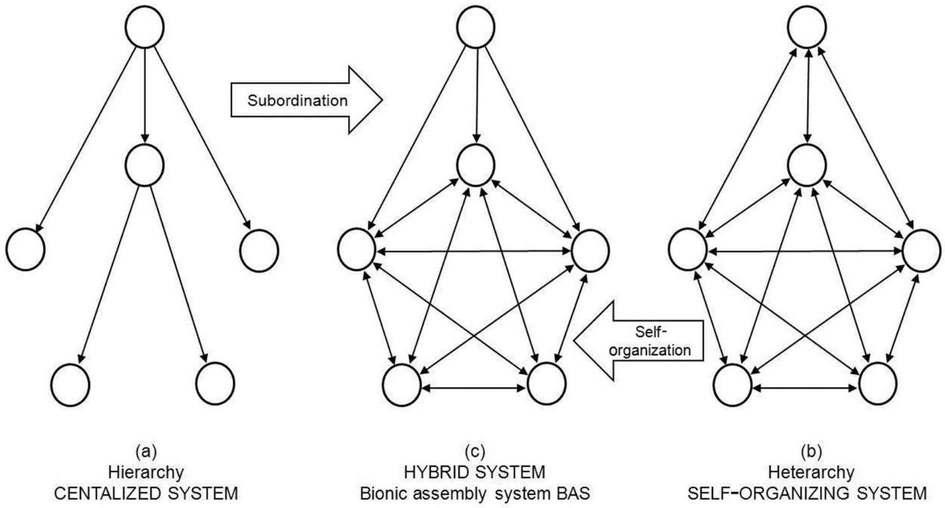

Fig. 1. Basic control structures: hierarchy, heterarchy and hybrid.

There are many definitions of self-organization [3–5]. As told in [6]: "*The self-organization is one of the main patterns of the organization of material, energy and information in the nature. It is present in inanimate and biological systems. The self-organization phenomena is present in the whole range of systems, of the size from less than an atom till the whole universe. Self-organization is a very complex phenomenon with many different phases. At the time being no unique definition of self-organization is existing. However, there are many definitions, which describe particular characteristics, affects and forms of self-organization.*"

Combination of those two concepts leads to the hybrid system (Fig. 1). This system is known as the bionic assembly system (BAS). The structure, functions and characteristics of this system are described in [6–8].

2. PLANNING

The main aim of planning a BAS is to achieve the highest possible productivity of the BAS during the assembly of an unlimited sequence of orders. Maximal productivity means maximal number of assembled products during one particular period of time, taking into consideration the external priority of BAS orders, system's bottle-necks, limitations in the number of production facilities, and the limited capacity of each essential production unit.

It is possible to achieve the above-mentioned aim only by carrying out all activities, which are placed on the critical path, in as short a time as possible. The work of assembly stations, mobile robots and operators has to be simultaneous and synchronized, based on the chosen BAS working scenario.

The interface between the factory planning system and BAS is a pool of BAS orders as shown in Fig. 2. Each BAS order has an external priority as a measure of order urgency. Normal urgency has priority 2, urgent order has priority 1 and low priority order is 3. Locked orders have priority 0.

