Conceptual Analysis of Fire Fighting Robots' Control Systems

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***Abstract* – This paper is dedicated to the overview of the firefighting robots' control systems. The main goal of this paper is to show the variety of different firefighting robots and to analyze their advantages and imperfections.**

Keywords – fire fighting robots; control system

I. INTRODUCTION

At present time, firefighting robot is desired to be an unmanned ground vehicle, developed for finding and fighting the fires. There are few types of such vehicles – for fighting home fires and, for example, for fighting forest fires. But most of the existing models don't have enough capabilities for autonomous movement and controlling. This models, even serial ones, are controlled by the remote operator via cameras. The annual firefighting robots' competitions, held by USA Universities are good chance to improve used technologies in autonomous control.

Firefighting robot's main goal is to decrease people injuries or deaths during firefighting in accidents and to increase efficiency of firefighting process due to simultaneous actions of people and robots.

II. MAIN TASKS

Subject to the purpose, the main task for the firefighting robot can be one of the following:

- for the home firefighting – robot must make its own way to the source of the fire in the most short time and to extinguish a fire. The field of action is constrained with current floor of house, no interfloor shifts are to meant and all doors at the floor are opened;
- for the industrial firefighting – the main principles are as above, except one thing: the firefighting compound must be safe not to cause a new accident. In addition, robot have to operate at longer distances;
- for forest firefighting –robot must make its own way to the source of fire in the woodland, knowing only the coordinates of the fire and to extinguish the it.

The following principles are suitable for any firefighting robot: after using up all the firefighting compound (water) or when the power level is close to the "required-for-return" level, the robot have to go to the supply station to enrich its power or firefighting compound capacity. The reserve for the unforeseen circumstances should exist (for example overexpenditure of power and dramatic situation changes).

III. REQUIREMENTS

Let's develop main requirements for the firefighting robot. They are divided into two kinds: hardware and software.

The hardware requirements are as follows:

- robot must be armed with a high-efficiency computer system for all subsystems data processing and for autonomous movement;
- power consumption of the robot must be as low as possible, with the possibility of suspending temporally unused subsystems;
- robot must also be equipped with optical and infrared cameras for complexing collected visual data and for making a movement decision;
- robot must be equipped with smoke, temperature and wind sensors for finding fire signs in case of its invisibility;
- the main tools for autonomous localization and mapping are to be included too. these tools are: infrared range sensors, laser scanners and range sensors;
- the forest fire fighting robot must be armed with high pass ability chassis for the "hard environments";
- for the indoor robots the sensor like wall-along sensors are to be installed;
- main computing system must be equipped with reserve memory blocks, duplicating data (for example RAID) for the unforeseen circumstances (for example data lost due to very high temperature);
- robot must be equipped with an antenna, allowing remote control at the distance about 2-3 km;
- robot's frame must be implemented from the fire-strong material, that poorly conducts heat to the inner parts of robot, providing their reliable defense;
- the main fire fighting tool is a controllable "water" cannon, installed on the rotating platform.

The software requirements are as follows:

- control system's software must work in real-time mode;
- control system's software have to be able to indepently make its decision about movement direction or about

starting firefighting (the possibility of behavior changing is meant too, by selecting an appropriate algorithm of operating);
- control system's software must include some features which provide creating local map with the data, collected from sensors;
- control system's software must include basic program tools for controlling main system's blocks;
- control system's software must provide a possibility for remote control by operator for any unforeseen circumstances (for example partial malfunction) or for robot's learning;
- the system's dataware must implement two formats for map files (2d and 3d), open for adding new objects;
- dataware, also, must implement an environment model, based on semantic net, open for adding objects of new type and for more precise definition of characteristics of existing objects and for learning. this model must be compatible with both map formats.
- dataware must include features for data protection (providing of its integrity);
- the prior robot's learning nust be conducted in a special computer system, based on given above requirements.

IV. World's Firefighting Robots Overview And Analysis

Now, let's have a good look at existing firefighting robots.

