Robotics for Environmental Monitoring

By Matthew Dunbabin and Lino Marques

Robotic systems are increasingly being utilized as fundamental data-gathering tools by scientists, allowing new perspectives and a greater understanding of the planet and its environmental processes. In the past, their use in environmental sciences has been relatively subtle and not highly publicized, but recent disruptive events (such as the 2010 eruption of Eyjafjallajökull in Iceland, the massive oil spill in the Gulf of Mexico from the Deepwater Horizon platform, and the tragic 2011 earthquake and tsunami in Japan) have reinforced and highlighted the importance and ability of robotic systems to efficiently and precisely measure and potentially reduce environmental events at scales that were never thought to be possible before.

One obvious advantage of utilizing robotics in environmental sciences is that they allow the monitoring and sampling of events that are too dangerous or impossible for humans to undertake.

With ever-increasing public awareness of robots being able to collect scientifically relevant information and interact with the environment, new opportunities are arising for large-scale environmental monitoring that are expected to push the frontiers of robotic and natural sciences.

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One obvious advantage of utilizing robotics in environmental sciences is that they allow the monitoring and sampling of events that are too dangerous, or impossible, for humans to undertake. Having the ability to measure these previously unmeasurable events poses the question of determining what exactly we are trying to measure and how can this be achieved given operating and environmental constraints. Then, with this ability to collect scientifically relevant measurements at unprecedented spatial and temporal scales, how do we efficiently process potentially enormous volumes of data and turn it into useful information.

Following the announcement of this special issue on robotics for environmental monitoring, we attracted a large number of impressive submissions from institutions around the world. These articles considered robotic systems and sciences applied to a diverse range of environmental monitoring applications within the marine, terrestrial, and aerial domains. Unfortunately, space limitations prohibit the presentation of all the articles in this issue. However, some will appear in the subsequent regular issues of the magazine as they are substantive pieces of work and illustrate unique applications and advances in robotics in this area.

This special issue contains a collection of six articles that illustrate the breadth of research activities, applications, and challenges within the environmental robotics research landscape and offers an interesting resonance with those opportunities and the above-mentioned problems.

The first article by Dunbabin and Marques, "Robotics for Environmental Monitoring," collates and discusses the significant advancements and applications of marine, terrestrial, and airborne robotic systems developed for environmental monitoring over the past two decades. It also discusses the emerging research trends for achieving large-scale environmental monitoring such as cooperative robotic teams, robot and sensor network interaction, adaptive sampling, and model-aided path planning.

The obvious benefit of field robotic systems is to remove scientists from immediate danger. Muscato et al., in their article "Volcanic Environments," discuss their long history of experiences in the development and application of terrestrial robotic systems for monitoring active volcanoes. They highlight the system requirements and challenges for collecting scientifically relevant information in these hostile environments. With this capability of measuring volcanic processes in situ, volcanologists are now empowered to better understand and investigate the precursors to volcanic eruptions, which will allow for a more precise prediction of the activity.

The next article, "Autonomous Gas-Sensitive Microdrone" by Neumann et al. provides an interesting example of new techniques for sampling environmental processes. It investigates the combination of navigation and chemical sensors to estimate environmental parameters such as wind speed and direction. It then examines different sampling approaches to generate gas distribution maps and predict source localization. The authors demonstrate their techniques using a micro unmanned aerial vehicle in laboratory and outdoor experiments.

The ability of robotic systems to measure large-scale environmental processes is demonstrated in "Autonomous Inland Water Monitoring" by Hitz et al. In this article, the authors discuss the development and application of a novel autonomous surface vehicle for monitoring lakes. Using the system, the authors have been able to test the validity of prior environmental modeling assumptions of homogeneity of an aquatic process. They demonstrate the ability of a single robotic vehicle to capture the spatial and temporal dynamics of evolving aquatic processes such as harmful cyanobacterial blooms that can pose serious public health issues.

The next article, "Monitoring of Benthic Reference Sites" by Williams et al., investigates a critical aspect of marine science in detecting and quantifying changes in the environment over long timescales. This article describes the establishment of an Australia-wide benthic observation system utilizing autonomous underwater vehicles to provide time series imagery of the seafloor. Furthermore, it provides an overview of their research toward generating automated tools to allow the processing of large volumes of high-resolution stereo imagery and multibeam sonar for three-dimensional seafloor reconstruction and image-based habitat classification. Through an extensive experimental campaign, the authors demonstrate the essential ability to revisit sites over year-long timescales to accurately map and quantify the changes of the seafloor.

Despite the incredible advancements of both research and commercially available robotic systems, regulators and authorities still impose significant restrictions on scientists in utilizing these systems for environmental monitoring, particularly near populated areas. The final article, "Sampling Severe Local Storms and Related Phenomena" by Frew et al., discusses specific regulatory, logistical, and technical challenges in deploying unmanned aircraft systems (UASs) for sampling severe local storms. Using their Tempest UAS as a case study, the authors discuss the approaches for addressing these challenges and present experimental results from their supercell thunderstorm penetration trials.

We hope the articles presented in this special issue on robotics for environmental monitoring illustrate the diversity of research, applications, and opportunities within not only robotics sciences but also natural sciences. We certainly enjoyed reading the articles and interacting with the authors during the editorial process.

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Finally, we express our gratitude to all the contributing authors for this special issue. We especially thank the individuals who served as reviewers of these articles. We also thank the editor-in-chief, Peter Corke, for the assistance provided during the editorial process of this special issue.

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