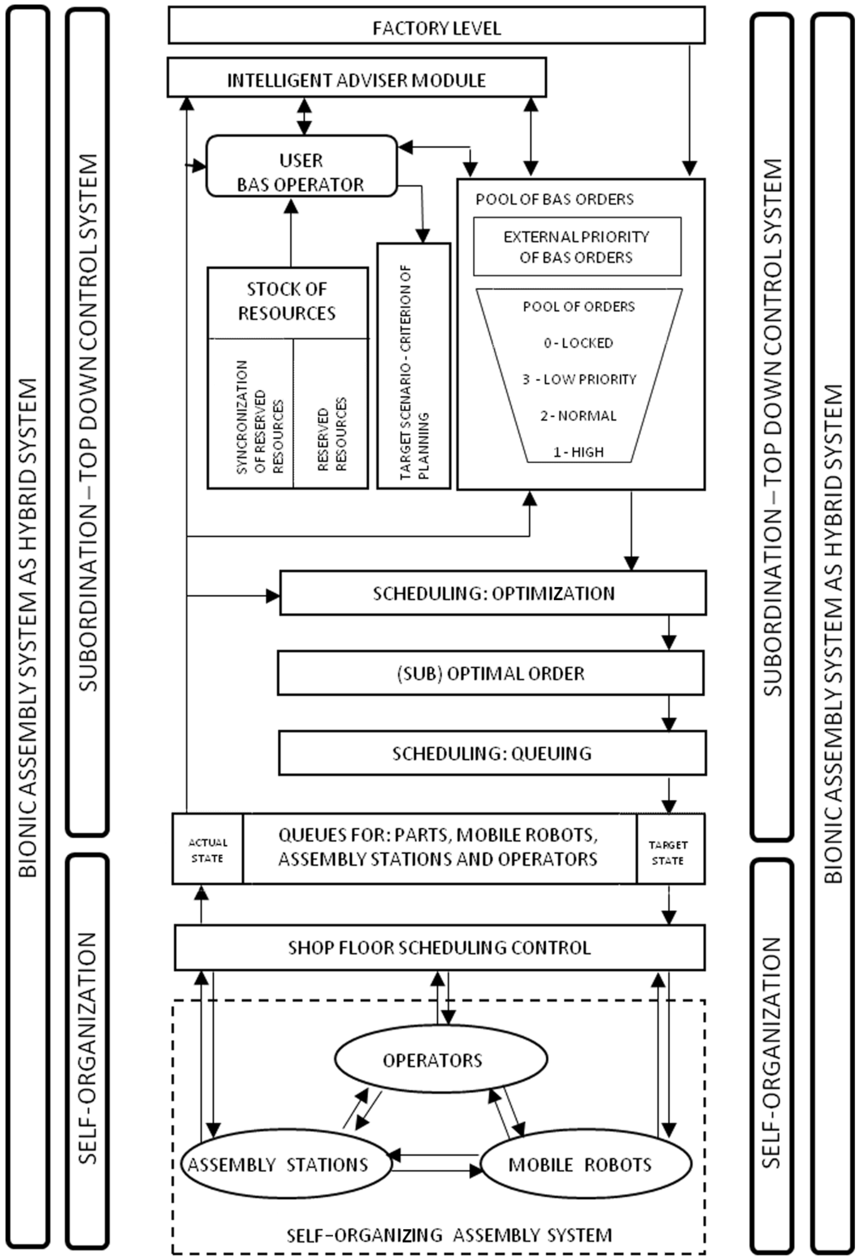

Fig. 2. Hybrid control structure of the bionic assembly system.

The scheduling optimization module has to find out the most suitable BAS order from the pool of BAS orders, taking into account the target scenario, criterion of planning, actual state of BAS and free and reserved resources of the system during the time planned.

The result of optimization is (sub)optimal order. This order will be built in virtual scenario of BAS in the case of simulation or in working scenario of BAS in the case of scheduling planning. The results obtained from scheduling planning give data, which build the queues. The queues determine the order and sequence of pieces, in which different products will be assembled.

3. COMMUNICATION

Each single assembly module or assembly station has two communication channels, one vertical to BAS central computer and the other horizontal to the mobile robots. Main tasks of the central computer of BAS are to plan the global production of BAS, synchronize the part supply and setups, bring the demands from factory level, and organize the BAS as an integral part of the factory. The horizontal communication between the assembly station and the mobile robot with the assembly pallet, which carry one particular product from one assembly station to the other in the search for the assembly station, which can complete the next assembly operation, is the kernel part of the self-organizing system.

The assembly pallets are transported through the assembly system by lineless mobile robots. After each assembly operation, the assembly station makes the quality check to find out whether the assembly operation was completed successfully; if yes then the assembly station gives this information to the mobile robot, which carries the product on the assembly pallet during the assembly process. This information has key role in the search for the station that can carry out the next assembly operation on the product.