Virtual Reality Simulation of Fire Fighting Robot [1] (Indonesia) is a virtual adaptation of competition robot, that took part in Panitia Kontes Robot Cerdas Indonesia competition in 2006. This system was developed in MATLAB/Simulink with the help of «Virtual Reality Toolbox» plug-in. It is oriented for initial testing of controlling algorithms. Its important to notice, that even the robot itself doesn't have enough level of functionality, because of low-detailed formalization of environment. The robot could operate only in corridor-room environment, without strange objects. Only one fire source is meant and there are auxiliary marks on floor, that mean for example room entrance.

Pokey the Fire-Fighting Robot [2] (USA) is the firefighting robot, that made its way out of competitions, and became more "serious" than other systems. In [2] there are detailed description of used equipment and basic algorithms of operating. Robots operating environment is a building, so the robot is equipped with necessary sensors, for example, with a line sensor, that could be unuseful in conditions of dense smoke. The main advantages of robot are:
- using of two types of fire sensors, working in different ways;
- using of complex firefighting tool;

The main disadvantages are:
- short distance of sensor's work. the fire could be recognized at the distance not more than 1.5m. at longer distances the sensors works bad, ad developers say;
- low efficiency of onboard computer, able only to carry main tasks, without its extension and complexization;
- absence of optical means of environment perception.

The device is described as autonomous mean of firefighting in houses and any civil buildings.

Fire Protection Robot [3] (USA) – another competition project, developed for «15th Annual Trinity College Fire Fighting Robot Competition». Robot has more complex organization, than one, shown above and is oriented for solving larger variety of tasks.

The main system's advantages are:
- more complex algorithms, used for fire detection;
- using of sound sensor for activating;
- presence of some additional navigation sensors;

The main disadvantages are:
- low-efficiency computer;
- low-power chassis;
- absence of home-return algorithm;
- absence of mapping;

Firefighting Robot [4] is an American Trinity College development, that was only on early-prototype stage (in 2008). It was supposed to this robot to be an autonomous device, with 15 minutes limited working time, after which it will return to the supply station. This approach is one of the best variants for firefighting in houses and non-industrial buildings.

The main disadvantages are:
- the little working time;
- low-stock of "water";

The planning low-cost is a system's main advantage.

In special order it's necessary to notice firefighting robots, included in Russian Ministry of Emergency Situations. Among them are "ABR-ROBOT", "El-4", "El-10". These models are far away from competition projects, they armed with a real armour and firefighting tools, but their main disadvantage consists in remote controlling. They aren't autonomous.

V. The Main Principles

All foregoing models of firefighting robots have its advantages and disadvantages. Estimating them can lead us to forming of the following operating principles:

1. Taking into account operating environmet is necessary. For the house robot the main operating model will be the "corridor-room" model. The forest robot will face a lot of crossroad conditions, such as slopes, hills, water bodies and some large objects, like fallen trees and will often round an obstacle of type "tree". The supposed semantic net nust be constructed with objects that are best for formalization of current environment and characterized

with connections with another objects. The model of environment nust not lead to ambiguities (the recursive connections must be expulsed, the "rings" must be minimized of expulsed too).

2. For providing qualitative navigationd of firefighting robot it is necessary to use SLAP (simultaneously localization and mapping) model [5][6].

3. System of decision making must be based on probabilistic principle with such organization of task-queue, which provides execution of high probability of success decisions. In case of failure, the task with lower success probability must be executed. In case of total failure there must be a one last decision: a moving to another place and generation another task list.

4. It necessary to organize a computing process in several threads, acting simultaneously with common data. It will dramatically improve system's efficiency in some tasks.

5. Designing the whole autonomous system is a complex problem, that must be divided in few stepsm allowing gradual approaching of the goal: autonomous operating.

VI. CONCLUSIONS

The above analysis gives us the following conclusions:

1. There is a great progress in world remote controlled firefighting robots' design. The next step is to make them to operate autonomous, by the gradual decreasing of human participation in device controlling process.

2. The design of firefighting robots is a very urgent problem, especially in Russia, where this problem is solved poorly (autonomous movement is meant).

3. The adequate formalization of environment is necessary for increasing precision of autonomous operating. The competition ideology must be forgotten, and the real conditions are should been taken into account.

4. The world's leader in firefighting robot design is USA, even though most of their robots are only competition compatible.

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