Disaster Risk and Reduction Management with Search and Rescue Robotics Approach

Evgeni Magid, Tatyana Tsoy

Laboratory of Intelligent Robotic Systems (LIRS), Intelligent Robotics Department, Higher Institute of Information Technology and Intelligent Systems, Kazan Federal University, 35 Kremlyovskaya street, Kazan, 420008, Russia

Fumitoshi Matsuno

Mechanical Engineering and Science Department, Kyoto University, 3 Kyoudaikatsura, Nishigyo-ku, Kyoto 615-8540, Japan

Jackrit Suthakorn

Biomedical Engineering Department, Mahidol University, 4, 999 Phuttamonthon, Salaya, 73170, Thailand

Mikhail Svinin

Robot Dynamics and Control Laboratory, College of Information Science and Engineering, Ritsumeikan University, Noji Higashi 1-1-1, Kusatsu 525-8577, Japan

E-mail: dr.e.magid@ieee.org, matsuno@me.kyoto-u.ac.jp, jackrit.sut@mahidol.ac.th, svinin@fc.ritsumei.ac.jp

Abstract

Most Asian countries suffer many heavy rains, associated flood and landslide disasters, which result into a need to run post-disaster search and rescue operations in urban environment. This paper describes typical urban search and rescue scenarios and problems, which arise in such scenarios. We present an overview of a novel international framework that will allow to provide effective disasters response using heterogeneous robotic teams and information collection system for a disaster site management and targets to become a worldwide standard.

Keywords: robotics, information system, urban search and rescue, ROS, Gazebo, heterogeneous robotic teams

1. Introduction

Countries of East Asia are vulnerable to natural disasters as there are more than 30 types of dangerous natural phenomena, including floods, tsunami and earthquakes, that regularly occur in this region. Every year these disasters take thousands of human lives and cause significant economic losses. Therefore, it is highly important to develop and experimentally validate cutting-edge technological solutions in order to deal with such natural disasters as well as with anthropogenic disasters that are caused by human activities. Science and robotic technologies could play a key role in disaster risk prevention and management, and their role in disaster risk estimation and taking care of disaster aftermath rapidly increases.

Rescue robotics deals with development, construction and use of robots in environments that are considered to be unreachable or too dangerous for human health and life. Rescue robotics applications include search for lost humans in wilderness and labyrinths of tunnels, exploration of volcano craters and pipe networks, running reconnaissance tasks in high pressure and poisonous environments under nuclear or chemical contamination, replacing human teams in scouting and mine clearing, supporting military and police operations etc. Rescue robots extend capabilities of human rescuers while significantly increasing their safety. One of particularly important application of rescue robots is referred as urban search and rescue (USAR) domain. A typical USAR environment is characterized by disaster victims that are often buried in locations, which could be hardly reached by human rescuers.

A growing number of emergencies require to employ modern technologies for collecting global data in order to perform natural hazards assessment and disaster prediction with remote sensing, Geological Information System (GIS), satellites and other high-tech tools. To support real-time disaster management, the development of an artificial intelligence based information systems is required. Such approach will allow using effective information exchange and robotic technologies, communication and decision-making systems that are combined with various types of robots[1,2].

Our international research project includes research teams from Russia, Japan and Thailand, and each team contributes unique expertise of the past and the on-going research activities toward a joint goal[3]. In this framework, heterogeneous robotic teams will construct a large collaborative map of a disaster site (Fig.1), which will help human rescue teams to speed up survivors extracting from a disaster site and evaluating dangers of construction collapse and environment pollution.

2. Urban Search and Rescue

A typical rescue site implies multiple tasks, which are usually performed by specially trained human personnel. Taking into account recent progress in robotics, some of these tasks could be transferred to joint human-robot teams[4]. In particular, these could be the tasks in which regular human teams performance is limited or robots may perform outperform humans. Such tasks include:

Reconnaissance and mapping. In wide area search and rescue scenarios reconnaissance and mapping help to estimate a situation at the site before mission launching. These could done by a swarm[5] of homogeneous or heterogeneous teams of unmanned aerial vehicles (UAVs). A large UAV swarm could perform automated scouting and mapping of wide areas, which allows to save time and collect information that helps deciding on further rescue mission flow[6]. The reconnaissance and mapping task could also be performed by unmanned ground vehicles (UGV)[7]. UGVs could construct more detailed maps, yet lack a property of large squares coverage. Both UAV and UGV swarm approaches require proper collaborative and coverage algorithms[8].

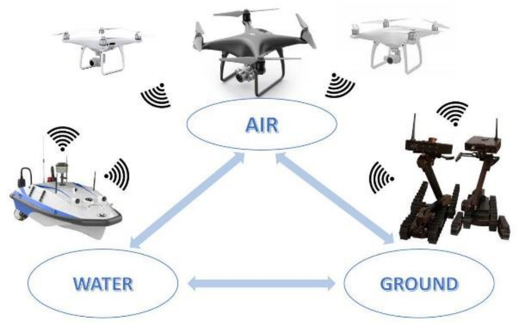

Fig. 1. Collaborative work of robotic teams in different types of environment allow effective data fusion and constructing a detailed 3D map of a disaster site.