The horizontal communication between the control system of an assembly unit and the mobile robot includes following information: pallets type, pallets status, product type, assembly stage of the product (which is the next assembly operation on that product), quality status of the product – was the last assembly operation completed successfully or not. If the last assembly operation was not successful, the quality status of the product will be negative, and all assembly units will tell that they are not responsible for the next operation. For such cases a special repairing station is organized in the system. At this place the robots/pallets are waiting for the shop operator, who will try to correct the part. If he cannot correct the mistake, he will move the product from the pallet and reset the pallet and send it to the system as a new pallet, being free to take the first part of next product. After the product has successfully completed all assembly operations and tests, it will be removed from the pallet and packed for transport. The robot/pallet will be reset and sent as the free robot/pallet back to the system.

4. DIFFERENT MODES OF THE ASSEMBLY PROCESS

4.1. Normal working mode

Each mobile robot gets an assembly order. It means to assemble one part of the product followed by next steps of the assembling plan to complete the order. Robot communicates with all assembly stations to find out, which station is able to complete the next assembly operation. If there are more candidate stations, it selects station with the shortest completing time of the operations [9].

It is very typical for assembly stations that there robots are waiting in the queue in front of the station:

$$ {}^{O_i}_{P_m}S_1:\ \blacksquare\ {}^{O_i}_{P_m}R_1\ \blacksquare\ {}^{O_i}_{P_m}R_2 \ldots \blacksquare\ {}^{O_i}_{P_m}R_{last} \tag{1} $$

In front of the station S_1 for operation O_i on the product P_m are waiting robots for the operation O_i for assembling the product P_m.

There are 3 priorities of orders (1 – high, 2 – normal, 3 – low). Typical situation in front of the station is shown in Fig. 2 and can be described as

$$ {}^{O_i,O_j,O_k}_{P_m,P_n,P_l}S_1:\ \blacksquare\ {}^{O_i}_{P_m}R_1^1\ \blacksquare\ {}^{O_i}_{P_m}R_2^1 \ldots\ \blacksquare\ {}^{O_i}_{P_m}R_{Last}^1\ \blacksquare\ {}^{O_j}_{P_n}R_1^2\ \blacksquare\ {}^{O_j}_{P_n}R_2^2 \ldots $$

$$ \ldots\ \blacksquare\ {}^{O_j}_{P_n}R_{Last}^2\ \blacksquare\ {}^{O_k}_{P_l}R_1^3\ \blacksquare\ {}^{O_k}_{P_l}R_2^3 \ldots \blacksquare\ {}^{O_k}_{P_l}R_{Last}^3 \tag{2} $$

In station S it is possible to make the ith operation on the mth product, jth operation on the nth product and the kth operation on the lth product. The queues of the robots in front of the station with respect of the priorities are formed in following sequence. In front of the station S_1 for ith operation on the mth product, jth operation on the nth product and kth operation on the lth product, are waiting robots for the ith operation for assembling the mth product, with the first priority, numbered from one till the last. Then follow robots for the jth operation for assembling the nth product, with the second priority, numbered from one till the last. The last in the queue are robots for the kth operation for assembling the nth product, with the third priority numbered from one till the last.

The shortest completing time of operation is the sum of waiting time in the queue in front of the station and assembling time at the station. All the robots in the system are following the trajectory, based on the criteria of the "smallest time resistance" for next assembly operation. For the operation, which can be completed at several assembly stations, it is necessary to solve the problem of changing the numbers of working stations.

