Search and Rescue Robots are Information Gatherers

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Summary. In many aspects robots by far cannot perform like a human being, but in some aspects they outperform any human. In this lecture I will argue to use robots for tasks where they outperform humans. This means that in stead of applying a robot for a task designed for a human being and thus replacing a human, one has to search for niches in the applications where a robot's strengths can be fully exploited. As examples I will discuss the applications of robots in the EU-funded projects Guardians and View-Finder, and explain the expected results and problems.

1 Introduction

The Guardians[1] and the View-Finder[2]projects apply robots for search and rescue operations. Search and rescue operations are usually aimed at rescuing human beings and some times animals. Under poor conditions - dim or no light or smoke - the recognition of a human being (or an animal) with current

[1] Guardians is running from 2007 to 2010, Partners: Sheffield Hallam University (coordinator), Robotic Intelligence Lab Jaume-I University, Spain; Heinz Nixdorf Institute University of Paderborn, Germany; Institute of Systems and Robotics University of Coimbra, Portugal; Space Application Services Belgium; K-Team Switzerland; Dept. of Electrical and Electronics Engineering TOBB University of Economics and Technology, Turkey; Robotnik Automation Spain and South Yorkshire Fire and Rescue Service, UK.

[2] View-Finder is running from 2007 to 2009, Partners: Sheffield Hallam University (coordinator); Eidikos Logariasmos Erevnon Dimokriteiou Panepistimiou Thrakis, Greece; Space Applications Services, Beldium; Galileo Avionica -S.P.A., Italy; Universita Degli Studi di Roma "La Sapienza", Italy; Przemyslowy Instytut Automatyki I Pomiarow, Poland Intelligence for Environment and Security SRL-IES Solutions SRL South Yorkshire Fire and Rescue Service, UK; Ecole Royale Militaire-Patrimoine/Koninklijke Militaire School-Vermogen, Belgium

technology is a hard task. Both projects aim for it but with little confidence and for the time being a human being performs surely much better. The next step, after a victim is located, is to rescue the person found, to do so the condition of the victim has to be estimated on the spot in order to determine the kind of help that is required. As to my knowledge, in this respect no machine can get close to a judgement made by a human being. To cut it short, these are not the tasks we will entrust a robot with in the near future.

Rescue scenarios are often depicted (in particular in films and movies) as piles of rubble with victims buried somewhere underneath. Many attempts are being made to improve robots, but nevertheless current robots are still inflexible with regard to adapting to the local conditions, and again, a human being is far superior.

If robots are still so clumsy, is there any use for robots in search and rescue operations? My answer is: yes certainly! To explore their usefulness one has to examen the circumstances of search and rescue operations in detail. The picture of a rescue scene being a pile of rubble isn't untrue, it may represent the kernel of the incident site but it is not the whole truth and the site is larger. A fire incident is usually depicted as a hero picking up a victim from the flames. Present day robots aren't very heat resistant. And again the flames are only a part of the incident. In case of a fire, smoke and the chemicals in the smoke make the site as much a hazard as do the heat and flames.

I will explain how the Guardians and View-Finder have proceeded. The View-Finder robots are intended to be operated in a scenario which we have called a *Partly destroyed urban terrain.* A pile of rubble might be part of it, but in practise the site will be partly accessible. The problem however is that the rescue workers do not know yet where and how well the terrain is accessible. The robots are to explore the site, collect information about its accessibility, presence of chemicals etc.. If the robots are not able to pass through an area, it is very likely this will be a problem for humans as well, and what has been gained is that from that point on is that the obstruction has been identified and located.

The Guardians project applies a swarm of robots on a undistorted terrain, however, the site is covered in smoke and or chemicals. The site is passable but in the smoke human beings easily get disoriented and may get lost. Tragic examples of firefighters getting lost are the 1991 case of a warehouse fire in Gillender Street London where two fire fighters died and a warehouse fire in 1999 in Worcester (USA) where five fire fighters lost their lives[3]. The task of the Guardians swarm of robots is to search the warehouse and accompany and safeguard a human fire fighter.