Debris penetration. Within this task small sized mobile UGVs penetrate debris deeper than a human or a rescue canine rescuers could do[9]. This enables victims discovery at a significantly faster rate. UGVs could be used for structural inspection of damaged constructions, because multiple on-board sensors combined with data fusion algorithms enable a significantly more complete and detailed building view than human natural senses. While searching post-disaster debris we distinguish three types of openings (referred as voids): semi-structured voids with partially resembling buildings, confined space voids that may be accessed by a crawling person or a canine, and subhuman confined space voids that are too narrow for human rescuers[4]. Such voids may be on fire, may lack oxygen or contain poisonous gases, which prevents human rescues from effective usage the voids. Thus, only a small-size robotic assistant could be used, and this becomes critical for confined space and subhuman confined space void types exploration. In our project we apply a number of various types of UGVs for debris penetration tasks, including Servosila Engineer crawler robot[10] (Fig.2).

Debris removal. These operations in search and rescue scenarios significantly differ from material removal tasks in construction or demolishing. Debris removal operation personal should always consider possibilities of discovering heavily buried victims that may be invisible to the personal at a working point or may be unconscious. In addition, unpredictable structure collapse could occur at any moment as a result of the removal operation. Debris removal tasks may employ exoskeletons and powerful mobile manipulators, but these types of robots are still in their early stage development[11].

Victim Search. Victims should be discovered and extracted within a minimally possible time after a disaster since a victim survival rate decreases rapidly – e.g., after two days of staying under a collapsed building a human's chance to survive becomes less than 40%, while after five days of staying under rubble the probability to extract him/her alive becomes extremely small. To be useful for victims search, a robot should demonstrate an efficiency of a human rescuer or a specially trained rescue canine[12].

Telepresence. This function of a robot allows faster inter team communications for rescue team members inside debris and provides an opportunity of a psychological or medical (telemedicine) support to a discovered victim while the rescue team prepares the victim extraction[13].

Hazmat situations. "Hazmat" refers to hazardous materials. Often during anthropogenic disasters a rescue site suffers from radioactive or chemical contamination. In such cases human rescues cannot efficiently operate within the site and rescue mission preparation and aftermath stages take significant time. Such hazmat cases as Chernobyl nuclear power plant and Fukushima Dai Ichi incidents could have been treated more successfully if robots were intensively used immediately after the disaster occurred[14].

Some of the above mentioned applications are similar to military or police robot applications but many are unique. Usually robots that were initially intended for other tasks are equipped and adapted for usage in search and rescue scenarios. Typically, during a robot assisted rescue operation a rescue robot is deployed on site for initial exploration purposes, and a human tele-operator remotely operates the robot from a safe place outside of the site, using wireless communication[15].

3. Suggested Framework Approach

Based on a theoretical scheme for managing a USAR robotic search in a disaster area[4] and experience of our international team we develop a joint information system for disaster management. The framework of a joint international operation for a disaster site management contains interaction protocols between robots within one team and between robots of different teams, agreements

Fig. 2. Servosila Engineer crawler rescue robot (photo by courtesy of "Servosila" company).

on mapping, data fusion and other collaborative features. The robotic teams include various types of wheeled and crawler UGVs, quadrotor UAVs, a snake-type unmanned underwater vehicle (UUV) and unmanned surface vehicle (USV), which operate as a large international team and supply the informational system with data that is obtained with sensing and mapping activities from water surface, underwater, air and rough terrain (fig.1).

The disaster site maps cover not only typical 3D spatial data but contain additional heat emission, chemical and radioactive pollution information, marks dangerous locations, victims, survivors, animals etc. For mapping tasks simultaneous localization and mapping (SLAM) based approach[15] is used. Yet, since each team uses different robots, different modifications of SLAM algorithms should be adjusted accordingly to sensory and locomotion capabilities of the robots.

The project develops path planning and disaster area coverage algorithms, control strategies and multi-robot joint SLAM technologies for heterogeneous teams of UAV/UGV/UUV/USVs. Robot Operating System (ROS) and Gazebo simulator[15] are used for initial modelling and verification of these algorithms. Figure 3 (left) presents an example of a single destroyed building in USAR scenario. An important contribution of the project to global USAR community is an attempt to create new protocols for collaborative robotic search. Figure 3 (right) presents an example of collaborative work of three Turtlebot robots under "Follow command" protocol[16]. Practical evaluation of the project is scheduled to involve citizens of Kochi prefecture (Japan) in cooperation with Kochi government within the artificial drills conditions. Only an appropriate level of synergy of the international teams will allow a successful construction of a joint informational system for a disaster site management.