4.2. Working mode after introduction of new alternative station

By introducing new stations, it is necessary to rearrange the queue of the robots, waiting in front of the other station:

$$
\begin{aligned}
{}^{O_i,O_j,O_k}_{P_m,P_n,P_l}S_1 &: \blacksquare\, {}^{O_i}_{P_m}R^1_1 \,\blacksquare\, {}^{O_i}_{P_m}R^1_2 \ldots \,\blacksquare\, {}^{O_i}_{P_m}R^1_{middle} \ldots \blacksquare\, {}^{O_i}_{P_m}R^1_{last} \\
&\blacksquare\, {}^{O_j}_{P_n}R^2_1 \,\blacksquare\, {}^{O_j}_{P_n}R^2_2 \ldots \,\blacksquare\, {}^{O_j}_{P_n}R^2_{middle} \ldots \blacksquare\, {}^{O_j}_{P_n}R^2_{last} \\
&\blacksquare\, {}^{O_k}_{P_l}R^3_1 \,\blacksquare\, {}^{O_k}_{P_l}R^3_2 \ldots \,\blacksquare\, {}^{O_k}_{P_l}R^3_{middle} \ldots \blacksquare\, {}^{O_k}_{P_l}R^3_{last} \qquad (3) \\
{}^{O_i,O_j,O_k}_{P_m,P_n,P_l}S_2 &: \textit{Ready for the assembling}
\end{aligned}
$$

The result of rearrangement of the queues is:

$$
\begin{aligned}
{}^{O_i,O_j,O_k}_{P_m,P_n,P_l}S_1 &: \blacksquare\, {}^{O_i}_{P_m}R^1_1 \,\blacksquare\, {}^{O_i}_{P_m}R^1_2 \ldots \,\blacksquare\, {}^{O_i}_{P_m}R^1_{middle} \,\blacksquare\, {}^{O_j}_{P_n}R^2_1 \,\blacksquare\, {}^{O_j}_{P_n}R^2_2 \ldots \blacksquare\, {}^{O_j}_{P_n}R^2_{middle} \ldots \\
&\ldots \blacksquare\, {}^{O_k}_{P_l}R^3_1 \,\blacksquare\, {}^{O_k}_{P_l}R^3_2 \ldots \,\blacksquare\, {}^{O_k}_{P_l}R^3_{middle} \\
{}^{O_i,O_j,O_k}_{P_m,P_n,P_l}S_2 &: \blacksquare\, {}^{O_i}_{P_m}R^1_{middle+1} \ldots \,\blacksquare\, {}^{O_i}_{P_m}R^1_{last} \,\blacksquare\, {}^{O_j}_{P_n}R^2_{middle+1} \ldots \\
&\ldots \blacksquare\, {}^{O_j}_{P_n}R^2_{last} \,\blacksquare\, {}^{O_k}_{P_l}R^3_{middle+1} \ldots \blacksquare\, {}^{O_k}_{P_l}R^3_{last} \qquad (4)
\end{aligned}
$$

In front of the station number one for the ith, jth and kth operation on the mth, nth and lth product are waiting robots on the ith operation for assembling the mth product, with the first priority, numbered from one till the middle. Then follow robots on the jth operation assembling the nth product, with the second priority, numbered from one till the middle. The last in the queue are robots on the kth operation for assembling the nth product, with the third priority numbered from one till the middle.

In front of the station number two, for the ith, jth and kth operation on the mth, nth and lth product are waiting robots for the ith operation on the mth product, with the first priority, numbered from middle + 1 till the end. Then follow robots for the jth operation for assembling the nth product, with the second priority, numbered from middle + 1 till the end. The last in the queue are robots for the kth operation for assembling the nth product, with the third priority, numbered from middle + 1 till the end, as shown in Eq. (4) and in Fig. 2.

