

Amsterdam Oxford Joint Rescue Forces Team Description Paper Virtual Robot competition Rescue Simulation League RoboCup 2014, João Pessoa - Brazil

Victor Spirin, Mustafa Karaalioglu, and Arnoud Visser

Universiteit van Amsterdam, Science Park 904, 1098 XH Amsterdam, NL
Oxford University Computing Laboratory, Parks Road, Oxford OX1 3QD, UK
<http://www.jointrescueforces.eu>

Abstract. This year the task of the Amsterdam Oxford Joint Rescue Forces is to break up the monolith architecture of the control architecture. On the one hand this will make the existing modules reusable by other researchers; on the other hand it opens the possibility to incorporate efficient modules from other research groups. A first attempt will be to incorporate 3DTK - The 3D Toolkit which provides methods and algorithms to process 3D point clouds.

Introduction

The RoboCup Rescue competitions provide benchmarks for evaluating robot platforms' usability in disaster mitigation. Research groups should demonstrate their ability to deploy a team of robots that explore a devastated area and locate victims. The Virtual Robots competition, part of the Rescue Simulation League [1], is a platform to experiment with multi-robot algorithms for robot systems with advanced sensory and mobility capabilities.

The shared interest in the application of machine learning techniques to multi-robot settings has led to a joint effort between the laboratories of the Universities of Oxford and Amsterdam. The result of this four year collaboration has boiled down in a number of shared publications [2–6] and a thesis [7] from Oxford University. Oxford is still active on this subject [8]. This year's challenge will be to make the world modeling truly 3 dimensional, by using an existing toolkit [9].

To be able to efficiently coordinate a team of robots in a disaster situation many state-of-the-art robotic techniques have to be integrated. Our approach is extensively described in previous Team Description Papers and aggregated in a Technical Report [10]. The later report gives an overview of the publications for the period 2008-2012. In addition, our team had several more recent publications [8, 11, 12, 6, 13–15]. In this paper we will concentrate on this year's innovations.

1 Team Members

USARCommander was originally developed by Bayu Slamet and all other contributions have been integrated into this framework. Many other team members have contributed to perception and control algorithms inside this framework.

The following contributions have been made and will be made this year:

Victor Spirin	: Communication & Coordination [8]
Mustafa Karaalioglu	: 3D scan matching
Arnoud Visser	: Planar 3D mapping

2 Communication & Coordination

The research on coordination teams of robot in an environment with limited communication has been the focus of the cooperation between Amsterdam and Oxford for a long time [16, 2–5, 17, 6, 8]. Central to the previous approach is to explore outside the communication range by assigning exploration and relay-roles to the robots, which build a chain of command (and information) by meeting each other at rendezvous points. Previously those rendezvous points were selected at gateways; the doorways and junctions that form the nodes of topological map of the environment.

This year's innovation is to include the chance to communicate through obstacles (specifically, walls) in the planning of rendezvous points. This approach could reduce the distance travelled by both the explorer and relay for information exchange. Although the wireless signal is attenuated by obstacles as walls (typically 6 dBi), at a short distance communication is still possible.

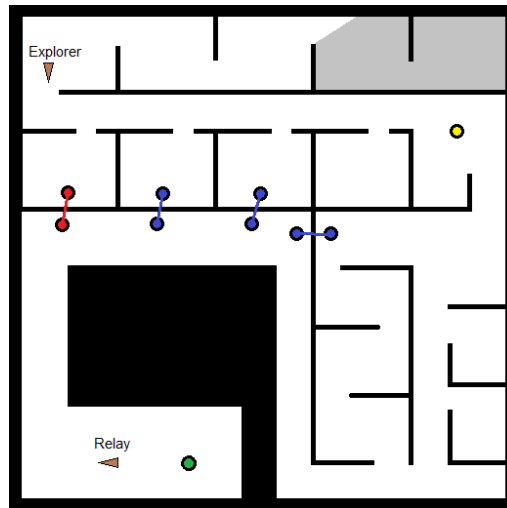


Fig. 1. Potential rendezvous pairs for communication through obstacles.

As an example, regard Figure 1. An explorer has partially explored an environment (obstacles are black, unexplored space is grey and explored space is white), and needs to deliver the new information to the base station (green) via a relay. Conventional rendezvous point is shown in yellow, potential rendezvous pairs through obstacles are shown in blue. The red point pair ends up being selected as the meeting location for the agents, reducing their travel time and increasing team connectivity.