4. Conclusions and future work

Every year natural disasters cause human live and economic losses. Recent developments in robotics increase efficiency of search and rescue operations and safety of involved rescue teams. This paper overviews typical search and rescue tasks and presents our ongoing work on development of international operation framework for a disaster site management with heterogeneous robotic teams that consist of UAVs, UGVs, surface and underwater vehicles. The project targets to provide a new working framework and control strategies for international robotic teams cooperative behavior within flood and landslide disaster areas.

Acknowledgements

This work was supported by the Russian Foundation for Basic Research (RFBR), project ID 19-58-70002.

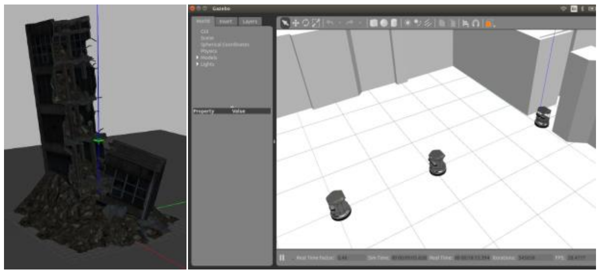

Fig. 3. Modelling robot behavior in ROS/Gazebo environment. A model of semi-structured USAR debris (left) and collaborative work of three Turtlebot robots that perform a "Follow command" protocol (right).

References

1. R. Stephenson and P. S. Anderson, Disasters and the information technology revolution, in *Disasters*, **21**(4), (Wiley Online Library, 1997) 305-334.
2. J. Lee, N. Bharosa, J. Yang, M. Janssen and H. R. Rao, Group value and intention to use — A study of multi-agency disaster management information systems for public safety, in *Decision Support Systems*, **50**(2), (Elsevier, 2011) 404-414.
3. International research project "Disaster management information system for disaster management", Access: *https://kpfu.ru/eng/itis/research/intelligent-robotic-systems-laboratory/research/disaster-management-information-system-for*
4. R. R. Murphy, Human-robot interaction in rescue robotics, in IEEE *Transactions on Systems, Man, and Cybernetics, Part C (Applications and Reviews)*, **34**(2) (2004) 138-153.
5. A. Zakiev, T. Tsoy and E. Magid, Swarm Robotics: Remarks on Terminology and Classification, in *Int. Conf. on Interactive Collaborative Robotics* (Springer, 2018) 291-300.
6. S. Verykokou, A. Doulamis, G. Athanasiou, C. Ioannidis and A. Amditis, A., UAV-based 3D modelling of disaster scenes for urban search and rescue. in *IEEE Int. Conf. on Imaging Systems and Techniques* (2016) 106-111.
7. I. Kevin, K. Wang, O. Singh, E.L. Teh and K. Aw, 3D terrain mapping vehicle for search and rescue, in *10th Int. Conf. on Sensing Technology* (2016) 1-6.
8. E. Galceran and M. Carreras, A survey on coverage path planning for robotics, in *Robotics and Autonomous systems* **61**(12) (2013) 1258-1276.
9. Hoeller, F., Königs, A., Schulz D., Autonomous reconnaissance and surveillance in urban structures-Eurathlon 2013, in *IEEE Int. Conf. on Autonomous Robot Systems and Competitions* (2014), 223-228.
10. R. Safin, R. Lavrenov, E.A. Martínez-García and E. Magid, ROS-based Multiple Cameras Video Streaming for a Teleoperation Interface of a Crawler Robot, in *J. of Robotics, Networking and Artificial Life* **5**(3) (2018) 184-189.
11. S. Park, Y. Oh and D.Hong, Disaster response and recovery from the perspective of robotics, in *Int. J. of Precision Engineering and Manufacturing*, **18**(10) (2017) 1475-1482.
12. M.M. Jackson, C. Byrne, L. Freil, G. Valentin, J. Zuerndorfer, C. Zeagler, J. Logas, S .Gilliland, A. Rapoport, S. Sun, and D. Peet, Technology for working dogs, in *Fifth Int. Conf. on Animal-Computer Interaction* (ACM, 2018) 17.
13. G.J.M. Kruijff, et al. Experience in system design for human-robot teaming in urban search and rescue, in *Field and Service Robotics* (Springer, 2014) 111-125.
14. K. Nagatani, et al. Emergency response to the nuclear accident at the Fukushima Daiichi Nuclear Power Plants using mobile rescue robots, in *J. of Field Robotics*, **30**(1) (2013) 44-63.
15. I. Afanasyev, A. Sagitov and E. Magid, ROS-based SLAM for a Gazebo-simulated mobile robot in image-based 3D model of indoor environment, in *Int. Conf. on Advanced Concepts for Intelligent Vision Systems* (Springer, 2015) 273-283.
16. E. Magid, A. Pashkin, N. Simakov, B. Abbyasov, J. Suthakorn, M. Svinin and F. Matsuno, Artificial intelligence based framework for robotic search and rescue operations conducted jointly by international teams, in *14th Int. Conf. on Electromechanics and Robotics "Zavalishin's Readings"*, 154 (Springer, 2019) *(in press)*.