4.3. Working mode after failure of one alternative station

In front of the stations number one and two for the ith, jth and kth operation on the mth, nth and lth product are waiting robots for the ith operation assembling the mth product, with the first priority, numbered from one till the last. Then, following robots on the jth operation for assembling the nth product, with the second priority, numbered from one till the last. The last in the queue are robots for the kth operation for assembling the nth product, with the third priority, numbered from one till the last:

$$
\begin{aligned}
{}^{O_i,O_j,O_k}_{P_m,P_n,P_l}S_1 :\ & \blacksquare\ {}^{O_i}_{P_m}R^1_1\ \blacksquare\ {}^{O_i}_{P_m}R^1_2 \ldots\ \blacksquare\ {}^{O_i}_{P_m}R^1_{last}\ \blacksquare\ {}^{O_j}_{P_n}R^2_1\ \ \blacksquare\ {}^{O_j}_{P_n}R^2_2 \ldots \blacksquare\ {}^{O_j}_{P_n}R^2_{last} \\
& \blacksquare\ {}^{O_k}_{P_l}R^3_1\ \ \blacksquare\ {}^{O_k}_{P_l}R^3_2 \ldots \blacksquare\ {}^{O_k}_{P_l}R^3_{last} \\
{}^{O_i,O_j,O_k}_{P_m,P_n,P_l}S_2 :\ & \blacksquare\ {}^{O_i}_{P_m}R^1_1\ \blacksquare\ {}^{O_i}_{P_m}R^1_2 \ldots\ \blacksquare\ {}^{O_i}_{P_m}R^1_{last} \blacksquare\ {}^{O_j}_{P_n}R^2_1\ \blacksquare\ {}^{O_j}_{P_n}R^2_2 \ldots \blacksquare\ {}^{O_j}_{P_n}R^2_{last} \\
& \blacksquare\ {}^{O_k}_{P_l}R^3_1\ \blacksquare\ {}^{O_k}_{P_l}R^3_2 \ldots \blacksquare\ {}^{O_k}_{P_l}R^3_{last} \qquad (5)
\end{aligned}
$$

In case of failure of the station number 2 mobile robots are moving to the station 1 in the following way. Robots on the ith operation assembling the mth product, with the first priority, numbered from one till the last are coming to the end of the queue of the ith operation for assembling the mth product, with the first priority, on the station two. Then, following robots for the jth operation in assembling the nth product, with the second priority, numbered from one till the last are rearranged with the same rule. The last is the rearrangement in the queue of robots for the kth operation for assembling the nth product, with the third priority numbered from one till the last.

The result of rearrangement of the queues is:

$$
\begin{aligned}
{}^{O_i,O_j,O_k}_{P_m,P_n,P_l}S_1 :\ & (\blacksquare\ {}^{O_i}_{P_m}R^1_1\ \blacksquare\ {}^{O_i}_{P_m}R^1_2 \ldots\ \blacksquare\ {}^{O_i}_{P_m}R^1_{last})(\blacksquare\ {}^{O_i}_{P_m}R^1_1\ \blacksquare\ {}^{O_i}_{P_m}R^1_2 \ldots\ \blacksquare\ {}^{O_i}_{P_m}R^1_{last}) \\
& (\blacksquare\ {}^{O_j}_{P_n}R^2_1\ \blacksquare\ {}^{O_j}_{P_n}R^2_2 \ldots\ \blacksquare\ {}^{O_j}_{P_n}R^2_{last})(\blacksquare\ {}^{O_j}_{P_n}R^2_1\ \blacksquare\ {}^{O_j}_{P_n}R^2_2 \ldots\ \blacksquare\ {}^{O_j}_{P_n}R^2_{last}) \\
& (\blacksquare\ {}^{O_k}_{P_l}R^3_1\ \blacksquare\ {}^{O_k}_{P_l}R^3_2 \ldots\ \blacksquare\ {}^{O_k}_{P_l}R^3_{last})(\blacksquare\ {}^{O_k}_{P_l}R^3_1\ \blacksquare\ {}^{O_k}_{P_l}R^3_2 \ldots\ \blacksquare\ {}^{O_k}_{P_l}R^3_{last}) \qquad (6) \\
{}^{O_i,O_j,O_k}_{P_m,P_n,P_l}S_2 :\ & \textit{Out of function}
\end{aligned}
$$

The rearrangement of queues in the case of failure of one alternative station is shown in Eq. (6) and in Fig. 2.

