Eurathlon 2013

Scenario Application Paper (SAP) – Review Sheet

Team/Robot IAIR/SMMS
Scenario Search and rescue in a smoke-filled underground structure

For each of the following aspects, especially concerning the team's approach to scenario-specific challenges, please give a short comment whether they are covered adequately in the SAP.

Keep in mind that this evaluation, albeit anonymized, will be published online; private comments to the organizers should be sent separately.

Robot Hardware

Based on commercially available research platform PIONEER 3AT, limited to flat surfaces and small slopes.

Processing

Laptop equipped with NVIDIA GPGPU GF540M for parallel computing, achieving real-time performance.

Communication

WLAN, ASUS RT-AC66U Wi-Fi 802.11ac router.

Localization

The SLAM system is the team's main contribution: An improved SoA 6DSLAM algorithm is used to generate a globally consistent 3D metric map in real time.

Sensing

Low cost 3D laser measurement unit, inertial measurement unit XSENS MTI-G

Vehicle Control

Autonomous navigation with semantic objects identification and online path planning.

System Readiness

Although based on successful previous work in the EU-FP6 ViewFinder project, this is still a research project.

<u>Overall Adequacy to Scenario-Specific Challenges</u>

During the FP6 ViewFinder project demonstration in the NATO base Beauvechain, Belgium, in 2009 the robot was able to build a 3D map in a smoke area up to distances of 20m. So it might cope with the scenario - as long as the terrain is not too rough. It is, however, unclear how OPIs can be detected.

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Scenario Application Paper (SAP)

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SCENARIO: Search and rescue in a smoke-filled underground structure

23-27. September 2013, Berchtesgaden, Germany

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Abstract:
In this scenario we would like to evaluate Small Mobile Mapping System (SMMS) in realistic conditions. We are motivated by the fact that small mapping system can be easier deployed on the side in USAR scenario rather than large machine. There may happen major difficulties to deploy large UGV when the transportation infrastructure is demolished. SMMS is supposed to be deployed in the field with the effort of one operator per robot. Our mapping system is composed of low cost 3D laser measurement unit (range 20m), inertial measurement unit (XSENS MTI-G), mobile platform (PIONEER 3AT robot) and computer equipped with NVIDIA GPGPU GF540M for parallel computing. We presented major improvements into 6DSLAM algorithm based on real-time data registration and loop closing using semantic matching. Thus, our approach efficiently improves the applicability of 6DSLAM in realistic scenarios. We have evaluated the system in the field, where obtained 3D metric maps were compared with geodetic measurements obtained with accurate terrestrial 3D measurement system (Z+F Imager 5010). The results from the field proof the applicability of our SMMS in the field. SMMS is shown on figure 1.

Figure 1: The prototype of Small Mobile Mapping System.

Our experience in the field of mapping the environment with smoke

Mapping and navigation in smoke is a challenging task. In our previous work[1] related with FP6 ViewFinder project (it was a successfully completed EU-FP6 project, grant number 045541 in Advanced Robotics IST-2005-2.6.1, executed from 2006-12-01 to 2009-11-30) we tested mobile robot equipped with orthogonally mounted 2D laser systems (LMS SICK 100, LMS SICK 200). Robot was able to build 3D map in smoke area up to the distance of 20 meters.

[1]J. Będkowski, P. Kowalski, J. Piszczek, A. Masłowski: ATRVJr – mobile robot for Fire Fighter Services, Workshop 'Risky Interventions and Environmental Surveillance RISE, January 2010, CD-ROM (available: http://mecatron.rma.ac.be/pub/RISE/RISE%20-%202010/ATRVJr-MobileRobotForFireFighterServicesBedkowski_Kowalski_P.pdf)

Figure 2: Mobile robot during EU FP6 View Finder project DEMO in NATO base Beauvechain, Belgium 2009.

