Eurathlon 2013

Scenario Application Paper (SAP) – Review Sheet

Team/Robot Space Applications Services
Scenario Mobile manipulation for handling hazardous material

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

The robot hardware adequately covers the requirement for navigation in a rough terrain with obstacles (kerbstones, tracks, rails). The manipulator is also appropriate for the scenario; the 6 DOF ARM2.0 with a two finger (pincer) gripper allows grasping of valves and lifting of loads.

Processing

An on-board computer - a MiniTX PC allowing basic sensor data processing and robot autonomy, provides processing. The team is considering replacing this computer with a high performance laptop in an effort to increase autonomy for the euRathlon competition.

Communication

The robot adequately covers communication needs with a Ubiquiti UniFi Outdoor Access Point operating in the 2.4 GHz band, compliant with Directive 199/5/EC. This has an effective range of approx. 180m.

Localization

The robot will be tele-operated by the team, thus localisation will be the task of the robot´s operator. If possible, the team may implement an autonomous localization system before the competition. An open source GMapping library to perform 2D SLAM is used to generate 3D maps for local navigation. The robot has a GPS device.

Sensing

The robot sensing provision adequately covers the scenario, with a sensor payload capable of acquiring 3D information on the environment (BumbleBee XB3 stereo camera), enabling human-in-the-loop navigation. The team is considering using a wrist-mounted camera on the robot arm to look over large obstacles.

Vehicle Control

Robot control adequately covers the scenario with human-in-the-loop control and waypoint navigation. The manipulator is tele-operated with some autonomous behaviours. If any of the autonomy aspects do not perform well, there is a back-up operation schema for full tele-operation provided.

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System Readiness

Most of the hardware and software elements of the robot are being developed and validated in ongoing FP7 projects.

Overall Adequacy to Scenario-Specific Challenges

A very good SAP: clear, detailed and focussed on describing how the robot can handle this euRathlon scenario. The overall adequacy of the robot to the scenario-specific challenges is good, even thought the system's technology readiness is not high.

Scenario Application Paper

Mobile Manipulation for handling hazardous material

Abstract : This document includes the common sections of the Scenario Application Paper for Eurathlon 2013 as applies to the team from Space Applications Services. It includes the description of the platform, communication setup, payload elements and approach to tackling mobile manipulation for hazardous materials.

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1 Introduction

This document describes the system proposed by the team from Space Applications Services for the mobile manipulation scenario of Eurathlon 2013.

Section 1 presents the history of Space Applications Services in the domain of mobile robotics, as well as the overall system concept. Sections 2 and 3 describe the robot platform (with expected payload items) and the base station. Section 4 will present the proposed communication architecture, before Section 5 addresses the onboard perception and autonomy of the system. Section 6 will focus on scenario specific challenges for mobile manipulation for handling hazardous material.

1.1 History

Space Applications Services has been active in the domain of robotics for some time, with a number of activities in Planetary Exploration, Search and Rescue and Haptics/Rehabilitation through a number of ESA and EC funded projects such as FP6 Viewfinder and FP6 Guardians. Ongoing research in mobile robotics is primarily through 3 FP7 projects: INTRO (Interactive Robotics research network - http://introbotics.eu/), ICARUS (Integrated Components for Assisted Rescue and Unmanned Search operations - http://www.fp7-icarus.eu/) and FASTER (Forward Assessment of Soil and Terrain data for Exploration Rover - https://www.faster-fp7-space.eu/). In the INTRO project, Space Applications has implemented a mobile robot capable of navigation and autonomous (marker based) manipulation (grasping). In the ICARUS project, the responsibility of Space Applications includes development of Command and Control interfaces to control heterogenous robots (UGVs, UAVs, USVs) including portable interfaces and haptic tele-manipulation. In the FASTER project, the responsibility of Space Applications includes development of autonomy and perception subsystems (including guidance, navigation and control) allowing collaborative autonomous operations of a planetary exploration rover with a scout rover. Results from past and ongoing projects will be integrated for the purpose of Eurathlon 2013.

Additionally, team members have past experience in robot competitions such as Robocup Rescue (both real and virtual leagues), as well as attendance as visitors to C-ELROB 2011.

1.2 General Approach

The approach adopted by the team from Space Applications Services centers around human in the loop control, with shared deliberative (and functional) capabilities between the base station (operator control interface) and the mobile robot platform.

Ideally, the operator uses high level commands such as local exploration or go-to-waypoint(s) to command the robot through a user centric graphical interface. Products of on board perception are sent from the robot to the base station, where more complex processing – such as 6D SLAM resulting in accurate 3D maps - may take place. Such high level commanding with on board autonomy allows the mobile robot to explore regions with intermittent communication while allowing a remote operator to make critical decisions and view the collected data in a timely manner. This approach will be complemented by a nominal approach allowing full tele-operation with minimal (obstacle avoidance) or no on board intelligence.

Two approaches for manipulation will be implemented – autonomous grasping based on detection of the object using vision, and tele-manipulation using a haptic capable interface.

2 Robot Platform

The platform used by the team from Space Applications Services will be the Clearpath Husky A200 (provisionally named ‘MILOU’). The Husky is a ruggedized, outdoor robot with significant mobility capabilities in highly unstructured environments resulting from a 4x4 drivetrain, and a high payload capacity.