3 Planar 3D mapping

One of the main challenges faced in the competition (and for robots in general) concerns building a map of the environment as the robot explores it. The Amsterdam-Oxford team currently has software that enables a virtual robot to build a 2-dimensional map from sensor data. Although useful in a number of situations, this is potentially quite limiting in the real world, as search and rescue operations are unlikely to take place in perfectly flat environments. Therefore, the aim of this project is to extend the mapping capability to 3-dimensional space. This would give rescue workers a better idea of the layout of the environment, and would help to highlight features and hazards that would not be apparent in a 2D map.

In a previous attempt by Nelson [18] to build a 3-dimensional map inside USARSim, the classical ICP algorithm [19] was implemented efficiently with a *Kd-Tree*, an approach already advocated by Rusinkiewicz and Levoy [20]. For efficiency reasons, not the full 3D point-cloud was used by Nelson. Instead, only the edge-points of surfaces were used, which gave an efficiency improvement of a factor 100. The ICP algorithm tries to reduce the distance between the 3D-datapoints by finding the optimal translation and rotation vector, which implies a full 6D localization.

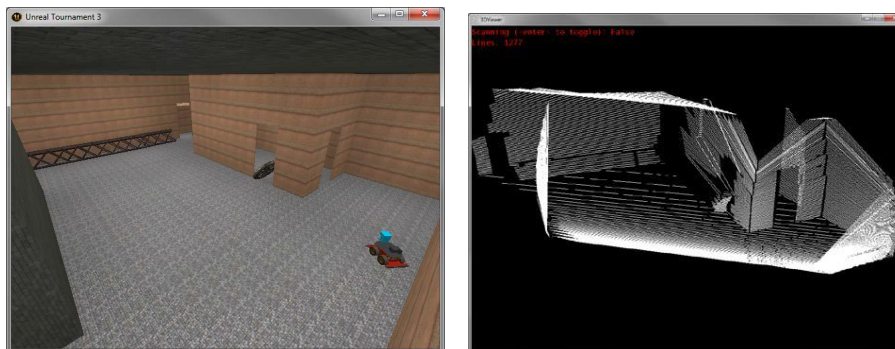


Fig. 2. Example of a 3D scan match inside USARSim. Courtesy Peter Nelson [18].

Yet, in the nomenclature of Borrmann *et al* [9] this is planar 3D mapping and not full 6D SLAM, because the 3D point-cloud consists of slices of a rotating 2D laser scanner. When acquiring this data while moving, the quality of the resulting map crucially depends on the pose estimate that is given by inertial sensors. In principle, the probabilistic methods from planar 2D mapping are extendable to full 3D mapping with 6D pose estimates. Yet, for 3D point-clouds it is essential to have a good strategy for reducing the computational costs of matching.

In the approach of Nelson [18], the 3D map is build based on *pairwise ICP*, which gives good results for local maps, but in the end registration errors sum up. Borrmann *et al* [9] solve this by adding a loop-detector in the code, which indicates when a place is visited for a second time. At that moment a 6D graph optimization algorithm for global relaxation based on the method of Lu and Milios [21] is employed.

The benefit of using the 3DTK Toolkit is not only that it contains Lu and Milios' SLAM algorithm, but in addition that the whole implementation is highly efficient, for instance the datastructure for the nodes is 8 times smaller than the datastructure used in PCL [22].

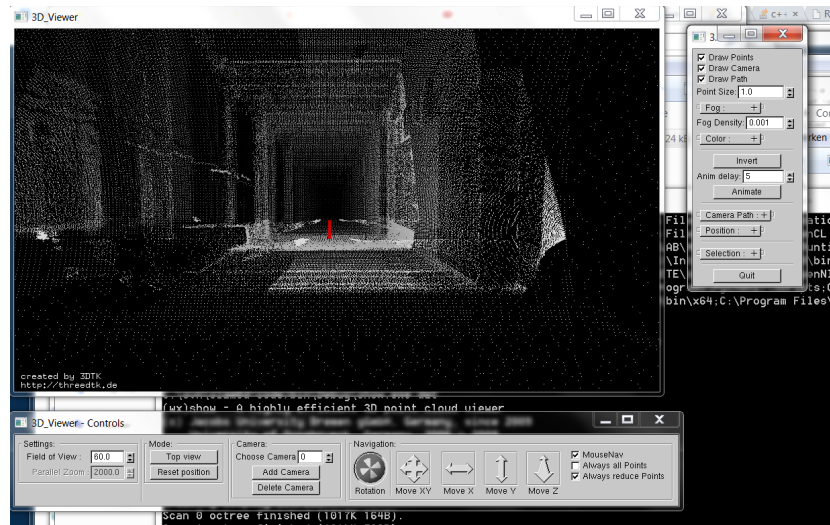


Fig. 3. Example of a 3D scan of a passage in Dagstuhl castle, recorded during the workshop 'Towards Affordance-Based Robot Control', 2006. Courtesy Andreas Nüchter [23].

