Analysis of the intellectual interaction of mechanical autonomous systems

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Abstract. A variant of synchronous systems interaction is developed. When the hierarchy of interaction between autonomous systems is introduced, the stages of the collective decision making process are highlighted. This ensures the selection of the best solution for its implementation.

1. Introduction
At present autonomous systems that control the operation of any mechanisms, devices, etc., are becoming increasingly widespread without any information for their functioning obtained from a human [1, 2]. As a rule, they have a certain system of decision-making. And they can develop any response reactions aimed at correcting it depending on the situation.

This leads to the problem of these systems interaction not only with a human (serious results have already been achieved to facilitate such interaction), but also directly between them [3-5]. Thus, there exists a serious problem of ensuring such interaction.

2. Statement of the problem of the autonomous systems interaction
There exists a scope of systems (world) \( R \). And there exists an interaction scope of systems \( W \). In the interaction scope of each system, there may exist other systems it exchanges information with [6].

In the scope of system, a set of autonomous systems \( S \) operates. Each system has a set of parameters \( E \). And each system is represented as a set of describing functions \( f \), and the information about the current state \( k \).

Systems can be either active \( S_A \) or passive \( S_P \).

Active systems can initiate actions to themselves or other systems. Passive systems can not initiate any actions, and they cannot form only responses.
In turn, active systems can be friendly $S_f$ or unfriendly $S_e$. Under normal conditions, there are no unfriendly autonomous systems since they all operate to achieve one goal (goals) and they do not interfere with the work of other systems in the scope of systems. In more complex conflict situations (or game conditions, competitions), when the operation of autonomous systems in the scope of systems is to separate the work of unfriendly systems, it is necessary to separate them to differentiate the dissemination of the information. Conflict and even more complex situations of restrictions about the received information, depending on the degree of confidence within the framework of this paper will not be considered.

### 3. Algorithm of interaction

The process of the systems interaction can occur in synchronous and asynchronous modes. In synchronous mode, the acts of data exchange among all systems and the acts of the systems operate alternately. While systems are acting, internal dynamic processing of information takes place simultaneously to prepare data for the following exchange. In asynchronous mode, each system initiates the data exchange when it is ready for it and it has the results of calculations to make the exchange.

#### 3.1. Synchronous interaction of systems

An active system when decision making about any action informs other active systems that are in the interaction scope of actions about their intentions. In turn, other systems check and analyze the received information taking into account the processes that currently occur, and they confirm or refute information. Having checked and processed the information from all the systems upon confirmation, the scope of systems takes place. If there exist several versions for action, the only one version with the highest performance rating is adopted. In order to support the adoption of such a decision, verification of the information obtained in autonomous systems takes into account the hierarchy of such systems [7].

#### 3.2. Hierarchy of autonomous systems interaction

If all systems have the same hierarchical weight, then there may be conflicting situations while such collective decision making [8]. Thus, it is necessary to enter a hierarchy between autonomous systems and to specify the weights of the hierarchy. These weights are taken into account in making a decision and point to the system that collects information and processes it to develop a final solution. There may be autonomous systems with the same weights. But there cannot exist systems with the same maximum weights for one problem, i.e., for each task, a hierarchical weights system is separately introduced. If the systems solve only one task, there exists only one system of hierarchical weights.

Thus, we introduced some restrictions on the systems functioning in order to avoid conflict situations in making a decision.

In order to avoid any conflict situations, we introduce the notion of a subordination cell for the implementation of an already adopted solution. Each active autonomous system can have one subordination cell for each task. This cell contains other autonomous systems that are subordinate to this one. Thus, in making a decision, the instruction is sent only inside this cell, and there are no conflict situations with the execution of instructions from systems with a higher level in the hierarchy.
Each subordination cell containing elements (autonomous systems cannot have more than one owner) a system with the highest weight of the hierarchy for the given task.

If the interaction scope of the system covers the entire action space, then all systems participate in the decision-making process.

Thus, the process of collective decision making can be divided into two stages. They are "discussion" of the obtained data, and the development of decisions by each system, then checking solutions for conflict, and choosing the best solution for its implementation.

4. Conclusion

Within the framework of the algorithm of interaction of autonomous intelligent systems, a variant of synchronous interaction of systems was proposed and the hierarchy of interaction of autonomous systems was introduced. Meanwhile, the authors took into account that when collective decision making is carried out, the verification of the adopted decision of another system takes place based on the estimation of time costs for such decision making by this system. That is, in each process the variable of the operation time of this process participates. Thus, in the process of the decision making, the decision itself is not derived with respect to the situation in the past (at the time when the information was processed), but at the current moment (or for some period of time in the future, with the purpose of predetermining the subsequent circumstances).

References

[1] Romanovsky M V 2005 Autonomous systems Fundamental Research 4 84-5
[2] Lebedenko E V and Kutsakin M A 2016 Approaches to the modeling of the process of interaction of autonomous elements of distributed information systems Questions of cyber security 3(16) 50-4
[3] Kortenkamp D, Bonasso R P, Ryan D and Schreckenghost D Traded control with autonomous robots as mixed initiative interaction (Houston: NASA Johnson space center)
[4] Nicolescu M N and Mataric M J A hierarchical architecture for behavior-based robots (Los Angeles: Computer science department university of Southern California)
[5] Murray S A Human-machine interaction with multiple autonomous sensors (San-Diego: Navy command, control and surveillance center)
[6] Reynolds C Interaction with groups of autonomous characters (Foster City: Research and development group)
[7] Pellkofer M, Lutzeler M and Dickmanns E D Interaction of perception and gaze control in autonomous vehicles (Munchen: Universitat der Bundeswehr)
[8] Chebotarev A N 2015 Coordination of interacting automata Cybernetics and system analysis 51(5) 13-25