Editorial: Special Issue on Safety, Security, and Rescue Robotics (SSRR), Part 1

On land, on water, and in the air, disaster response is always a race against time in order to reach out to as many survivors as possible. Rescue robotics is an emerging technology that can be of great use for accelerating this search, and thus for saving human lives. While there has been a notable increase in the deployment of rescue robots for local incidents and disasters, there remain core problems that need to be solved until this emerging technology is ready to be widely adopted.

This special issue on Safety, Security, and Rescue Robotics (SSRR) appears in two parts, the first in May 2016 (Issue 3) and the second in June 2016 (Issue 4). This part deals with core problems of mobility, communication, and structure recognition on unmanned vehicles operating on rough terrain, under the sea, and in the air. This is the third special issue on SSRR published by the Journal of Field Robotics. Our previous issue in March-May 2011 focused on the overall design as well as crucial components for advanced locomotion, and our previous issue in January-February 2008 focused on lessons learned from field trials in the search and rescue domain.

Several natural disasters that occurred in the past were in connection with the flooding of larger areas. In such situations, unmanned underwater and surface vehicles can be of great use for disaster mitigation. The paper by Ozog *et al.* presents an approach to long-term multi-session mapping on underwater vehicles with a focus on ship hull inspection tasks. The proposed method uses a combination of visual features and locally planar surface patches for registering multiple maps and combining them into a single representation of the ship hull. The authors describe how to use generic linear constraints to iteratively sparsify a map over several sessions, which allows for real-time operation. Results are presented from two long-term datasets collected from two large ships illustrating how the proposed method is robust towards significant changes in the local visual appearance of the hull structure.

In their field report Qi *et al.* describe their solution to collapsed-building detection by integrating low-altitude statistical image processing methods on rotary-wing unmanned aerial vehicles. The system design is based on requirements collected from both literature and experience from search and rescue after earthquakes. In 2013 the system supported the Chinese International Search and Rescue Team to accurately detected collapsed buildings for ground rescue guidance at low altitudes after the earthquake in Lushan, China.

The paper by Rollinson and Choset presents a method of achieving whole-body compliant motions with a snake robot that allows the robot to automatically adapt to the shape of its environment. This allows a snake robot navigating a pipe to adapt to changes in diameter and junctions, even though the robot lacks mechanical compliance or tactile sensing. The compliant controller estimates the overall state of the robot in terms of the parameters of a low-dimensional control function, i.e., a gait. The controller then commands new gait parameters relative to that estimated state. The system enables more sophisticated motions that would previously have been too complex to be controlled manually.

Autonomous navigation is challenging when considering a natural outdoor environment and a robot that has many degrees of freedom. Belter *et al.* propose a navigation system combining robust environment perception with onboard sensors, efficient environment mapping, and real-time motion planning. The key idea of the motion planner is to use a higher-level planner for coarse path planning, considering the terrain cost, on a low-resolution elevation grid, and a lower-level planner to find a sequence of feasible motions on a more precise but smaller map. The system has been thoroughly tested under real-world conditions in experiments with two six-legged walking robots with different perception systems.

The paper by Yamada *et al.* proposes a blade-type crawler vehicle with improved performance over rough terrain. The economical micro unmanned ground vehicle (MUGV) has been designed for observing craters during volcanic eruption. Observing a crater during volcanic eruption is a dangerous task, which is still being performed directly by volcanologists. The vehicle is capable of rapidly capturing arbitrary images and video of volcanic eruptions without being affected by winds or volcanic ash.

Communication is a serious issue during disaster response and mobile robots capable of actively extending communication range are a promising approach. The paper by Min *et al.* presents a networked robotic system design capable of enhancing wireless communication range and bandwidth. The system is composed of active communication nodes implemented as mobile robots equipped with directional antennas. The authors propose a weighted centroid algorithm that facilitates active antenna tracking and direction-of-arrival estimation. The effectiveness of the system has been evaluated under several varying conditions.

The response to the call for this special issue was very strong and following directly after the International Symposium on IEEE International Symposium on Safety, Security, and Rescue Robotics (Linköping, Sweden) in October 2013. We selected 13 articles for the special issue of out of 49 papers that were originally submitted. All articles have undergone the journals rigorous review process and were partially presented at the Symposium.

We wish to thank Sanjiv Singh for his advice during the reviewing process. Our sincere appreciation goes to Sanae Minick for guiding and supporting the overall process while being very assistive at several administrative details. Our reviewers deserve special recognition for their thoroughness and patience.