Currently, an attempt is made to incorporate an implementation of the Weighted Scan Matcher [24] into the 3DTK toolkit, which is implemented in C++. At the same time the implementation of the Weighted Scan Matcher in our user interface USARCommander (implemented in Visual Basic) is carefully validated and when possible replaced by the efficient 3D implementation of the 3DTK toolkit.

4 Innovations

The scan matching in the 3DTK Toolkit is based on the classical ICP algorithm. In a previous publication [24] we have demonstrated that we could outperform ICP by reducing the correspondence error with the Weighted Scan Matching algorithm. When implemented inside the 3DTK Toolkit, we could study if the increase in robustness is worth the increase in computational complexity.

Although ICP is the most widely used algorithm, it cannot only be outperformed in robustness, but also in convergence speed. ICP exhibits linear convergence, while quadratic convergence is possible [25]. Quadratic convergence could be accomplished with algorithms based on *squared distance minimization* [25] or the simplification *squared tangent plane distances* [26], which is better known in the robotics community.

5 Optimizations

This year the robustness and responsiveness of our user interface has been greatly improved by a number of bug fixes in the code. During the competition at the Iran Open 2014 finally a memory leak was found which prevented us from scaling up the control of larger robot teams. After the Iran Open competition the responsiveness was improved by using event notifications instead of CPU-consuming event polling. In addition, the camera subview is now cut out of the Unreal Tournament window at the robot side (instead of the user interface side). This is both an improvement in realism (the robot camera does not have the whole Unreal Tournament overview) and in efficiency.

6 Infrastructure

Our team will also participate in the Infrastructure competition [27]. The challenge will not only to create new sensors and robots, but to also demonstrate the usage of those new possibilities, especially for rescue scenarios. Possible extensions of the USARSim environment relevant for the Virtual Robot competition are the Uniform Robot Description Format and the Ricoh Theta. Another relevant extension would be a model for the next version of the Kinect sensor.

7 Conclusion

This paper summarizes the plans for improvement of the algorithms of the Amsterdam Oxford Joint Rescue Forces, after a three year break where the UvA Rescue team operated on their own (for instance at the Iran Open competition 2014 and the Infrastructure competition at the RoboCup 2012 in Mexico). In 2013 our team was active in the Darpa Robotics Challenge. Many developments inside our framework are not only valuable inside the Rescue Simulation League, but could also be valuable for the Soccer Simulation, the RoboCup@Home,

RoboCup@Work [28] and the Standard Platform League [13]. For the Virtual Robot competition, developments in the user interface and full 3D mapping are important.

References

1. Visser, A., Ito, N., Kleiner, A.: Robocup simulation innovation strategy paper. In: RoboCup Symposium Track on the Advancement of the RoboCup Leagues. (2014) submitted.
2. de Hoog, J., Cameron, S., Visser, A.: Role-based autonomous multi-robot exploration. In: Proceedings of the International Conference on Advanced Cognitive Technologies and Applications (Cognitive 2009). (2009)
3. de Hoog, J., Cameron, S., Visser, A.: Autonomous multi-robot exploration in communication-limited environments. In: Proceedings of the 11th Conference Towards Autonomous Robotic Systems (Taros 2010). (2010)
4. de Hoog, J., Cameron, S., Visser, A.: Dynamic team hierarchies in communication-limited multi-robot exploration. In: Proceedings of the IEEE International Workshop on Safety, Security and Rescue Robotics (SSRR 2010). (2010)
5. de Hoog, J., Cameron, S., Visser, A.: Selection of rendezvous points for multi-robot exploration in dynamic environments. In: International Conference on Autonomous Agents and Multi-Agent Systems (AAMAS). (2010)
6. Visser, A., de Hoog, J., Jimnez-Gonzalez, A., Ramiro Martnez de Dios, J.: Discussion of multi-robot exploration in communication-limited environments. In: Workshop "Towards Fully Decentralized Multi-Robot Systems: Hardware, Software and Integration" at the ICRA Conference. (2013)
7. de Hoog, J.: Role-Based Multi-Robot Exploration. PhD thesis, University of Oxford (2011)
8. Spirin, V., Cameron, S., de Hoog, J.: Time preference for information in multi-agent exploration with limited communication. In: 14th Towards Autonomous Robotics and Systems conference (TAROS 2013). (2013)
9. Borrmann, D., Elseberg, J., Lingemann, K., Nchter, A., Hertzberg, J.: Globally consistent 3d mapping with scan matching. *Robotics and Autonomous Systems* **56** (2008) 130 – 142
10. Visser, A.: UvA Rescue Technical Report: A description of the methods and algorithms implemented in the uva rescue code release. Technical Report IAS-UVA-12-02, Informatics Institute, University of Amsterdam, The Netherlands (2012)
11. Akin, H.L., Ito, N., Jacoff, A., Kleiner, A., Pellenz, J., Visser, A.: Robocup rescue robot and simulation leagues. *AI Magazine* **34** (2013) 78–86
12. de Waard, M., Inja, M., Visser, A.: Analysis of flat terrain for the atlas robot. In: 3rd Joint Conference of AI Robotics and 5th RoboCup Iran Open International Symposium (RIOS). (2013) 1–6
13. van Noort, S., Visser, A.: Extending virtual robots towards robocup soccer simulation and @home. In Chen, X., Stone, P., Sucar, L., Zant, T., eds.: RoboCup 2012: Robot Soccer World Cup XVI. Volume 7500 of Lecture Notes in Computer Science. Springer Berlin Heidelberg (2013) 332–343
14. Amigoni, F., Visser, A., Tsushima, M.: Robocup 2012 rescue simulation league winners. In Chen, X., Stone, P., Sucar, L., Zant, T., eds.: RoboCup 2012: Robot Soccer World Cup XVI. Volume 7500 of Lecture Notes in Computer Science. Springer Berlin Heidelberg (2013) 20–35

