Control of the Allocated Microrobots Collectives

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Abstract[1]

The microsystem techniques (MST) finds the increasing application in various areas of a science and techniques, there are new, functionally sated designs of microrobots. Nevertheless, problems of creation of big microrobots collectives and their effective use till now it is not solved, thus various approaches and schemes of designing are offered for control of such collectives. In article one of variants of designing of a control system for the allocated collective of microrobots is described.

1. Introduction

Now a perspective direction of development of a microrobotics is development and creation of systems of autonomous control by movement of mobile robots. The similar problem for full-size ("big") robots is solved by substantial growth of an information flow of feedback channels, realization of intellectual adaptive algorithms for control systems and planning which functioning is based on the fullest and authentic reconstruction of surrounding conditions. Collective of "big" robots it more often some independent units with similar functionalities, and more often with the universal tooling, capable to execute a task in view also are independent. According to the above-stated, autonomy of collective is realized by transposition of some functions of control of functioning or movement from the operator on an onboard control system that allows to lower requirements to a information channel and to reduce time of its work, and in some cases and completely to exclude its use on big time intervals of work. I.e. it is supposed, that the control over performance of operations by such collective lays on the operator which visually or on the basis of the information are given from sensor controls of robots accordance adequacy of applied efforts can and to bring corrective amendments as required.

The decision of this task for collective of microrobots is represented to more complex by virtue of their small and midget sizes, limitations computing and power resources, significant influence of an environment, etc. Autonomy of agents of such collective should be full, since management from the operator everyone separate microrobots not probably except for a command stop. The small and midget sizes exclude an opportunity of installation of several tools or their fast change, therefore at control it is necessary to consider rigid specialization of each agent. By virtue of even the set forth above features, control of collective of microrobots - not trivial and specific task.

2. Existing Approaches to Control of Collectives

As each microrobot is capable to execute the limited quantity of operations, and most likely is focused on performance only by one for performance of tasks (complexes task) in view teamwork of collective of microrobots is required, that can lead at competent distribution of tasks to reduction of time of the decision of a task or scope of greater number of objects. Control of groups of cooperating microrobots demands application of the allocated intellectual control systems that is represented interesting in the scientific and practical goals.

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For control of robots collectives it is offered to use three types of control systems architecture [1]:

1. centralized;
2. decentralized;
3. multiagent.

The centralized control system for a microrobotics is practically inapplicable in view of the small sizes of agents and absence of an opportunity of the organization of bidirectional channels of information interchange between each robot of collective and the central unit. Other lacks of such approach are significant times of delay in management and reduction of reliability of collective of microrobots as refusal of the central unit puts out of action all collective.

To remove the above described lacks the decentralized architecture of control systems, based on local processing of the information and autonomous control of each microrobot is capable. However at such approach often there are local refusals and the disputed situations demanding additional external signals for coordination of work. But also such system practically is not created, since only small part of the information on an environment (the limited quantity of onboard sensor) that is obviously not enough for construction of an adaptive control system and construction (correction) of a plan of action is accessible to the microrobot. A special case, more viable, is clusterization collective [1], but offered iterative algorithms of its realization demand creation the small size cluster.

In opinion of many researchers the most preferable variant of construction of a control system of the allocated collective of robots is use the multiagent approach [2]. Each microrobot is independent enough, by way of control, the agent. The principle of action multiagent operating structures is based on decomposition of the taskof collective, on a number of the local tasks assigned to agents, distribution of these tasks between agents, planning of collective behaviour of agents, coordination of interaction of agents, sanctions of disputed situations, etc. At the multiagent approach construction of hierarchical control & planning system, allocation a supervision level sold by the agent-coordinator, and granting of agents intellectual control systems is supposed. The basic difference multiagent systems from centralized is parallel performance of tactical tasks, but thus necessity of the organization of operative information interchange through the coordinator is kept. Each agent of such system possesses ample opportunities of adaptation to changing properties of an environment, also except for a tactical level adaptation is realized at a strategic level. Unfortunately, such approach has powerful lacks at its use for construction of control systems by collectives of microrobots. For designing multiagent control systems methods of collective behaviour of automatic devices, the theory of games, ways of the cooperative decision of problems on the basis of the allocated artificial intellect, the theory of schedules, methods of optimum planning and adaptive management [3] are used. The basic requirement at realization multiagent control is necessity of allocation (creation) of agents-coordinators for operated collective, thus its computing capacities necessary for the decision highlevel tasks of adaptation should be considerably above, than at ordinary objects. Failure of the agent-coordinator conducts to loss of functionality of collective. This problem may be taken off by duplication of agents-coordinators, but for collectives of microrobots such variant leads to complication of procedures of planning and allocation.