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Editorial: Special Issue on Safety, Security, and Rescue Robotics (SSRR), Part 2

On land, on water, and in the air, disaster response is always a race against time in order to reach out to as many survivors as possible. Rescue robotics is an emerging technology that can be of great use for accelerating this search, and thus for saving human lives. While there has been a notable increase in the deployment of rescue robots for local incidents and disasters, there remain core problems that need to be solved until this emerging technology is ready to be widely adopted.

This special issue on Safety, Security, and Rescue Robotics (SSRR) appears in two parts, the first in May 2016 (Issue 3) and the second in June 2016 (Issue 4). The second part deals with core problems of exploration, mapping, and robot team cooperation on unmanned vehicles operating on rough terrain, and in the air. This is the third special issue on SSRR published by the Journal of Field Robotics. Our previous issue in March-May 2011 focused on the overall design as well as crucial components for advanced locomotion, and our previous issue in January-February 2008 focused on lessons learned from field trials in the search and rescue domain.

Fully autonomous exploration and mobile manipulation on rough terrain are still beyond the state of the art. The paper by Stückler *et al.* describes an integrated robot system to semi-autonomously perform planetary exploration and manipulation tasks. The robot explores, maps, and navigates in previously unknown, uneven terrain using a three-dimensional laser scanner and an omnidirectional RGB-D camera. They also present teleoperation interfaces on different levels of shared autonomy, which allow for specifying missions, monitoring mission progress, and on-the-fly reconfiguration. The integrated system has been demonstrated at the 2013 DLR SpaceBot Cup and DARPA Robotics Challenge.

The use of mobile robots in search and rescue has significantly increased, but robots are still mainly remotely controlled by experts. In the paper by Faessler *et al.* they describe a vision-based quad-rotor micro aerial vehicle that can autonomously execute a given trajectory while providing a dense three-dimensional map of the area in real-time. The system integrates a visual odometry pipeline, state estimation and control, and dense 3d mapping. The platform is based on off-the-shelf components so that the total cost can be kept comparably low. The quad-rotor has been demonstrated over 100 times at multiple trade fairs, at public events, and to rescue professionals. Code, datasets, and videos are publicly available to the robotics community.

Micro aerial vehicles are particularly well suited for the autonomous monitoring, inspection, and surveillance of buildings, e.g., for maintenance or disaster management. In the paper by Droeschel *et al.* they propose a complete multi-layered mapping and navigation system with a multimodal sensor setup for omnidirectional obstacle perception consisting of a three-dimensional laser scanner, two stereo camera pairs, and ultrasonic distance sensors. Detected obstacles are aggregated in egocentric local multi-resolution grid maps. Local maps are efficiently merged in order to simultaneously build global maps of the environment and localize therein. The approach has been evaluated with a real autonomous micro aerial vehicle including a complete mission for autonomously mapping a building and its surroundings.

In their field report, Murphy *et al.* report lessons learned from deploying three commercially avail- able small unmanned aerial systems to the 2014 SR-530 Washington State mudslides. The flights allowed the geologists and hydrologists to assess the eminent risk of loss of life to responders from further slides and flooding, as well as to gain a more comprehensive understanding of the event. This illustrates the evolution of SUASs from tactical data collection platforms to strategic data-to-decision systems. The deployment provides lessons on operational considerations imposed by the terrain, trees, power lines, and accessibility, and a safe human to robot ratio. The paper further identifies open research questions in computer vision, mission planning, data archiving, and mining.

Several tasks in rescue robotics, such as 3d mapping and victim search, are depending on algorithms for coverage to coordinate observations by single or multiple sensors over time. The paper by Tamassia *et al.* considers the problem of coverage in outdoor environments when deploying multiple robots equipped with conventional cameras. They use a descriptor for visual coverage that encodes a measure of the information gain contained in the observed area. A coordination approach is used to compute the trajectories of the robot team in order to maximize coverage gain. The method is evaluated in realistic simulation frameworks using real world data and is compared to random, semi-random and uncoordinated approaches.

Searching for victims in unstructured environments by a team of robots requires adaptive mechanisms to efficiently partition the search space among the team members. The paper by Liu *et al.* presents a hierarchical reinforcement learning based control architecture for multi-robot teams to cooperatively explore and identify victims in cluttered environments. Their approach allows for effective task allocation and task execution while integrating human decision makers. The method is validated by extensive experiments in simulation and in the real world.

One goal of developing autonomous capabilities for rescue robots is to facilitate automated search for survivors in larger environments. While unmanned aerial vehicles are already deployed today for searching flat terrain, there are almost no solutions for searching confined 3d structures such as collapsed buildings. Dornhege *et al.* proposes a solution to the multi-robot coverage search problem in complex 3d environments. The authors evaluate different planning algorithms and their combinations empirically. They finally propose a solution that is feasible for coverage search in 3d and ready for real-world applications.

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