

MODELING OF SUPERVISOR'S ACTION MEASUREMENTS IN CONTROL OF MULTI-AGENTS MOBILE ROBOTIC SUBSYSTEM

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Abstract: The ways of modeling of supervisor's action measurements in control of multi-agents mobile robotic subsystem using cognitive idea are discussed. The architecture of a transport subsystem, which can work efficiently both in the newest and existing manufacturing systems as well as rules for co-operation and coordination of vehicles have been presented. Computer simulation results are given.

Keywords: Measurements in robotics, cognitive supervisor's measurements modeling, multi-agent robotic subsystems.

1. INTRODUCTION

Present market situation requires highly flexible, open for configuration changes and inexpensive manufacturing systems. Moreover, such systems have to be continuously improved, what in fully automated systems is impossible – improvement requires stopping and rebuilding the whole system or a significant part of it.

Manufacturing systems with various level of automation should allow for safety and efficient co-operation of fully automated parts of the system, manually controlled machines, and operators. The co-operation between operators and automated transport trolleys, for example mobile robots should be possible as well.

Such a situation results in hardly ever computer based integration of manufacturing systems, especially in SMEs and companies requiring high flexibility. The solution for this problem would be applying modern software and computer technology and using the possibilities that they create. Using the solutions like distributed databases, agent software and object technology can solve specific problems appearing in systems with various level of automation.

The matters connected with control the manufacturing process and more generally: with control systems, are the subject of research [2, 5, 6, and 9]. The problem of improving well-known and widely-used control systems of manufacturing or a desire to create a completely new kind of those are supported by increasing demands of the clients

who expect to be offered products of the highest possible quality and the lowest price at the same time.

As a result, decentralized structures based on the interaction between the agents, which are parts of the control system, have been elaborated and are often tested through physical implementation. Multi-Agent Systems (MAS) are based on the universal technology of creating software enabling one to model and implement both individual and social behavior of the agent in the system.

Transport subsystem has been chosen because of its exceptional and meaningful role in the manufacturing system. It has the main influence on setting of the manufacturing system. Supplying the stock of spare parts and tools as well as automating the transport of items between working posts and stores are essential to ensure efficient work of most of those systems without human interference.

2. ARCHITECTURE OF SUBSYSTEM

The task of control of the transport subsystem can be presented as following: it is planning the orders and distributing them among the transport agents in such way that the costs, depending on time, distance and the importance of the task, were as low as possible [1].

The superior role is played by *manufacturing control system*, which distributes the tasks and supervises the work of all machines in the manufacturing system. It is responsible for the correct proceeding of the manufacturing, which means receiving manufacturing orders, materials deliveries, manufacturing capability of the system, time interdependence, exchange of the tools and creating the time-table of the whole manufacturing process. Manufacturing control system generates the tasks neither for the subsystem of material fluency nor for each vehicle, but sends the time-table to the subsystem. The same information is also sent to the transport subsystem, which is responsible for delivery and collection of each item. This subsystem is also given information about the present state of each machine and the state of local and main stores.

The transport subsystem, on the basis of income data, decides on the order of the tasks and time relations between

them. During proceeding the element by the machine, it receives alarm information if the process does not follow the plan, e.g. when the proceeding has been unexpectedly interrupted, the time has been prolonged etc. On the basis of that information necessary changes in vehicles control are made in the moment of crisis.

The co-operation between automated materials handling system and manufacturing control system is presented in figure 1.

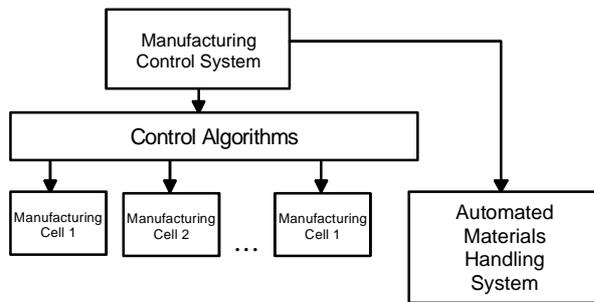


Fig. 1 Co-operation between automated materials handling system and manufacturing control system.

The suggested solution combines hierarchic and remote multi-agent structure. It means that there is a decisive module in the multi-agent system, which gives orders to other elements in the system. If everything proceeds as planned, the module does not interfere in control. It gets into action when there is a failure or other crisis or such a situation is foreseen.

