Editorial

Special Issue on Long-Term Autonomy

This special issue of The International Journal of Robotics Research (IJRR) focuses on the theme of Long-Term Autonomy and is concerned with the leap from laboratories to long-term service roles. Naturally, there are big questions to which we would like answers. What are the challenges we must overcome in order to get robots out of lab and into the world? What assumptions should we relax to move forward? What direction should the community go in as a whole? These are difficult questions and this special issue will merely scratch the surface of the answers, but in opening a dialogue we hope to help focus the community moving forwards.

This special issue is another chapter in a dialogue that began a few years ago through a series of workshops:

- ICRA 2011 workshop on long-term autonomy;
- RSS 2011 workshop on autonomous long-term operation in novel environments (ALONE);
- ICRA 2012 workshop on long-term autonomy;
- RSS 2012 workshop on long-term operation of autonomous robotic systems in changing environments;
- ICRA 2013 workshop on long-term autonomy.

These workshops have grown in size and are often standing-room only; we hope this trend continues and we encourage others to attend and contribute.

We are delighted to have accepted nine papers to this special issue on a variety of topics that can be broadly classified into two main long-term autonomy themes: (i) localization and mapping for dynamic environments, and (ii) lifelong learning for adaptive behavior. These have also been recurring themes in the workshop series. One of our papers is a data paper, a special type of IJRR paper that formalizes the process of providing a user-friendly dataset to the community to facilitate comparison and simplification of large-scale experiments; this data paper certainly lives up to the moniker “long-term” as it provides 42 km of data, the full distance of a running marathon. Additional data papers can be found at: http://ijr.sagepub.com/cgi/collection/datapapers.

As a community, robotics has focused intently on the problem of localization and mapping since the mid-1980s. Much progress has been made under the banner of simultaneous localization and mapping (SLAM). However, for long-term autonomous operations in real-world environments, localization and mapping must be viewed as tasks that continue over the lifetime of a robot. Real environments change in their shape and appearance over time, both gradually and acutely. Our authors have provided a number of exciting new approaches to handling environmental change to support lifelong localization and mapping.

Non-linear, optimization-based SLAM has become a core tool in recent years. State-of-the-art systems typically divide the task of building a pose graph into a “back-end”, which has the task of book-keeping all of the uncertainties in the system and appropriately relaxing the graph into a common frame, and a “front-end”, which recognizes revisited places and adds appropriate loop-closure constraints for use by the back-end. Latif, Cadena, and Neira’s paper, “Robust loop closing over time for pose graph SLAM”, provides a novel method of maintaining the front-end/loop-closure decisions over time. Their method makes use of all available information to detect and remove past incorrect loop closures. The method can be executed in an incremental manner, with the result that more accurate maps can be constructed and maintained during robot operations. They validate their work on a variety of real-world datasets.

Saarinen, Andreasson, Stoyanov, and Lilienthal’s paper, “3D normal distributions transform occupancy maps: An efficient representation for mapping in dynamic environments”, combines two popular map representations, Normal Distribution Transforms (NDT) and Occupancy Grids, into a framework that allows them to build consistent laser-based maps online for use in dynamic environments. They demonstrate their approach using data from a milk-factory robot, whose environment is constantly changing as cargo is moved about.

Churchill and Newman’s paper, “Experience-based navigation for long-term localisation”, attacks the problem of outdoor, vision-based localization of a vehicle along a route. They demonstrate that despite large changes in lighting and weather across many route traversals, they can build a map consisting of a finite number of experiences that are sufficient to “span” the appearance of the route. They
is demonstrated using a legged robot whose limbs are
to detect problematic situations and adapt. The method (of the undamaged robot) to that of the actual robot, in order
in the form of comparing the behavior of an internal model
troller to maintain performance. Here, introspection comes
in robotics with the T-resilience algorithm”, considers the
problem of a damaged robot that needs to adapt its con-
mment undergoing continual change. Their approach seeks
to find high-level line features of the environment that do
not change in order to robustly localize over long periods of
time. They demonstrate their method on datasets consisting
of over 10 million laser scans from over 130 km of indoor
driving gathered over a year and a half.

Fallon, Johannsson, Kaess, and Leonard’s data paper,
“The MIT Stata Center dataset”, provides a large-scale
dataset consisting of vision (stereo and RGB-D), laser, and
proprioceptive data gathered using a PR2 robot over 42 km
and 10 stories of the famous Stata Center. Given the variety
and quantity of data, along with good ground-truth, high-
quality comparisons of long-term indoor localization and
mapping, and other techniques, should be possible.

The second theme in our special issue is lifelong learn-
ing for adaptive behavior. We cannot hope to equip robots
with everything they need to know about the world prior to
deployment. Some things will have to be learned along the
way. Introspection, the ability for a robot to gauge its own
performance, appears to be a promising notion to help in
behavior adaptation for long-term autonomy.

Koos, Cully, and Mouret’s paper, “Fast damage recovery
in robotics with the T-resilience algorithm”, considers the
problem of a damaged robot that needs to adapt its con-
troller to maintain performance. Here, introspection comes
in the form of comparing the behavior of an internal model
(of the undamaged robot) to that of the actual robot, in order
to detect problematic situations and adapt. The method
is demonstrated using a legged robot whose limbs are
removed, broken, and rendered inoperable. They show the
ability to continue to walk by adapting behavior.

Ott and Ramos’ paper, “Unsupervised online learning
for long-term autonomy”, examines the problem of learn-
ing to predict collisions with obstacles from sensor data,
simply by interacting with the environment (unsupervised),
in an introspective manner. Through an online clustering
method based on affinity propagation, they are able to learn
models of obstacles from high-dimensional sensor streams,
using onboard sensors such as bumpers for labeling. They
demonstrate this on two problems: learning to predict col-
lisions from laser data, and learning to classify obstacles
from vision data.

nicely fits into both of our special issue themes. They con-
sider the problem of having a robot perpetually improve its
ability to navigate through introspection and selective data
retrieval. They demonstrate this concept in the context of
place recognition (often used as the front-end in pose graph
SLAM), and in particular the popular FABMAP algorithm,
which uses a training set of images to learn a statistical
model of the appearance of a robot’s environment. In the
current paper, they allow the robot to download and incor-
porate new training images from an off-board repository to
better explain perplexing images that it has gathered from
the world, rather than relying on a static training set. They
show the utility of their method on over 32 km of outdoor
data.

Together, we believe these nine papers represent some
of the most interesting and promising avenues of research
towards building autonomous robots that can operate for
long periods of time without human intervention. We hope
readers of this special issue will enjoy these contributions
and that this will be the first of several such issues in the
coming years. We would like to take this opportunity to
thank the authors for their many wonderful submissions, the
reviewers for their insights and suggestions, John Holler-
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who kept us going in the right direction all along. Happy
reading!

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