Below, in section 2, I will review the robot tasks in the View-Finder project and in section 3 discuss the application of the Guardians robot swarm. I will outline the major techniques and the related questions and problems for each mode of operation and the expected results.

[3] http://www.usfa.dhs.gov/downloads/pdf/publications

2 The View-Finder robots

In the emergency of a fire or in the aftermath of a disaster, the struck area is rather difficult to access and may have become hazardous, hostile or toxic. A pressing task for the Officer-in-Charge is to decide whether the conditions allow human beings to enter the site. However, to establish whether the ground can be entered safely, information is essential and the challenge is to quickly acquire and gather in situ data as well as to dig out any available data bases for additional information about the site. The View-Finder project applies tele-operated robots for inspecting the site. To reduce the risks for humans the robots will enter the ground first to gather in-situ data and verify expectations. The main task of the robots is to detect the presence of chemicals and collect camera images. If necessary, they warn the humans in their vicinity. The bulk of the data is forwarded to an advanced base station for further inspection.

The robots are off-the-shelf wheeled robots for the common fire ground and caterpillars for more difficult terrain. They are equipped with a wide array of chemical sensors supported by conventional sensors. The sensor data are transmitted to the mobile base station that collects and combines the sensor data. While the robots are surveying the ground, the base station monitors their movements and data produced: (toxic) gas distributions, airflow and temperature and connects this into maps.

The in-situ data gathering work of the robots supports clearance decisions and provides detailed information to the (human) intervention teams and services. The data provided by the robots are for a large part input to the Map Building unit, which provides an overview of the data for human interpretation at the base station. The map building process is essential to support the rescue actions. During the operation the operator needs to follow the robots activities. The means are provided through the robot's perceptual devices and its internal states. An over-viewing, interpreting and representing module has to pre-process information and draw the operator's attention towards "what is important" so as to allow him/her to make the proper choices: following a path, enter a covert way, turn around an unvisited area, inspect a tube or a wire connection, check whether a visible victim is really reachable, according to some specific knowledge acquired during the exploration.

Besides the human operator(s), the control or base station is serving the operation commander who is supervising the advancing robot(s) and human explorer(s). An extensive and sophisticated Human Machine Interface presents the information to the commander and to provisions operative human control over the robot.

At the level of operating the robots there are several problems to be solved. One is to interweave human control with the (mostly) autonomously operating robot and to enable the operator to single out an individual robot and take control over it and its sensors. The human interface also has to ensure the human supervisor and human interveners are provided a reduced but good and relevant overview of the crisis ground (including the presentation of the map, sensor-data and images taken by particular sensors/robots).

3 The Guardians swarm

The specific objective of the Guardians project is to apply a swarm of robots in a warehouse in smoke. Some surveys/collections on recent advances and the state of the art in swarm robotics can be found in [1, 4, 5] and a web database on swarm robotics related literature is currently being compiled at http://swarm-robotics.org/.

The Guardians swarm will be able to operate in several autonomous modes. In the basic mode the robots navigate on their own and do not communicate, but just react to each other's behavior, we call this *non-communicative* swarming. The *communicative* mode complements the basic non-communicative mode and allows 'higher' level cooperation, for instance coordinated navigation.

Non-communicative swarming has to be achieved without central or on-line control. The advantages of the non-communicative swarming approach are that the swarming behaviour is relatively independent of the number of robots that are active, making the swarm robust to failures of individuals and its size may vary considerably. It also functions as a fall back if communication fails. A drawback is that as the swarm behavior depends on many parameters and is inherently complex, it is hard to fully predict the behaviour.

Communication improves the abilities for swarm control considerably. For communication based swarming several approaches can be found in the literature, with an abundance of multi-agent based approaches, refer to [2] for a recent overview. Obviously when the robots can communicate they may exchange information about their local environment, enabling better informed conclusions as they may use the information of all other robots. The wireless communication technology also enables position detection. This is important since most position detection systems, for instance GPS, require satellite signals. However, the reception of satellite signals is likely to fail indoors. With positions known and the overall information available the swarm has the basic ingredients for map building, also some robots may act as temporary position beacons and one could even use the robot swarm to set out a complete triangulation of an area.