In transport subsystem working in a manufacturing system there are two levels of planning the task: higher, dealing with distributing the tasks among the vehicles in the system, and lower, responsible for performing the given tasks. The first level, called *strategic planning*, is done in the supervisor's module. On this level the tasks are planned. The results of this planning in the form of a task are sent to the transporting vehicle. The steering item of the vehicle fulfils the *tactic plan*, so the task of planning a single job is done by an individual mobile agent.

In figure 2 the architecture of multi-agent transport subsystem supervised by a model of human-operator is shown.

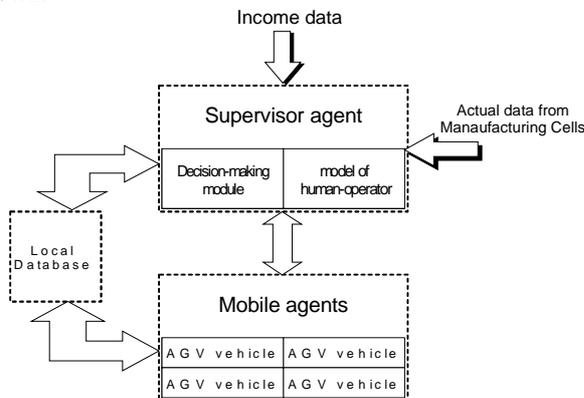


Fig. 2 The architecture of transport subsystem.

2.1. Transport vehicle

The actions of modern transport subsystems are based mainly on automatically guided vehicles (AGV) [13, 14, 15] allowing the transport of sub-elements, partly-done items, tools or wastes. The type of the vehicle determines its use and range of actions. The architecture of transport vehicle is shown in figure 3. Their intelligence means that they are able to move in the unknown environment.

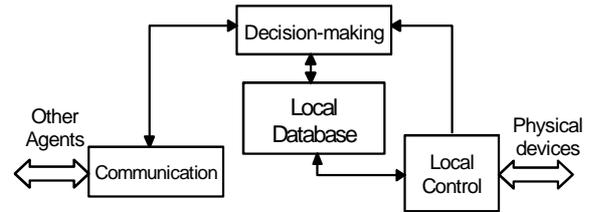


Fig. 3 Transport vehicle architecture.

2.2. Co-operation between transport vehicles

In the suggested architecture of transport subsystem co-operation between all agents is done with respect to the following rules [2]:

- goal-oriented co-operation,
- weak co-ordination,
- co-operation through organization,
- mixed organization,
- mixed planning,
- direct and chart communication.

3. HUMAN – OPERATOR MODELING

The results of the research proves that in the process of making decisions in transport subsystem, or more generally, in control system of manufacturing, there must be a man as the one who can deal in extraordinary situations [7]. The way of dealing with this problem is modeling a human-operator. In the presented solution the thinking processes, taking place in human brain during making important decisions or in critical situations, are the subject of modeling.

The model of human-operator is not and should never be the ideal picture of a real operator. The main reason is the fact that apart from the positive features there are also plenty of negative ones. The main drawbacks the modeling of which seems not needed are: control delay, reaction time, fatigue and involvement, work conditions, motivation and so on. Modeling negative features, which can influence the control process in a negative way, is not wanted. So in the presented case supervisor is a module combining the advantages of mechanical systems which disadvantages are made up for by the operator with advantages of human-operator, whose negative features are corrected by control system.

3.1. Making decision by the human

The research of human brain conducted in the field of cognitive philosophy [11] resulted in the statement that human being takes action not only on the basis of stimuli from outside but also as a result of a certain representation existing in their mind. Both stimuli and representations can activate the thinking process on two levels:

- *cognitive level* - the main function of the brain is predicting events in changeable time horizon and making decisions taking into account their possible results; it is a level of conscious actions, where regulating functions are based on the perception of visual stimuli as well as verbal and thinking processes;
- *behavioral level* - steering reactions are generated on the basis of subconscious signals (perceived but not recognised); this level guarantees reactivity and stability of operator's knowledge to some extent.

Another important conclusion drawn from the research of human brain [11] is the fact that symbol systems have enough necessary features to perform intelligent actions, which means that human cognitive processes are likely to be symbolic. The main subclass of symbol systems is rule systems, many of which can be referred to as expert systems. Yet, it does not mean that the term *rule system* means the same as *expert system*. The main feature of expert system is its function, i.e. solving specialized problems which require professional expertise. While the main feature of rule system is its structure, i.e. the set of rules and operating with them.

3.2. Cognitive level

The main task performed on the cognitive level is foreseeing unwanted situations in order to avoid them by adapting standard behavior. It means that the knowledge about future states is used to decide which actions should be taken at present.

