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Use of Mobile Robots Groups for Rescue Missions in Extreme Climatic Conditions

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Abstract

In some cases, rescuing people in danger with the help of autonomous evacuation devices is the only way to save their lives. This is true, in particular, for oil platform accidents, which nowadays result in a lot of victims. This paper describes a way to solve this problem using a group of rescue robots. Taking into account the specific character of organizing rescue missions in extreme conditions, the article considers general principles of group formation and dividing the group into subgroups with different functions. Autonomy of individual robots and robot groups, redundancy of robots and interchangeability are considered as ways of increasing reliability. Some general approaches to solving the key problems of evacuation are also stated.

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1. Introduction

Due to increasing oil and gas extraction in the coastal (shelf) areas, there has recently been an increase in the number of accidents and, therefore, the number of victims among the staff. Rescue missions already conducted show that the currently known devices and methods of rescuing are inefficient and a lot of people die. These days, the rate of people's survival in the sea areas of the Arctic shelf in case of a technological disaster is no more than one third, two times less than the survival rate in warm non-freezing seas.

Currently, robotic tools are just beginning to be used and then only to automatically move saved. A search tools

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and the people evacuation tools from distress technical objects are not developed, and does not apply. Now such means of escape used: lifejacket, lifebuoy, life ring and life end.

Evacuation system with platforms and floating plants: helicopter, personal device descent control platform, chutes, walkway or stairs, lifeboats and capsules, rescue compartment.

At the same time robotic systems are used more and more widely to support people's activities in extreme and dangerous conditions. It is proven [1, 2] that for a number of tasks using groups of robots that optimize the resources used (in a wide sense of the term) is quite efficient.

Let's look at the general principles of forming groups of rescue robots [4].

1. Heterogeneity. Subgroups of robots have different functional capabilities: some watch the situation, some explore the environment, some search for people, some transport these people etc.
2. Autonomy. All robots in a group (as well as the group as a whole) complete local tasks without human intervention, because presence of a human operator near the malfunctioning object is inadmissible, a remote operator would be unable to estimate the situation fast and correctly and presence of a professional pilot on board the vehicle is unlikely.
3. Redundancy. The number of robots has to exceed the necessary minimum in case of breakdowns.
4. Interchangeability of robots (perhaps with some decrease in quality of the group) to provide stability of operation.
5. Robustness, i.e. stability of system's operation even in case of significant deviation of the object from the properties known in advance.

2. Heterogeneity

Groups of robots are divided into the following subgroups:

- Watching robots. They conduct constant observation of the situation from previously chosen positions. Positions (observation zones) are chosen to cover as much of the accident-prone area of the served object as possible. Robots can patrol an observation zone in case of complicated geometry of the zone or to watch dangerous moving objects.
- Scout robots. In case of emergency they search for people who need to be evacuated and for dangerous objects, changes in the state of which must be watched.
- Worker robots. They are used for emergency rescue and recovery operations (ERRO) that are required for saving people's lives and reduce the chances of disaster expansion.
- Loading robots. They help people to get out of dangerous places. They also search for the safest ways for people to go and watch the situation to secure people.
- Transporting robots. These are heavy multi-purpose vehicles for transporting groups of people to safe areas.

Field experience of using heterogenic groups of mobile robots shows that the "differentiation of labour" among robots inside a group dramatically [4] reduces the time required for a rescue mission and, therefore, makes it possible to save as many lives as possible and minimize economic losses caused by rescuing and the disaster itself.

3. Autonomy

Here the autonomy means there is no trained human operator on board. In the event of a technological or natural disaster the situation changes rapidly and often unpredictably. It is essential to provide connection with zone monitoring systems (meteorological, navigational, ice, ecological etc.) for rescue and evacuation purposes. Such a connection is one of the key factors of a successful rescue operation.

Robots in a group have channels of data exchange, so the group is able to change its features promptly and independently to adapt to the changing situation.

In our case, the autonomy is provided in the following way. A distributed software for the group control system is used on the robots. The structure of this software is presented in figure 1.

This structure shows relations between different modules of the software. Distributed parts of the software are indicated by thick frames.