The swarm is to be applied in industrial environments where the reception of wireless signals is very variable and communication failures are to be expected. The robot swarm brings its own wireless communication network and expands the network as required. The swarm is able to build up and maintain the communication network itself, we define this as the *networking* mode of the swarm. The robots check the strength of the wireless signal, and if the signal is too weak or lost they search for a (better) signal. At swarm level, searching for a wireless signal and building a network transfers into what is called *ad-hoc networking*. In ad-hoc networking the topology of the network changes as the circumstances require. A wireless communication network usually consists of network nodes and clients. The robots can act both as clients and as network nodes, thus while the swarm advances and when necessary some robots will act as network nodes. The result is a mobile ad-hoc network consisting of a set of adjustable and moving nodes.

The robots are also provided with an artificial nose to warn for chemicals. The nose enables the individual robots as well as the swarm to apply *olfactory-based* navigation and chemical plume detection. Relevant aims for the warehouse scenario are: signalling traces of chemicals, locating the source and tracking the chemical plume.

The robot swarm is to support rescue operations whilst the rescuing is done by a human being. Therefore the swarm has to assist and to accompany a human being, in this novel *assistive* mode the swarming behaviour is adapted to enable cooperation between the robot swarm and the human. The robots are autonomous, a feature with far stretching consequences for the human-robot interface: the human swarm interface is essentially very different from the human-robot interfaces applied in telerobotics, for instance in the View-Finder project. In telerobotics several humans may operate one robot, in Guardians however, it is basically one human being cooperating with several robots. A basic question is whether the human squad-member is leading the swarm or whether the swarm is guiding the human being.

Whether supporting or leading, the swarm of robots should in general not increase the navigation related load (physical or cognitive) [3] of the human being. This is even more true in the context of human robot interaction in a fire fighting situation. The smoke and the noisy breathing equipment, pose a difficult design problem for the human robot swarm interface. One cannot rely on the commonly used audio-visual communication means and the project is forced to look at other means to establish communication between the human and the robots. The objective of having a human participate in the swarm of robots is to add some qualities which are not inherently available in the robotic swarm. Human control in swarm robotics allows for dynamic control of specific swarm activities based upon local circumstances and human expertise. In addition, feedback from local robots can enhance the task performance of the human being.

4 POTENTIAL IMPACT

South Yorkshire Fire and Rescue Service (SyFire) proposed the use-case scenario of searching a warehouse covered in smoke. Performing research in this scenario will deliver several important innovations and results:

-a review of the currently applied search strategy and procedures, which date back to the Second World War. Using robots completely new strategies may arise, that may be useful even without robots being applied;

-applying robots (even if only partially successful) may enhance and speed up this time consuming search task;

-a continuously evolving ad-hoc wireless network will be developed, which can be applied on robots as well as on human fire fighters;

-several solutions for localization are developed, based on sensors and on communication; each of which might aid the current orientation problem of the fire fighters;

-the robot-nose and chemical sensors devices do speed-up the identification of possible toxic gases and enhance decision making by the commander on whether and how the ground can be entered by a human fire fighter.

At a built-up terrain, and in an industrial warehouse in particular many metal obstacles may be present that pose several communication and connection problems. The Fire and Rescue services are desperate for wireless mobile communication systems that do not require that network nodes have to be positioned previous to the network being operational. The ad hoc network, the nodes of which are in the project carried by the robots, would be an ideal solution for the communication problem; implemented with or without robots. The wireless network provides also one of the (rough) means to locate the robots and the human fire fighter. In applications this functionality allows that the operational command can keep track of the fire fighter even when the person is not or no longer responding.

Guardians project: www.guardians-project.eu
View-finder project: www.shu.ac.uk/mmvl/research/viewfinder/

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