15. Kootbally, Z., Balakirsky, S., Visser, A.: Enabling codesharing in rescue simulation with usarsim/ros. In Bethke, S., Veloso, M., Visser, A., Xiong, R., eds.: RoboCup 2013: Robot Soccer World Cup XVII. Volume 8371 of Springer's Lecture Notes on Artificial Intelligence. (2014) 593–600
16. de Hoog, J., Cameron, S., Visser, A.: Robotic Search-and-Rescue: An integrated approach. In: Proc. of the Oxford University Computing Laboratory student conference 2008. Number RR-08-10 in OUCL (2008) 28–29
17. Wellman, B.L., de Hoog, J., Dawson, S., Anderson, M.: Using rendezvous to overcome communication limitations in multirobot exploration. In: Proceedings of SMC (IEEE International Conference on Systems, Man and Cybernetics). (2011)
18. Nelson, P.: 3d mapping for robotic search and rescue. 4th year project report, University of Oxford (2011)
19. Besl, P.J., McKay, N.D.: A method for registration of 3-D shapes. *IEEE Transactions on Pattern Analysis and Machine Intelligence* **14** (1992) 239–256
20. Rusinkiewicz, S., Levoy, M.: Efficient variants of the ICP algorithm. In: Third International Conference on 3D Digital Imaging and Modeling (3DIM). (2001) 145–153
21. Lu, F., Milios, E.: Globally Consistent Range Scan Alignment for Environment Mapping. *Autonomous Robots* **4** (1997) 333–349
22. Elseberg, J., Borrmann, D., Nüchter, A.: One billion points in the cloud - an octree for efficient processing of 3d laser scans. *ISPRS Journal of Photogrammetry & Remote Sensing (JPRS)*, Special issue on terrestrial 3D modelling **76** (2013) 76–88
23. Nüchter, A., Lingemann, K., Hertzberg, J., Surmann, H.: 6d slam3d mapping outdoor environments. *Journal of Field Robotics* **24** (2007) 699–722
24. Visser, A., Slamet, B.A., Pfingsthorn, M.: Robust weighted scan matching with quadrees. In: Proc. of the 5th International Workshop on Synthetic Simulation and Robotics to Mitigate Earthquake Disaster (SRMED 2009). (2009)
25. Pottmann, H., Huang, Q., Yang, Y., Hu, S.: Geometry and convergence analysis of algorithms for registration of 3d shapes. *International Journal of Computer Vision* **67** (2006) 277–296
26. Chen, Y., Medioni, G.: Object modeling by registration of multiple range images. In: Robotics and Automation, 1991. Proceedings., 1991 IEEE International Conference on. (1991) 2724–2729
27. Visser, A.: UvA rescue - team description paper - infrastructure competition - rescue simulation league - RoboCup 2014 -João Pessoa - Brazil. Intelligent Robotics Lab, Universiteit van Amsterdam, The Netherlands (2014)
28. Negrijn, S., Haber, J., Galama, Y., Visser, A.: UvA@Work - RoCKIn2014 - Toulouse, France. Team Description Paper, Intelligent Robotics Lab, Universiteit van Amsterdam, The Netherlands (2014)