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Data transferring model determination in robotic group

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HIGHLIGHTS

- This idea of data transferring model in the group of robots is proposed.
- Justified technical vision system choice.
- Described technical vision system method of obstacle detecting.
- The mechanism of leader changing method based on fuzzy logic was used.

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ABSTRACT

This paper describes the basic idea of data transferring in the group of robots while they move in an area with a high density of obstacles with the goal of increasing their movement speed by creating and synchronizing an area map that is made by each robot separately. This paper provides a brief review of existing robotic swarm projects and definition of the problems in robot teamwork, shows pathfinding methods and their analysis, justifies our technical vision system choice and describes its method of obstacle detecting that is based on dynamic triangulation. According to some behavioristic models, using fuzzy logic, the method of leader changing was used. This knowledge helps with the choice of appropriate models of data transferring, makes their simulation and creates a proper network between the robots to avoid data loss.

1. Introduction

The progress in different classes of mobile robot design and manufacturing and the results of their successful use in various fields brings the problem of effective management of robotic group (RG) movement in the collective operations that cannot be performed effectively by individual robots. These can include such operations as taking water samples in the waters of major ports, search and detection of any objects on land and sea areas, operation in specified areas with toxic chemicals, and others.

One of such problems is the robots group movement controlling in the conditions of strong destruction (obstruction) after the earthquakes. Such hazardous terrain can cause a signal loss during the robots communication, no matter which type of network for data transferring is used (Wi-Fi, 3g, EDGE, etc.).

For analysis of data exchange network structures and justification of their choice we did introducing a series of laboratory

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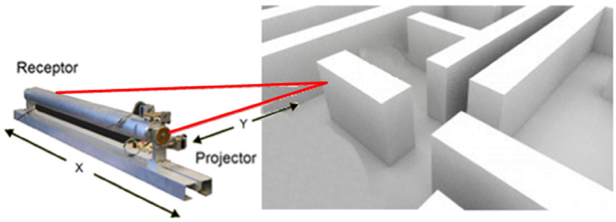

Fig. 1. Use of TVS in case of obstruction.

constraints and environmental conditions in which the experiment will be conducted.

Assuming that we have a limited space with dimension $m \times n$ where a group of five robots need to explore as quickly as possible an unknown territory to collect data about the environment, where space has a low (or no) lighting and obstruction. While others are using cameras, we will build our solution basing on the use of a technical vision system (TVS) [1] that helps immediately to get the Cartesian coordinates of objects in the zone of interest, whenever possible—immediately scaled to robots own coordinate system (and its size). Systems with similar construction are described in [2,3]. Upon receiving data about obstacle apparition from TVS (Fig. 1), the robot must send information about this obstacle with its coordinates to the server for synchronizing terrain data with other robots. Thus, the knowledge of general terrain maps by all robots will prevent unnecessary movement in impassable routes and increase the rate of recognition of unknown terrain.

Most of the researchers in the area of robotic group movement are limited by the experiments with simple, smooth and cyclical/closed trajectories [4,5] and the use of "follow the leader" methodology, while we consider the problem approximate to the real situation. The results of our pathfinding methods modeling will allow to determine the desired trajectory as close as possible to smooth on the real terrain, adjusting to the conditions that were detected by the TVS, in a strictly defined geometric pattern and coordinate the actions of the robots group.

As mentioned before in hazard terrain, there is a probability of signal failure between the robot and server. This particularly leads to the need of network structure to be changed. The data obtained by individual TVS of each robot must be properly processed on the server and synchronize all of the robots. The organization of interactions in our robotic group is based on the static swarm model [6]. It is characterized by the absence of a given control center and is a variation of a fixed network—a set of agents. Our "changing the leader" method based on [6–8] allows solving this problem of network structure reorganization by selecting the most appropriate communication point (robot) for sending requests to the server. Furthermore, this method can be used in other areas of task distribution.

This paper is organized as follows. Section 1.1 provides a brief review of the existing robotic swarm projects and a definition of problems in robots teamwork which solution is the main goal of this paper. The choice of maps storage method and algorithms to work with them (the calculation of routes, etc.) are represented in Section 2, while selection, justification and TVS operation description (to determine passable and impassable places) are briefly explained in Section 3. Group of robots behavior determination is represented in Section 4. Knowing the method of solving the above problems, the model of a data exchange system (Section 5) can be developed. In Section 6, the conclusions are made.

1.1. Definition of problems in robots teamwork

There are many examples of systems that implement collective behavior and can be used for tasks similar to ours. Some of the examples are represented in Table 1.

According to the reviews of different robotic swarm projects in [9–14], a number of specific problems that occur in robots teamwork can be allocated. Among them are:

– Unpredictable dynamics of the environment;
– Incomplete and contradictory knowledge of robots (agents) on the state of the environment and the other participants;
– Variety of options to achieve the goal, the team structures, roles, etc.;
– Distributed and dynamic nature of the team action planning;
– Problems related to the fact that the swarm is a set of physical objects existing in a real complex environment (communication problems, the territorial distribution of swarm and so on);
– Communication problems or data exchange (network architecture, protocols, etc.).

Therefore, a qualitative solvation of communication problems will make our purpose twofold. By scaling objectives, affecting on data exchange in a group of robots that were described above, we can distinguish two tasks:

(1) Make a solution of the problem of a RG movement by monitoring their local coordinates and search of presumed routes;
(2) Solve the task of roles distribution.

The description of our task solution of data transferring model selection in robotic group is as follows: Firstly, it is based on the existing original technical vision system with dynamic triangulation, which allows obtaining the Cartesian coordinates of visible objects in a more simplified form than the data from the cameras. It helps to solve the first task of robots position monitoring, and search the routes. Secondly, we implemented the voting system based on fuzzy logic [16–18] for the communication network formation between robots in a group. This makes possible to choose the better node (robot) to transfer received data from TVS between a robot and the server, and for task distribution in a robotic group. These two approaches allow to dynamically select the data transferring model for further robot actions coordinating and accelerating the process of movement in hazard terrain.

2. Methods of robot swarm territory mapping and routing

Determination of the method of territory map storing should be based on routing methods. That is why we review some algorithms that are suitable for our task.

There are many different methods to search for the shortest routes:

1. Classic [19,20] (Dijkstra's, Floyd–Warshell's, Prim's, Kruskal's, algorithms, etc.).
2. Heuristic [21,22] (A* algorithm, ant algorithm, genetic algorithm, etc.).

2.1. Analysis of classic algorithms

Based on data from [19,20] we made the research for Dijkstra's, Bellman–Ford's and Floyd–Warshell's algorithms by generating the nine oriented graphs with 100, 200, 300, 400, 500, 1000, 1500, 2000 and 2500 nodes.

Based on capabilities of algorithms, analysis is divided into two parts: the search for routes from one node to all and from all to all nodes. In the first case analyzed only Dijkstra's and Bellman–Ford's algorithms, as Floyd–Warshell's algorithm is used only for the search of all to all, and in the second all three algorithms.

The analysis results are presented in the form of tables (Tables 2–3) and graphics (Figs. 2, 3) (analysis was carried out in the case of "one to all" and "all to all" search) where tables represent the amount of time (in nanoseconds) needed to find a shortest path in case of 100–2500 nodes for each of the algorithms.