3. The Wavelike Control Algorithm for Collective of Microrobots

Proceeding from the set forth above deficiencies and being based on specificity of operation of microrobots, it is offered to build peer-to-peer architecture of a control system with dynamic allocation of agents-coordinators (delegation some functions of control during functioning, virtual agent-coordinator) and wave character of extending of the controlling and sensory information. The main problem facing to collective of microrobots is an execution of the set from the outside or predetermined operations set from the outside in working area. For increase in an overall performance of collective at its initialization (the moment of detraining) it is necessary to ensure its random distribution on a working area, thus allocation should be executed autonomously. It is attained by usage of algorithm of "leveling of potentials »: each n-th microrobot "possesses" a charge Q_R^n which is the sum of the individual charges Q_{Ri}^m oscillated according to distances up to proximal m of microrobots, being in a band of responsivity of sensors of a location:

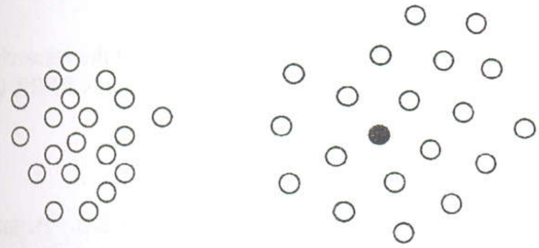
$$Q_R^n = \sum_S^m Q_{Ri}^m , \quad (1)$$

$$Q_{Ri}^m = \begin{cases} 0, & if \ d_g = d_i \\ \dfrac{d_g - d_i}{\sqrt{(d_g - d_i)^2}}, & if \ d_g \neq d_i \end{cases} , \quad (2)$$

where d_i - distance between i-th pair microrobots;

d_g - the set distance between microrobots in collective, should be less bands of responsivity of sensors.

Then each microrobot exchanges with neighbours in the field of operation of sensors by the information on leaking charges on the basis of which the vector of driving $\vec{V}_{Ri}^m$ is evaluated. Magnitude of motion vectors depends on a charge of pair microrobots, they are routed to each other if charges are opposite, and to the different sides if charges are equal. The Resultant of driving V_R^n is evaluated as a vector sum of all $\vec{V}_{Ri}^{m}$. If does not superimpose any entry conditions on layout of microrobots they uniformly are arranged in working space rather «a barycentre of collective», fig.1. Determining in addition boundary conditions of collective it is possible to achieve the definite form of the area of a coverage which are distinct from a circle: quadrate, a rectangle, an ellipse, etc.



a) b)

Figure 1. Algorithm of Leveling of Potentials: a) Initial State of Collective of Microrobots; b) "Uniform" Allocation, without the Definition of a Pattern

Each agent of such collective of microrobots can be presented by a following set of performances μR_n (XY_n, f_n, E_n, Z_n, Q_R^n), where XY_n – local (grid) coordinates of the agent, f_n – a functionality of n-th microrobot, E_n – efficiency of execution of the previous operations (previous history of operation), Z_n – significance of the active job. Coordinates of the robot – magnitude dynamic and gauged in relative coordinates, as coordinates use indexes of a matrix of allocation GM. Matrix GM (j, k) looks like the following, "1" – presence of the robot at a node of a grid, "0" – absence of the robot at a node of a grid:

$$GM = \begin{vmatrix} 1 & 1 & \cdots & 1 & 1 \\ 1 & 1 & \cdots & 1 & 1 \\ \cdots & \cdots & \cdots & \cdots & \cdots \\ 1 & 1 & \cdots & 1 & 1 \\ 1 & 1 & \cdots & 1 & 1 \end{vmatrix}, \quad \text{if J=K}, \qquad (3)$$

$gm(j,k) = 1$, allocation quadrate;

$$GM = \begin{vmatrix} 0 & 0 & 0 & 1 & 0 & 0 & 0 \\ 0 & 0 & \cdots & 1 & \cdots & 0 & 0 \\ 0 & \cdots & \cdots & 1 & \cdots & \cdots & 0 \\ 1 & 1 & 1 & 1 & 1 & 1 & 1 \\ 0 & \cdots & \cdots & 1 & \cdots & \cdots & 0 \\ 0 & 0 & \cdots & 1 & \cdots & 0 & 0 \\ 0 & 0 & 0 & 1 & 0 & 0 & 0 \end{vmatrix}, \quad \text{J=K},$$

$$gm(j,k) = \begin{cases} 1, & if\ (j-\dfrac{J}{2})^2 + (k-\dfrac{K}{2})^2 \le \dfrac{1}{4}J^2 \\ 0, & another\ variants \end{cases}, \qquad (4)$$

allocation on "circle", etc.