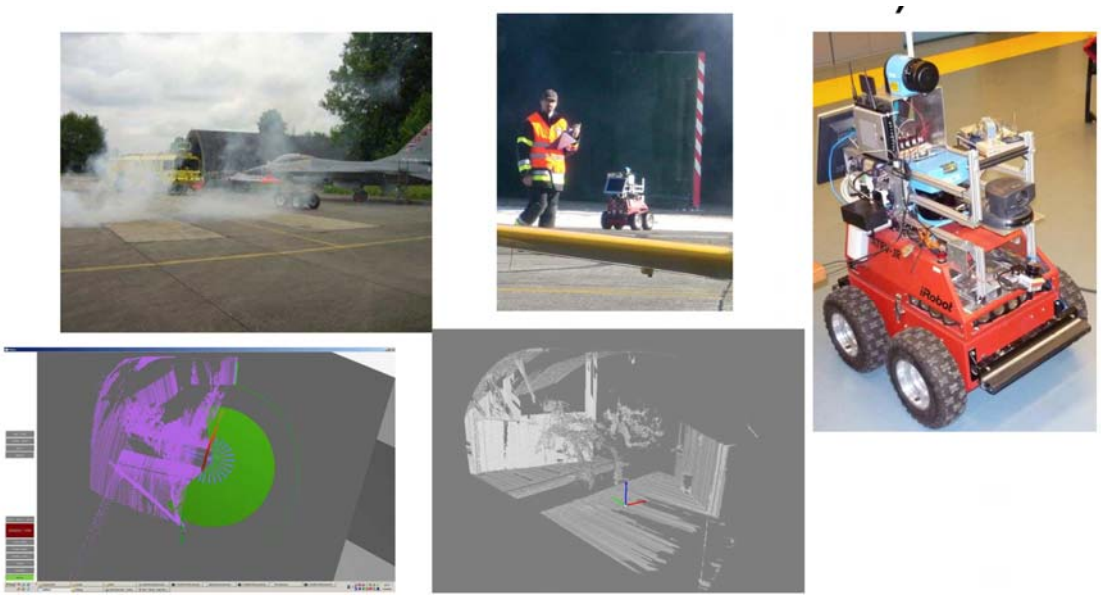

Figure 3: Results of 3D mapping in smoke.

New approach for mapping in smoke

During Eurathlon 2013 we are going to evaluate new filtering algorithms integrated into 6DSLAM framework. Semantic classification with help in extraction of smoke and its elimination during consistent 3D map building.

Description of mobility:

Current prototype is built based on commercially available research platform PIONEER 3AT. It is limited to drive on flat surfaces and able to move over relatively small slopes, therefore we do not consider this mobile platform to be used in difficult/extreme terrain. It can work up to two hours.

Description of localization and mapping

Localisation and mapping was our main research effort [3]. We developed low cost shock resistant 3D laser range finder based on LMS SICK 100 mounted onto rotated head. Our approach is based on improved SoA 6DSLAM algorithm described in [1]. To map environments without occlusions, multiple 3D scans have to be registered. After the registration phase performed in real time a semantic loop closing technique finds matchable scans. If their registration result falls below a threshold, these scans are considered as overlapped. Local maps and robot poses are organized into a graph. Once loop is detected and loop error is distributed over all scans, a 6-DoF graph optimization algorithm [2] for global relaxation is used. The result is globally consistent 3D metric map. To deploy our SMMS into the field we decided to extend SoA 6DSLAM by additional functionalities to cope with problems occurring in real task scenarios. Figure 4 demonstrates the extended architecture of the mapping algorithm. The additional functionalities are:

- data decomposition (we implemented regular grid decomposition to improve Nearest Neighbor Search procedure by decreasing the computational time),
- data filtering and sub sampling (instead of filtering existing in SoA approach, our methods efficiently eliminates noise and dynamic obstacles such walking people), we hope that this method will work with smoke.
- 6DoF GPUICP (we implemented new ICP methods using parallel computing to obtain real-time execution),
- new loop detector - Complex Shape Histogram (it is efficient loop detector using semantic information),
- loop error distribution over all scans (it helps LUM procedure to create consistent map).

The result of mapping in realistic conditions is shown on figure 5.

[1] Oliver Wulf, Andreas Nu¨chter, Joachim Hertzberg, and Bernardo Wagner. Benchmarking urban six-degree-of-freedom simultaneous localization and mapping. *J. Field Robot.*, 25(3):148–163, March 2008.
[2] F. Lu and E. Milios. Globally Consistent Range Scan Alignment for Environment Mapping. *Autonomous Robots*, 4:333–349, 1997.
[3] Janusz Marian Bedkowski, Andrzej Maslowski, Geert De Cubber, (2012) "Real time 3D localization and mapping for USAR robotic application", Industrial Robot: An International Journal, Vol. 39 Issue: 5.

