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RL-Based Robots for Seismic Sensor Deployment

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Introduction

NIFTi was a large-scale four year integrated project funded by the EU Cognitive Systems unit. 1 The NIFTi consortium consisted of six academic partners (i.e., the institutions of the authors of this paper), sharing experience in human-robot interaction, human factors and cognitive user modeling, field robotics, spatial and visual modeling of outside environments, and versatile planning and execution; two user organizations (the Italian National Firebrigade Corps and therefore the Firebrigade of the town of Dortmund) and BLUEBOTICS2 , a corporation who developed the novel rover platform Absolem for NIFTi (Fig. 20). NIFTi's aim was to research cognitive architectures which could meaningfully sense, act and cooperate with humans in real-life environments. Regarding the difficulty of cooperation in cognitive architectures, when NIFTi started, it had been entering a search landscape that primarily focused on autonomy, and high-level communication. Little or no attention was given to creating the cognitive architecture adapt to the human in understanding the environment, planning and acting, communicating. Within the words of the leading experts on human-robot teamwork: "Whereas early research on teamwork focused mainly on interaction within groups of autonomous agents or robots, there's a growing interest in better accounting for the human dimension. Unlike autonomous systems designed primarily to require humans out of the loop, the longer term lies in supporting people, agents, and robots working together in teams in close and continuous human-robot interaction." (Sierhuis & Bradshaw, p.c. 2009). NIFTi adopted the goal to bring the human factor into cognitive architectures while developing robots capable of collaborating with human team members under the complex outdoor circumstances of a disaster response. to deal with this aim, NIFTi put strong emphasis on system integration, embedded within a user-centric approach to system development. The 2 firebrigade organizations included as partners within the NIFTi consortium enabled close involvement of end users, the last word stakeholders during this game, throughout the whole R&D cycle. They provided input to system specifications, participated in yearly exercises and evaluations, and provided feedback for further iteration cycles of the event process. Emphasis on system integration required that each one developed functionality be integrated within the NIFTi system, and exposed to evaluation by the top users. To facilitate this across-the-board integration, NIFTi adopted a scenario-driven roadmap. The roadmap defined progressively more complex real-life scenarios: A tunnel accident (years 1 and 2), a chemical rattler accident (year 3), and an earthquake disaster response (year 4). These scenarios were all instantiated at user training areas, subjecting the NIFTi system to realistic circumstances.

NIFTi organised its R&D around a sequence of scenarios that gently increased in complexity, including operational context complexity (from flat 2D, to semi-unstructured 3D) and collaborative context complexity, like team size, its composition and geographical distribution (from 1 human/1 robot to a geographically distributed team consisting of multiple humans and robots). The robots utilized in NIFTi were an Unmanned Ground

Vehicle (UGV, Fig. 20) and an Unmanned Aerial Vehicle (UAV microcopter, Fig. 21). This scenario roadmap played a key role in providing an integrated conceptual picture for the project, to strongly drive integration of the varied strands of R&D. Furthermore, by basing the scenarios directly in real-life situations in disaster response, we could ground R&D in real needs of Urban Search and Rescue (USAR) teams. The sections below describe the roadmap and therefore the individual scenarios in additional detail.

The NIFTi system constitutes a posh ecology of robots, network communication infrastructure, and a mess of graphical user interfaces (mobile, smart-table, monitor). All of those components share an equivalent network. We use the ROS framework as main middleware for communicating information between these different components. In summary, for the system & network infrastructure, we used ROS for running processes on the robot. Data was streamed over WiFi to at least one or more operator control units (OCU) and other visualization tools (RViz), and for logging purposes (rosbag's). Off-board computers were used for processing 3D laser range data (point clouds), and for the OCU and visualization. We used a 2.4GHz WiFi network, with an antenna nearby the doorway to the particular deployment area. The antenna was 50cm long, had 14dBi gain, and was extended with a Ubiquiti high power bullet enabling a transmission power of maximally 28dBm. Each robot (UGV and UAV alike) was also equipped with a bullet, and an omnidirectional rod antenna with a 9dBi gain. As we were mostly working in large open spaces, we didn't experience substantial problems with network coverage. One among the ways to create robot-centric situation awareness is to style algorithms performing mapping of the robot sensory data into situation interpretation within the robot perspective (given for instance by the interfaces of algorithms that the robot exploits). Such interpretation of things awareness vastly differs from the user perspective since its primary goal is that the effectiveness of the used algorithms. During this field we contributed in two ways: first, we developed an algorithm for terrain perception—the terrain-adaptive odometry; second, we implemented a strong 3D metric mapping algorithm; both contributions improve the robot localization and are described below.

Abstract

The integration of reinforcement learning (RL) and robotics has been successfully applied in various industrial settings. One of the these settings involve the deployment of seismic sensors over wide oil and gas fields. The sensor deployment problem can be formulated as a challenging optimization problem where Markov decision processes (MDPs) can be efficiently used. Our RL-based robot can deploy seismic sensors over soft and rough areas covering wide oil/gas fields. Our prototype robot resulted from an innovation work that is currently protected under two published US patents. A demonstration of the robot capabilities can be found.

[1] A. M. Albaghajati, M. T. Nasir, L. Ghouti and S. El Ferik, “Seismic sensor deployment with a stereographically configured robot,”US Patent No. 9891626, 13 February 2018.

[2] A. M. Albaghajati, M. T. Nasir, L. Ghouti and S. El Ferik, “Apparatus and method for deploying sensors,”US Patent No. 9798327, 24 October 2017.

[3] Youtube video link 1: https://www.youtube.com/watch?v=NHRwFqAiCOM

[4] Youtube video link 2: https://youtu.be/j5mzLTalJFY

Conclusion

We presented an summary of what we achieved within the NIFTi project. We've robust models of 3D dynamic environments, fusing information from a good sort of sensors. We've highly robust and adaptive robot platforms (UGV, UAV) that use these models to work within the complex environments typical for disaster response. And that we have embedded all of that information, of these platforms, into the utilization context of a human-robot team. Humans have access to information at different operational levels, to make an assessment of the general situation, and collaborate with robots as team members to guide further operations. The way information is presented takes under consideration that these contexts are stressful, with people working under varying cognitive load. What's displayed, how, and when, is tailored to suit the present load and usage. While further improvements are possible and needed at the extent of the individual functionalities and system components, the important global achievement of NIFTi is that robots, and therefore the information they supply , are made useful to people. NIFTi achieved this through closely integrating research and development with a scenario-driven roadmap, end users, and real-life experiments. Reality, and real user demand, drove the NIFTi R&D – and therefore the NIFTi R&D showed that, despite the very fact that robot-assisted disaster response may be a complex and difficult task, we will 24 October 21, 2014 Advanced Robotics 2014˙DisasterResponseRobotics.merged make substantial advances towards real-life deployments of those systems. The NIFTi Mirandola deployment is an example of that.

Biography

GhoutiL has completed his PhDin Computer Science from Queen's University of Belfast, UK in December 2005. He is an Associate Professor at Prince Sultan University, Saudi Arabia. He has over 100 publications and holds 28 US Patents. Dr. Ghouti has been serving as an editorial board member of reputed Journals and chaired an international conference on Machine Learning and Data Science.