The problem of a uniform coverage of a working area is dominating and is executed by all microrobots which have been not borrowed in execution of operations or in initial time. Since microrobots represent the highly specialized mechanisms created on execution only of one operation for execution of problems forming technological groups $Tt_l\{\mu R_k\}$ is required, consisting of the microrobots, capable to execute a demanded set of elementary operations $F\{f_n\}$. In collective those microrobots with necessary functionality are infused, that most close are to an operational place. Thus the robots forming group, for all other members of collective are represented as one microrobot which is being at centre of an operational place. The autonomous initiator of creation of technological group Tt_l $\{\mu R_k\}$ - a local node of perturbations, the microrobot, capable to recognize a problem demanding the solution, and most close being to a place of holding of technological operations appears. From a node of perturbations queries for adjacent microrobots concentrically miss and further in the form of concentric waves there is a query, thus to the robots, capable to execute demanded operation, the vector of driving to centre of perturbations is transmitted, and they automatically turn off the algorithm of a random distribution dominating over "idling inaction".

External commands have the similar mechanism of extending, but at the first pass of a wave of perturbation from boundaries of collective the local node is, and then the algorithm of initialization of technological group presented above works. To ensure «natural fading» waves of perturbation, the following rule is accepted: only the node can oscillate a wave in all directions if the microrobot appears in a role of a relay (transmits perturbation further) the wave further is transmitted only to those microrobots that are in sector ±45, opposite to a direction of arrival of a wave of perturbation. The repeated disturbing wave with similar parameters is ignored, fig.2.

At performance of a task the technological group Tt_l realizes the dynamic scheme of interaction – "changing leader". Each time the leader in group becomes the robot which is carrying out the function, the others - execute commands on a disposition in working space. The relative positioning of microrobots depends on type of a task, external conditions and density of a grid.

To avoid the robot's oscillation (movement around its node of a grid) it is necessary to set some small size insensitivity - minimally admissible level of a charge Q_R^n.

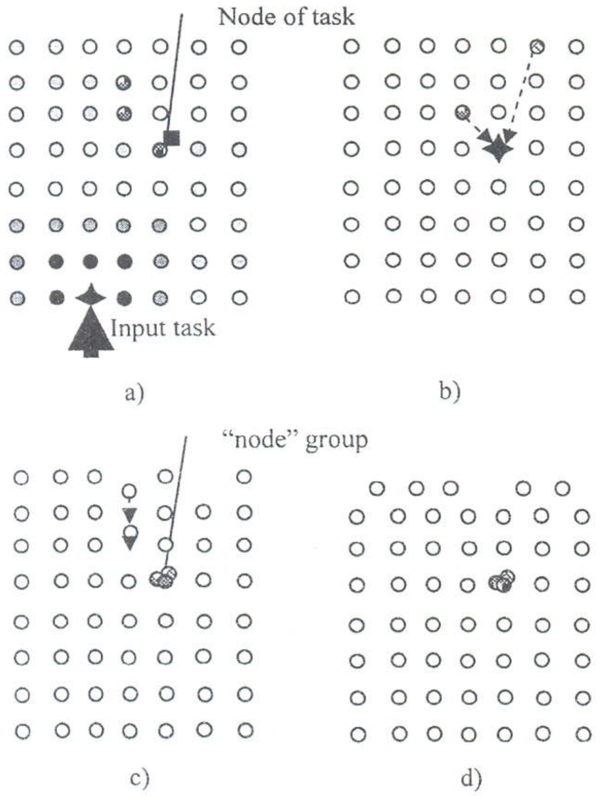


Figure 2. Forming of Technological Group and Conversion of Collective (from Fig. a to Fig. d)

Each microrobot in collective is equipped by intellectual systems of control and planning, for example for planning trajectories it is offered to use genetic algorithm [4, 5]. All algorithms are developed in view of limitation of the microrobot's computational capability, consider its specificity and specificity of a set of tasks to its collective.

4. Conclusion

The offered control algorithm the arranged collectives allows to solve challenges without construction of central office of control, selection of special agents-coordinators. The mechanism of extending of the controlling information and architecture of interacting of microrobots considers boundedness of their computing-informational resources, rigid specialization, etc. Usage of the big collectives consisting of microrobots with various specialization, will allow increasing adaptivity of system as a whole - a parallelizing and execution of the big number of problems, stability to destructive processes (crash microrobots, loss of functionality, etc.). Special interest represents usage of the given algorithm in common specific problems - a maximization of "area coverage".

Acknowledgments

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