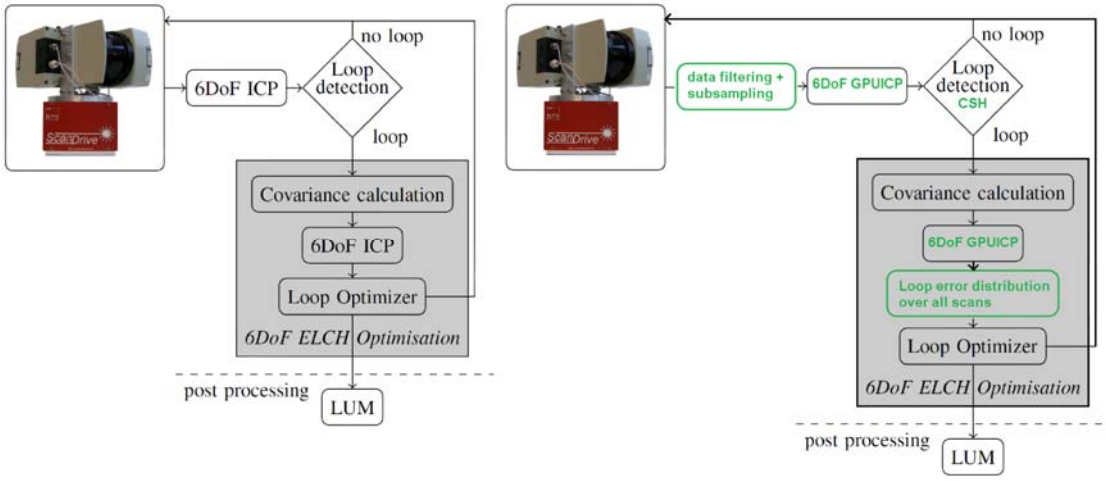

Figure 4: Extended SoA 6DSLAM (left) by additional functionalities to cope with problems occurring in real task scenarios (right).