5. SCHEDULING STRATEGIES

Scheduling strategies are designed to fulfill the key aim: just-in-time delivery of products according to the specification of customer order. The scheduling strategies are task-oriented to fulfill the order for one particular customer in good time. That means one customer has ordered different quantities of different types of products, and all his products have to be assembled, packaged and prepared for the delivery and transportation at predefined day and time (yyyy-mm-dd hh:mm).

The first step in the production planning at the factory level is to combine orders from different customers to find the best way to fulfill the wishes of all customers. The result of this planning is called system order. It tells what and how many (product types and their runs) and how urgent (priority) has to be assembled during the next period of time. All unlocked orders in the pool of the orders are making the system order (Fig. 2.) Assembling a run of one product type is called assembly order. The logic and hierarchy of working cycles during the completition of one system order are shown in Fig. 3 [10].

These activities are happening in the following way.

1. The group of assembly orders with the highest priority is selected from the system order.
2. From this group the first product type is selected.
3. The first piece in the run of that product type is assembled.
4. Mobile robot is getting order to assemble that piece. It takes suitable assembly pallet and goes from the assembly station for assembling of the first part till the assembly station for assembling the last part of that piece and finally to the unloading and packaging station. During the assembling procedure mobile robot can have alternative ways. This happens when 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, the robot follows the criteria of "the shortest completition time" of the next assembly operation. The time for the completition of the next operation is the sum of the waiting time and operation time. During the assembling procedure of one piece of a product, mobile robot is coming to different situations as shown in Fig. 4. What to do in the particular situations can be determined with following "if-then" rules, shown in Fig. 5.

This assembly process is happening in the shop-floor and follows basic principles of self-organization. Participants in the self-organizing process are mobile robots, assembly stations and shop-floor operators. This part is shown at the bottom of Fig. 2.

```
Start
{
    For (i=1;i=iSYSTEM ORDER;i=i+1)
    {
    Completition of System Order in BAS according to the priorities starts with the highest priority (j=1) and
    finishes with the lowest priority (j=3)
            For (j=1;j=3;j=j+1)
            {
                    For (k=1;k=last;k=k+1)
                    {
                            For (l=1;l=lRUN;l=l+1)
                            {
                                    For (m=1;m=mLAST;m=m+1)
                                    {
                                            Find and go to the most sutable assembly station and make
                                            ijklm_ASSSEMBLY_OPERATION ( )
                                    }
                                    l-th example of k-th product type is finished
                            }
                            Run of k-th product type is finished
                    }
                    Runs of all product types with j-th priority are finished
            }
            i-th system order for all priorities is finished
    }
    All system orders are finished
}
End
```

Fig. 3. Logic of working cycles during the completition of BAS system orders.

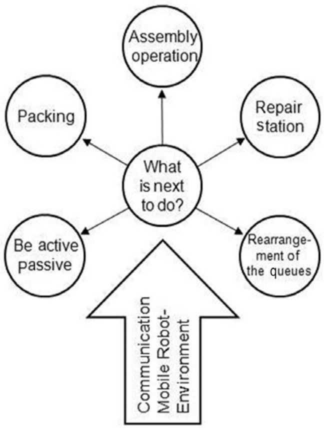

Fig. 4. Five basic tasks for mobile robots.

a) rule
if {the next step of assembly is packing}
then {the new assembly order, a robot has to go to the loading/unloading station}

b) rule
if {the quality state of product is negative}
then {the robot has to go the repair station. wait to the shop floor operator. the shop floor operator will try to repair the product. if this is not possible, he will remove it from the system, and will prepare the pallet and the mobile robot for assembling of the next (new) product. the results of repair operation: the state of assembly and the quality state}

c) rule
if {a assembly station becomes active or passive}
then {the rearrangement of the queues of alternative assembly stations}

d) rule
if {the quality state of product is positive and the next operation is assembly operation}
then {find out which assembly station(s) can perform the next assembly operation; if there are more than one, find out which is better, taking into consideration existing queues and priorities}

e) rule
if {the mobile robot is present and the assembly station is busy or there are waiting robot(s) with equal or higher priority or there are robot(s) of equal priority which are waiting for longer time}
then {the mobile robot has to wait in the queue of the assembly station for the next operation}

f) rule
if { the assembly station is free and there are no robot(s) with higher priority in the queue}
then {docking, execute assembly operation, check the quality of results of the assembly operation, write the new state of assembly and the quality state of product, undocking}

Fig. 5. Mobile robots' acting rules.