The operation dispatcher ensures the correct work sequence of different parts of the software. Only three functional capabilities are required for the mobile robot to function in the group:

- data exchange with other robots in the group
- operations, specific for the robot
- correct movements along the trajectory

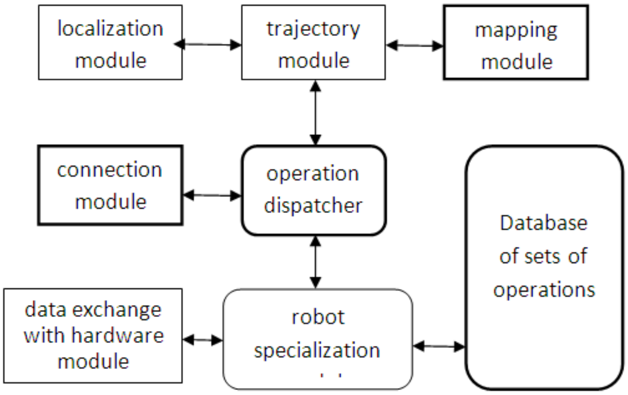

Fig. 1. The software structure.

For the robot to correctly move along the trajectory (which is ensured by the trajectory module) it is necessary to know where on the map the robot is. Therefore, the trajectory module requires two modules: a mapping module and a localization module.

The mapping module [5], as stated above, is distributed, i.e. it is executed simultaneously on all the robots in the group. Each robot has a set of sensors of the surrounding environment and each robot makes its own map. These maps are merged to make a general map of the surrounding environment.

The localization module determines current positions of the robot. There may be several such positions:

- the robot's position in a certain global (basic) coordinate system
- the robot's position in the group coordinate system
- the robot's position in the coordinate system of a certain object of interest

The robot specialization module is responsible for the specific functions this robot is supposed to fulfill and for adapting operations for this particular robot. This is the module that produces control signals for the robot. Accordingly, this module uses a database of sets of operations, common for the whole group.

There must be one common database of sets of operations for the whole group because in the case of reconfiguration (if some robots break down or degrade) the capabilities of one robot may be replaced with the capabilities of another one. Specialization modules adapt the required operation to the capabilities and configuration of this robot.

The exchange with hardware module sends control signals to the actuators of a robot and receives signals from the robot's sensors.

4. Redundancy

In machinery, redundancy is one of the ways to increase safety and reliability. It is most often essential for securing people's lives. In case of saving people from an oil platform after an accident, when working in extreme weather conditions, redundancy is not just important, it is compulsory.

For a homogeneous robot group where all the robots are similar and fulfill the same functions, redundancy is trivial: the more robots, the higher redundancy.

For a heterogeneous group this approach is inapplicable for two reasons:

- different conditions in which different subgroups operate. For example, watcher robots do not directly participate in rescue missions, so for them redundancy is less important, while scout robots have to enter the very center of the disaster and explore the situation, perhaps at the cost of their failing. In this case redundancy must be at its highest.
- different functional capabilities and, therefore, different cost of robots. For example, watcher robots may have a very simple design and a low price, while transporting robots are supposed to take on dozens of people and transport them over hundreds of miles, so they need to be highly reliable, which results in a high price. Therefore, high redundancy of transporting robots is economically inexpedient.

5. Interchangeability

It is possible to increase reliability of a group without excessive redundancy by utilizing interchangeability of robots. Interchangeability easily increases reliability and chances of rescue missions' success with minor price growth and complication of robots.

Let's look at possible kinds of failures and related kinds of interchangeability.

The most difficult situation is the failure of an onboard computer of a robot's control system. In this case the robot is not able to complete the mission (it can be used as a retransmitter or as a temporary shelter for evacuees).

The second difficult situation is the failure of an onboard radio channel. In this case the robot completes the part of the group mission it is capable of completing and (depending on functionality) proceeds to entirely independent work or stops its operations.

The third situation is engine and/or chassis failure. In this case the robot can operate as a shelter, a stationary watcher, a retransmitter and a calculator.

The fourth situation is one of the sensors breaking down. For example, if a range finder of one of the robots fails, it can be replaced by those of other robots. Such a replacement will, perhaps, result in less accuracy, but the general functionality will not decrease.

6. Robustness

The redundancy and interchangeability, described above, increase the system's robustness. The system does not lose stability in the case of breakdowns and it is possible to continue the rescue mission.

Additional measures are also applied to increase robustness, providing an expanded range of conditions for the operation of different subsystems of robots and the group in whole.

The range of applicability conditions of components and subsystems can be increased in well-known ways. Below we review the ways to increase the applicability range for software and mathematical subsystems of the group control system.