Cognitive level in this meaning can be described with Rosen's theory of anticipating systems [10]. Those are systems where:

$$S_{n+1} = f(s_1, s_2, s_3, \dots, s_n, s_{n+1}, s_{n+2}, \dots, s_{k-n}), \quad k > n,$$

where:

- $s_{1...n-1}$ – class of the past states of environment;
- s_n – actual state of environment;
- $s_{n+1...k-n}$ – class of the states prediction of environment.

According to Rosen, anticipating system has the structure as presented in figure 4 and consists of the following elements:

- dynamic reason system S;
- dynamic system M, which is the model of S;

- effectors E, enabling one to operate both on signals entering S as well as S itself in such a way that dynamic features of S can be changed.

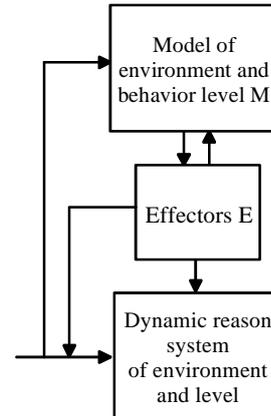


Fig. 4 The architecture of anticipating system.

Model of the operator can be formally described as:

$$f(B, M, U, R)$$

where:

- B – system describing behavioral level;
- M – environment model (surroundings + B);
- U – class of unwanted states;
- R – set of rules describing how to modify;

If a state belonging to the class of unwanted ones U is identified as a result of prediction of environment states M, then the rule R will influence behavioral level B, in order to bring the trajectory of environment states back to the acceptable range. Function $f: U \rightarrow R$ determines how behavioral level should be modified in the particular case. Projection $f: U \rightarrow R$ results from the specification of U and R so it does not need to be expressed explicitly.

Algorithm:

While performing the algorithm, agent's working course is done in the specific sequence. Each course starts with creating a copy of the agent's inner model, on the basis of which prediction takes place. Then present environment state is tested and compared with both goal and unwanted state. If unwanted state is reached, knowledge on behavioral level is corrected to regain the acceptable range.

3.3. Behavioral level

Behavioral level has reactive architecture extended with monitoring, diagnostic and predicting features. All of those forms of agent's actions have their automated equivalents. Due to the complexity of this issue, they have been predefined here as reason-result relations, which are the most common ones.

Automated acting, i.e. making decisions by the operator on the behavioral level, is a complex task, far more than a course of reactions as an answer to a particular signal from

the environment. Automated acting is an ability to behave in typical, frequently repeating conditions.

Algorithm:

The cycle of the algorithm begins with the review of environment state (perception of the environment) and choosing the task (action selection) to be performed in the next step (action completion). When the tasks have been finished, it is checked if the goal has been reached and if possible results of the action are as expected. If predicted state differs much from the wanted one, new action is generated.

3.4. Co-operation of the levels

The architecture of the suggested model can be compared to hybrid architectures where each level has its function and fulfills particular tasks. The architecture of human-operator consists of two levels: the one guaranteeing reactivity (behavioral level) accompanied with the one analyzing long-term plans and goals (cognitive level). Co-operation between both levels greatly influences the effectiveness of the model behavior. The levels cooperate directly, taking into account states of the environment, signals from the planning system together with their current states.

3.5. Mind representation

Research shows that intelligent human behavior depends not so much on associating abilities but is rather connected with gained knowledge. However, not only adding and accumulating new facts but also creating links between them as well as between the previously acquired ones is important.

4. SUPERVISING THE ACTIONS OF SUBSYSTEM

Human-operator supervising work of transport subsystem in order to gain knowledge about the surrounding world performs monitoring, making diagnosis, steering and foreseeing [4, 8, 12]. All of these kinds of activities take place both on cognitive and behavioral levels. The way they occur and the influence they make on the decision-making process vary significantly. The other important finding is that while working the operator performs a number of predefined tasks with hierarchic structure. It means that operator in complicated surrounding fulfills the tasks in determined way. The value of income and outcome variables are roughly defined which enables the operator to perform a certain set of actions. When a failure occurs, human brain usually does not perform logical deduction but searches available models of behavior. When the solution is not found, logical thinking is activated. In figure 5 the suggested relation between model of operator supervising work of transport subsystem and the system itself is presented.