5. The procedures 3 and 4 are repeated since the very last piece of the run is assembled.
6. The procedure is repeated for the next product type in the priority group.
7. When the last product type in the priority group is assembled, the whole procedure from step 2 till 6 is repeated for the next priority group.
8. End of system order: when the last piece in the run of the last product type in the lowest priority group is finished, the system order is completed.
9. It is a time to prepare the next system order for the time coming. Generation of system orders can be made also more continuously.

6. BAS BASIC CHARACTERISTICS

The basic characteristics of the proposed BAS are the following.

1. The variable structure of the system, the number of stations can vary from one of each type to unlimited.
2. This system is possible to organize as a worker-friendly system, which has the possibility to be highly automated from one side and has the ability to integrate workers, from the other side.
3. Product mix and size of the run can vary in extremely wide range.
4. Self-organizing behaviour of the system makes it robust against external and internal disturbances.
5. Variable dynamic layout of the system can be used for optimization of the working scenario and system parameters.
6. The BAS can very quickly respond on the demands of a master scheduling system [11,12].

7. CONCLUSIONS

The proposed concept of a bionic assembly system is logical result of the development of flexible assembly systems. BAS has stronger characteristics of self-organizing, robustness and adaptation. The main problem is the conflict between hierarchy and heterarchy. The concept is suitable for application in most complex flexible assembly systems. The concept accepts variations in the structure of the assembly system. Introducing additional assembly stations without changes in scheduling strategies and scenarios can increase the capacity of the system. This system is possible to organize as a worker-friendly system, which has the possibility to be highly automated from one side and has the ability to integrate workers from the other side. This characteristics of the system open basically a new trend in the development of automation, (re)integration of workers in highly automated industrial environment. This development can be highly interesting for solving the present situation in developing countries, which have high rate of unemployed skilled people who cannot be integrated in classical automated systems. Variable layout of the system can be used for optimization of the working scenario and system parameters. Future research will be focused on system reconfiguration, system starting procedures and solution of conflict situations between centralized and self-organizing parts of the system.

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REFERENCES

1. Pyanichnikov, V. E., Katalinic, B. and Platonov, A. Application of the autonomous mobile robots "AMUR" for the modeling of the self-organizing systems. *Intellectual and Adaptive Robots*, 2011, **6**(1–2), 8–18 (in Russian).
2. Tomomi Kito and Kanji Ueda. Introducing bounded rationality into self-organization-based semiconductor manufacturing. Part 2. In *Dynamics in Logistics*. Springer, 2008, 65–73. DOI: 10.1007/978-3-540-76862-3_5.
3. *** http://www.merriam-webster.com/ dictionary/organization, accessed on 2012/05/27.
4. *** http://thesaurus.com/browse/ organization, accessed on 2012/02/27.
5. ***http://www.businessdictionary.com/definition/self-organization.html, accessed on 2012/04/26.
6. Katalinic, B., Cesarec, P., Stopper, M. and Kettler, R. Self-organizing systems in nature and technology. In *Proc. 7th International DAAAM Baltic Conference on Industrial Engineering*, Tallinn, Estonia, 2010.
7. Katalinic, B., Visekruna, V. and Kordic, V. Bionic assembly systems: Design and scheduling of next generation of self-organising complex flexible assembly system in CIM environment. In *Proc. 35th CIRP International Seminar on Manufacturing Systems*. Seoul, Korea, 2002.
8. Kukushkin, I. K., Katalinic, B., Cesarec, P. and Kettler, R. Reconfiguration in self-organizing systems. In *Proc. 22nd International DAAAM Symposium* (Katalinic, B., ed.). DAAAM International, Vienna, 2011, 641–642.
9. Katalinic, B., Kukushkin, I. K., Cesarec, P. and Kettler, R. Hybrid control structure and scheduling of bionic assembly system. In *Proc. 8th International Conference of DAAAM Baltic, Industrial Engineering* (Otto, T., ed.). Tallinn, Estonia, 2012, 483–489.
10. Berger, F., Laengauer, C., Hornung, J., Hamilton, P., Dolezal, C., Zeitlinger, R. and Cesarec, P. Bionic assembly system: queuing, technology matrix and life file. In *Proc. 20th International DAAAM Symposium*, 2009, 21–22.
11. Katalinic, B. Collective behaviors of an interconnected bionic assembly system – working scenarios and strategies. In *DAAAM Internationals Scientific Book*, Chapter 58 (Katalinic, B., ed.). DAAAM International, Vienna, Austria, 2007.
12. Pyanichnikov, V., Platonov, A. and Katalinic, B. Supervisory group control of mobile technological robots. Report at the 1st Russian-German Seminar on Space Robotics, Stuttgart, 2012, Karlsruhe Institute of Technology and German Airspace Academy, Stuttgart, 2012.