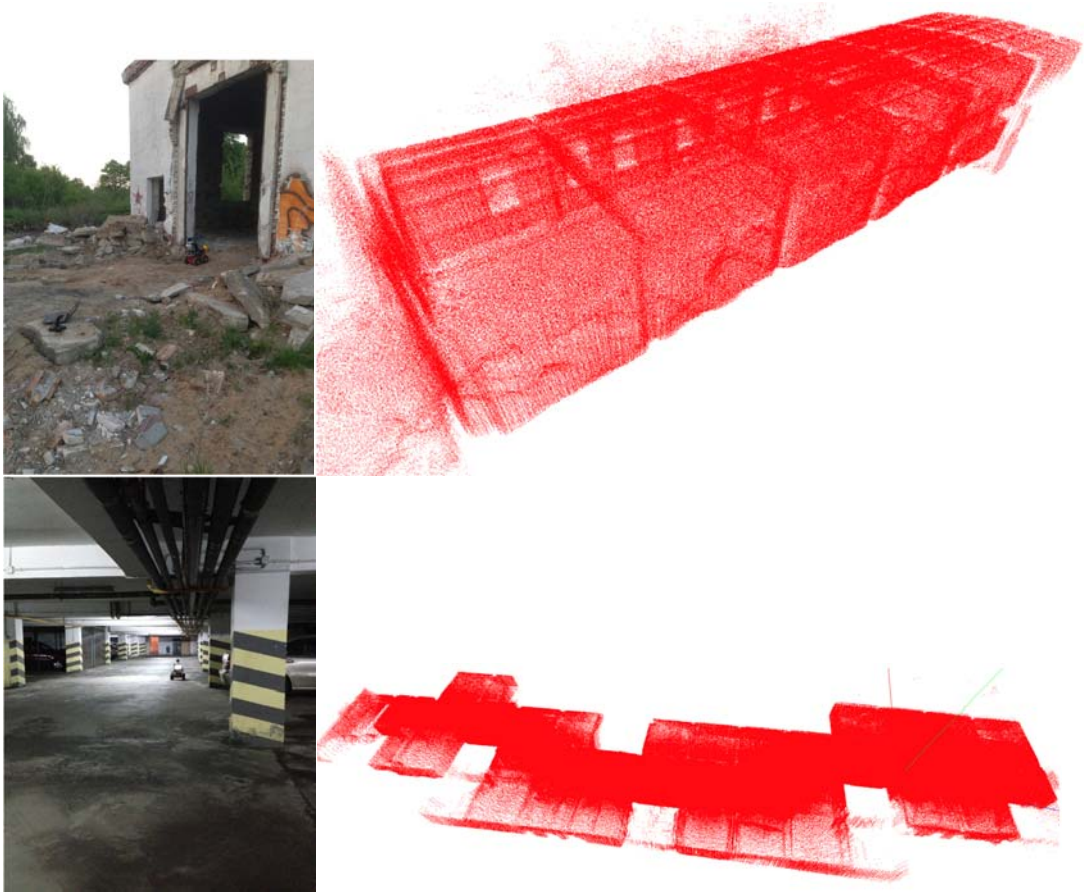

Figure 5: The result of mapping in realistic conditions. Top – USAR like building. Bottom – underground garage.

Navigation in USAR like environment

We developed new robot control architecture based on parallel computing capabilities of on-board robot computer. This architecture controls the sequence of algorithms used for autonomous navigation in difficult terrain such USAR like scenario (figure 6). Following control algorithms are executed in the loop:

- data registration,
- semantic objects identification (floor, wholes, slopes, walls, traversable/not traversable area, etc…)
- path planning,
- computation of qualitative decision concerning navigation.

Robot is able to update navigation plan during 3D data acquisition. All computation is performed on GPGPU, therefore it is possible to achieve the performance considered as a real-time (constant execution time).

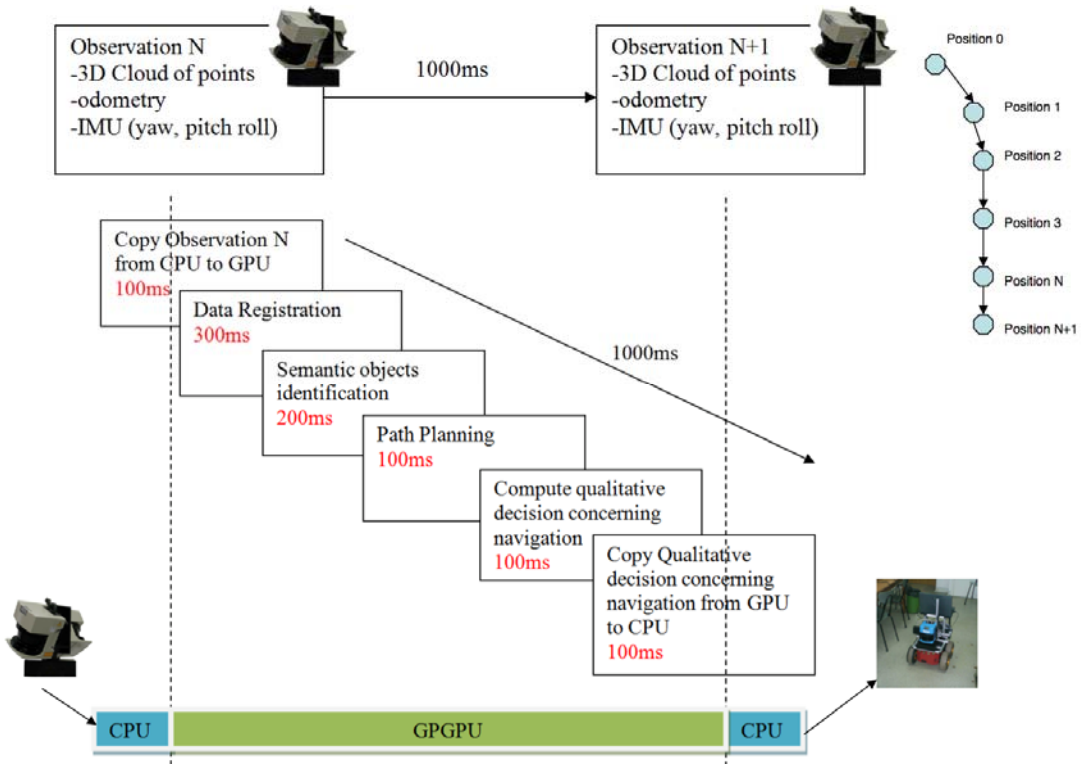

Figure 6: The sequence of algorithms used for autonomous navigation in difficult terrain such USAR like scenario.

Communication

During Eurathlon 2013 we would like to evaluate new communication module based on Router ASUS RT-AC66U Wi-Fi 802.11ac 5GHz.

Acknowledgement

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