For this purpose, the following must be taken into account:

- Volatile number of robots. The number may not only decrease. Some robots might be in support and their usage increases the number of robots. The number of robots can also increase if the robots that broke down earlier are used again for an operation where this failure is insignificant.
- Mapping errors. Some robots, due to various sensors' inaccuracy, can cause significant errors in the common map. A way to minimize the impact of such errors is to form separate parts of the map and compare them. If the parts of the map at the intersection differ significantly, the different parts are "weighed" and the map most suitable for the local environment is used at any given moment. In this case "non-linear scaling" depending on the current group configuration works well.
- Failure of the localization system currently used. The situation is considered, when the localization system has already failed, but it is not yet recognized by the control system. In this case wrong position determination might result in significant propagation error, leading to fatal consequences. To counter such errors one must use logical tests of trust to localization and integrate data provided by sensors of various physical nature for the purpose of localization.

Conclusion

In a real situation (temperature reaching minus 50 C, wind up to 40 m/s, storm with the Beaufort number up to 10, blizzard, visibility less than 10 m etc.) the weather conditions of a rescue mission may change almost instantly. Therefore, a temporary pause in a rescue mission must be possible to provide stability of operation, if the current probability of losing the major part of the group exceeds a certain limit. To determine this limit, additional research is required.

Before and during a rescue mission operations must be planned in such a way that as many lives as possible are saved. The approach is to transport on an evacuator robot the person who is easier to transport at the moment. Waiting for a group of people to gather in one place, while seemingly effective, is dangerous – the situation may change at any moment and the whole group may die.

A transporting robot with a person on board must leave the most dangerous zone till another evacuee is ready to be transported onto the robot. Then the robot approaches and the next evacuee is transported.

There is a difficult problem of choosing a moment when to stop the phase of saving from the most dangerous zone and start the evacuation phase. The solution must be made either remotely by the mission leader or by the senior of the group, using the current information and expert judgment, based on previous experience.

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References

[1] I.A. Kaljaev, A.R. Gajduk, S.G. Kapustjan. Raspredelennye sistemy planirovanija dejstvij kollektivov robotov (Distributed systems for planning operations of robot groups), Moscow: «Janus-K», 2002, 292 p. (in Russian).
[2] I.A. Kaljaev, A.R. Gajduk, S.G. Kapustjan. Modeli i algoritmy kollektivnogo upravlenija v gruppah robotov (Models and algorithms of collective control in robot groups), Moscow: Fizmatlit, 2009, 280 p. (in Russian).
[3] D.Ja. Ivanov. Informacionnyj obmen v bol'shih gruppah robotov (Information exchange in large robot groups)// Zhurnal «Iskusstvennyj intellekt» (Journal "Artificial Intelligence"), #4, 2010 (in Russian).
[4] A.V. Timofeev, R.M. Yusupov, Principy postroenija integrirovannyh sistem mul'tiagentnoj navigacii i intellektual'nogo upravlenija mehatronnymi robotami (Principles of designing integrated systems of multi-agent navigation and intellectual control over mechanotronic robots)// International Journal "Information Technologies & Knowledge" Vol.5. (in Russian).
[5] I.A. Vasilyev. Uopravlenie koliesnym mobil'nym robotom (Control for a wheeled mobile robot)// Zhurnal «Avtomatizacija v promyshlennosti» (Journal "Industry automation"), #03, 2012 (in Russian) (**peer-relieved**).
[6] I.A. Vasilyev. Mobile robot localization. // Journal of computer & information technology. #4(94), 2012(in Russian) (**peer-relieved**).
[7] V.E. Pryanichnikov, V.P.Andreev. The Application of Network Technologies to Constructing Group Controlled Systems with Machine Vision for Mobile Robots / Annals of DAAAM for 2009&Proc. of the 20th Intern. DAAAM Symp. "Intelligent Manufacturing &Automation: Focus on Theory, Practice and Education", Vienna, Austria. 2009.
[8] V.A. Agamalian, E.S.Kalinina, S.E. Simanov, S.G. Tsarichenko. Development of integrated group control system for robotic complexes. // Robotics and Technical cybernetics, 2(3)-2014
[9] A.V.Timofeev, R.M. Yusoupov. Intellectualization of control and navigation processes for robotic system. . // Robotics and Technical cybernetics, 2(3)-2014