Hübriidkoostamissüsteemi juhtimisstruktuur ja tootmiskorraldus

Branko Katalinic, Valentin E. Pryanichnikov, Kanji Ueda, Toms Torims, Ilya Kukushkin, Paulina Cesarec ja Roman Kettler

On kirjeldatud hübriidjuhtimisstruktuuri, selle töötamisvõimalusi ja töötsüklite teostuse loogikat koostamisoperatsioonide sooritamisel bioonilises koostamissüsteemis (BAS) varieeruva tellimuste täitmise järjekorra puhul. Erilise tähelepanu all on probleem, kuidas otstarbekalt välja arendada ja kasutada alamsüsteemidevahelist kommunikatsiooni. On vaadeldud koostamisprotsessi erinevaid minemivõimalusi, tegevuste järjestamise strateegiaid ja täiendavaid võimalusi, mida võib pakkuda mobiilrobotite kasutamine koostamisoperatsioonide sooritamiseks.

Biooniline koostamissüsteem on uudne kontseptsioon tänapäevaste koostamissüsteemide arendamisel, mis kasutavad üheaegselt kombineeritult kaht juhtimispõhimõtet: tegevuste hierarhial põhinevat tsentraliseeritud ja iseorganiseeruvat juhtimissüsteemi.

Töö on loogiliseks edasiarenduseks paindlike koostamissüsteemide väljatöötamise valdkonnas. BAS-kontseptsioonil on paremad adaptsiooni ja paindlikkuse näitajad. Põhiprobleem seisneb jäiga ja paindliku töökorralduse ühildamises. Väljatöötatud kontseptsioon pakub häid rakendusi keerukamate koostamissüsteemide juhtimiseks. Kontseptsioon arvestab erinevusi koostamissüsteemi struktuuris. Lisades täiendavaid koostejaamu, muutmata töö järjestusstrateegiaid ja -stsenaariume, on võimalik suurendada süsteemi tulemuslikkust. Süsteemi on võimalik kujundada töötajasõbraliku süsteemina, mis on ühelt poolt kõrge automatiseeritustasemega ja teisalt võimeline töötajaid integreerima. Need omadused näitavad automatiseerimise arenduses uut suunda, milleks on töötajate (re)integratsioon kõrge automatiseeritustasemega tööstuses. Arendused võivad praeguse olukorra lahendamiseks olla huvipakkuvad arengumaadele, kus on palju töötuid oskustöölisi, keda ei saa klassikalistes automatiseeritud süsteemides rakendada. Edasised uuringud keskenduvad süsteemi ümberkonfigureerimisele, selle käivitusprotseduuridele ja konfliktsituatsioonide lahendamisele tsentraliseeritud ning iseorganiseeruvate süsteemiosade vahel.