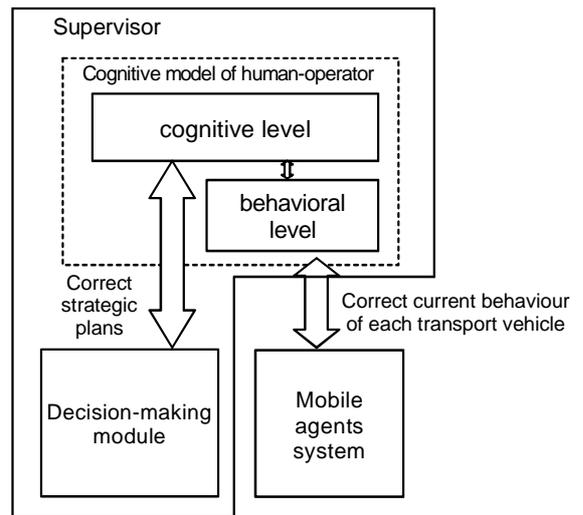


Fig. 5 Relation between model of human-operator and transport subsystem.

Behavioral level of cognitive model of human-operator corrects current behavior of each transport vehicle as soon as a failure or dangerous situation occurs. If behavioral actions do not give satisfying results, then cognitive level is sent information about the event.

Cognitive level using adaptation ability and special kind of anticipation is able to influence the results of strategic plans generated by decision-making module. On this level future conditions of the surrounding are predicted, which enables it to detect the ones in which the actions of behavior level may not be effective or the ones which may be contradictory or not effective in generating strategic plans.

In figure 6 hypothetical model of human brain responsible for supervising transport subsystem in manufacturing system is presented.

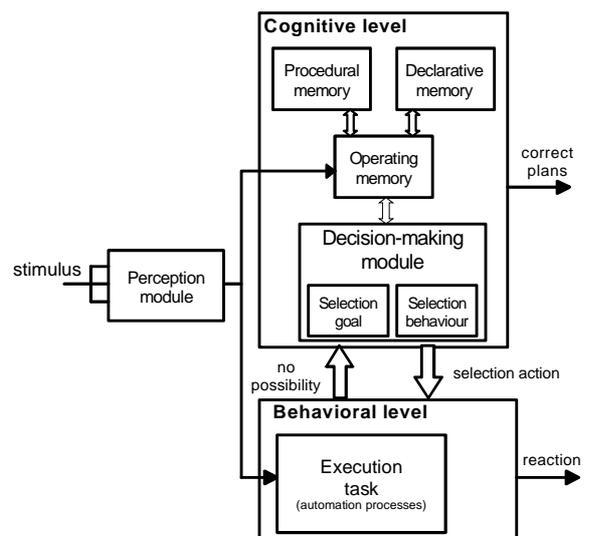


Fig. 6 A hypothetical model of human brain responsible for supervising transport subsystem

4.1 Algorithm of human-operator model's actions

Suggested human-operator model is responsible for checking if transport subsystem, which is a part of manufacturing system, works correctly. It is not a general model of human mind. It only supervises the performance of a multi-agent transport vehicles system. The model does not interfere in the missions of individual vehicles; its task is only to react efficiently in the case of unexpected situations and failures.

Step 1:

During proper work only cognitive level is activated:

- monitoring current states of the transport vehicles with the use of perception system;
- predicting future states of transport vehicles, including dangerous states, on the basis of their current position and movement;
- predicting future states of transport vehicles, including dangerous states, on the basis of strategic planning;
- changing strategic plans, which have been generated by the Decision-Making Module if an occurrence of a dangerous situation is foreseen.

Step 2:

In the case of an unexpected situation, which requires human reaction, behavioral level is activated in order to prevent the danger:

- halting the work of model's cognitive level
- starting performing (by behavioral level) *Preparation* action, which includes: (1) choosing monitoring parameters, (2) diagnosis, (3) control. The aim of this action is to plan the task in such a way to reach the intended goal or instead sub goal is chosen. As a final step of *Preparation* action, the sub goal is projected into control action. It means that suitable orders are sent to AGVs.
- starting performing (on behavioral level) *Realization* action, which includes: (1) monitoring, (2) predicting, (3) acting. *Realization* action can be performed when the state is active and leaving the state is not possible. It means that previously no change requiring another diagnosis and control action has been detected. Now monitoring the values of parameters important for reaching the sub goal together with predicting the changes in values of parameters - sub goals is done. The aim of the prediction on this level is to find any deviation from the plan which is being performed.

The model of human-operator perceives the environment of transport subsystem through the perception system where output digital signals activate processes on both behavioral and cognitive levels. Behavioral level acts quickly thanks to diagnosing situation through differentiating automatically the stimuli characteristic for the given situation combined with reactive method of planning enabling one to restore the correct work of transport subsystem. If actions taken on behavioral level are not efficient, events are sent to cognitive level where deeper analysis of the current situation on the basis of data from memory modules (stored as semantic networks and set of rules) takes place.

This cognitive model differs greatly from hybrid behavioral architectures used in robotics, both in co-operation mechanisms of the levels and their competencies. In architectures used in robotics there are usually three levels: reactive, coordinating and mission planning ones. Between reactive and mission planning levels single, not connected modules are put. They provide the agent with ability to adapt, solve problems and deal with unusual situations. It is the coordinator who links those reactive components. In cognitive model there are only two levels: behavioral and cognitive ones. Cognitive level influences the autonomy of behavioral level's actions while behavioral level is a reactive agent, performing additional functions of diagnosing and predicting.

5. COMPUTER SIMULATION

Theoretical exposition presented above is now being modeled and verified via simulation in order to find the best structure and way of presenting human-operator in the manufacturing system [16]. Because available simulation programs such as Soar, ACT*, Arena [10] or Simul18 make it possible to conduct only part of the research, concentrating on the issues they have been designed for, program platform JAVA [3] has been selected. This solution will make it possible to do further research avoiding the restrictions of other program platforms. What is more, JAVA is a safe and interpretable, not compiled language, thanks to which it is independent of all software and hardware levels.

An example of the windows of simulation package is shown in figure 7 and figure 8.

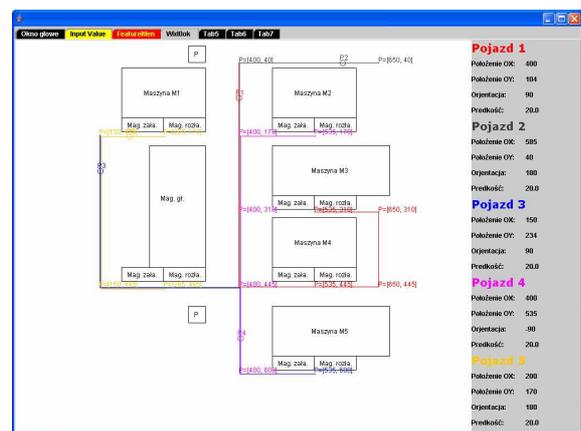


Fig. 7 The simulation program. Part 1.

Programs written in JAVA fulfill the requirements for information applications in modern manufacturing systems. The program makes it possible to configure the transport system in order to match the structure of manufacturing system and present layout of the machines in the working room vehicle.

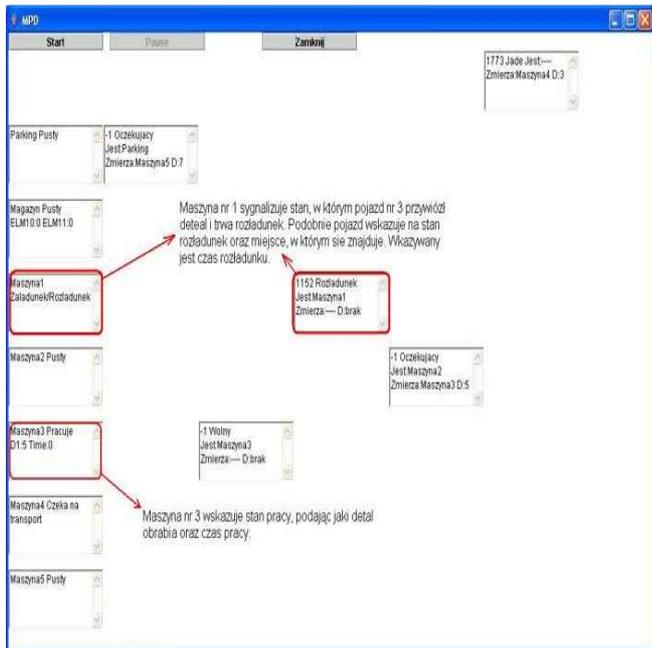


Fig. 8 The simulation program. Part 2.

6. CONCLUSION

It seems that combining the existing manufacturing systems, also the ones with varied automation, with an independent transport subsystem is a solution with synergic effect. The existing manufacturing system can be easily equipped with modern transport subsystem without interfering in its structure.

Comparing to centralized systems, multi-agents ones solve problems much faster. It is possible thanks to the dispersion of difficulties and limited exchange of the information between agents (only the most crucial data is transmitted between the agents).

Modeling the actions of human-operator supervising transport subsystem at work seems to be an interesting idea. What is the most important this solution provides possibilities of development in the future. The attempts to limit the role of a human being in the process of making decisions in manufacturing systems as the element responsible for the majority of errors, may result in designing completely new kinds of manufacturing systems.

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