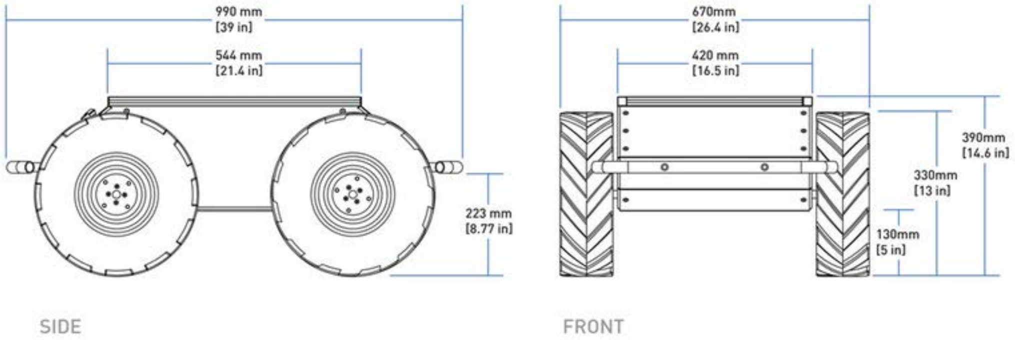

Figure 1. Diagrammatic representation of the Husky A200 [Source: Clearpath Website]

Table 1. Technical Specifications of the Husky A200

Weight & Dimensions	
External Dimensions	0.99 m x 0.67 m x 0.39 m
Weight	49.8 kg (without payload) / ~ 70kg (with payload/sensors)
Ground Clearance	0.13 m
Payload	75 kg (maximum) / 20kg (all terrain)
Performance	
Speed	1 m/s (mximum)
Max. Climb Grade	45 degrees (100% slope)
Max. Traversal Grade	30 degrees (58% slope)
Power Autonomy	8 hrs (basic usage) / ~ 1.5 hrs (driving + payload/sensors)
Operating Temperature	-10 C to 30 C
Environmental Protection	IP 54

The basic Husky platform has been customized to support some of the payloads by the addition of an all-weather plate and a mast. The next subsections will describe some of the payload elements that are expected to be used during the Eurathlon 2013.

2.1 On board Computer

Currently, the on board computer for the mobile robot is a MiniITX PC allowing basic sensor data processing and autonomy on the robot itself. For Eurathlon 2013, we are considering replacing this with a high performance laptop (potentially a Sony Vaio Z series or a Dell Latitude E6530) in an attempt to allow greater processing power and increase the power autonomy. A final decision will be made based on the final on board processing load and the possibility of interfacing with various sensors and actuators.

2.2 Manipulator

The Husky payloads will include the 6 DOF ARM2.0 from Invenscience LC with a two finger (pincer) gripper. Technical specifications can be seen in Table 2. While this will primarily be used for the manipulation challenge, the possibility to use a wrist mounted camera to look over large obstacles is being considered.

Table 2. Technical Specifications of the manipulator

Weight	10.6 kg
Reach	2.74m diameter
Lift	5 – 18 kg
Environmental Protection	IP 63

Figure 2. Invescience ARM 2.0

2.3 Pan Tilt Actuator

An actuated pan-tilt mechanism will be used with the SICK LMS151 and / or the BumbleBee XB3 (see Section 2.4 for sensor details) mounted. The purpose will be to retrieve 3D point clouds of the environment and look in detail at specific regions (operator controlled) for advanced perception and tele-manipulation.

2.4 Sensors

The possible sensor payload for the robot includes:

- PointGrey BumbleBee XB3 (Stereo Camera): used for 3D perception
- SICK LMS151 Laser Range Finder: used for 2D/3D perception
- XSens MTi: Inertial Measurment Unit
- Hokuyo URG-04LX Laser: used for obstacle avoidance
- Septentrio AsteRx2i HDC: used in outdoor environments for localization, with RTK if available
- Logitech Webcam(s): Additional cameras for perception and tele-manipulation

Additionally, if available on loan the Dräger X-am 7000 chemical sensor will be included to identify points of interest.

3 Base Station

The base station (robot command and control center) is a centralized system that provides a visualization of the scenario and incoming sensor data and robot satus, and allows management of operations through online configuration of robot autonomy. It hosts maps with different layers of the area, allows for automated and manual planning of missions, high level and teleoperated control of robots, acquisition and fusion of sensor data from robots. This center comprises of a rugged laptop, mouse, joystick and haptic capable interface.

3.1 Novint Falcon

The base station will include a Novint Falcon haptic feedback interface. This device will be used to provide the operator with 3DOF control of the end effector position.

4 Communication

Communication between the base station and robot platform will be based on the use of the Ubiquiti UniFi Outdoor Access Point operating in the 2.4GHz that is compliant with the applicable provisions of Directive 199/5/EC. It implements a 2x MIMO system, allowing the use of 40MHz bandwidth for higher data rates, and has an effective range of ~180m.

Two network architectures are under consideration: the first with the access point at the base station, and the second where the access point is deployed in the field by the robot platform (e.g. at the entrance) increasing the effective communication range.

On loss of communication, on board autonomy will allow the rover to immediately backtrack its path to recover communication, or achieve local goals before returning to communication range.

5 Perception & System Autonomy

5.1 Localization & Mapping

Primary means of acquiring localization information will be the GPS device (for outdoor usage), the XSens MTi IMU and wheel odometry, which will be fused to give a single pose estimate using an Extended Kalman Filter.

On board localization and mapping will focus on the utilization of the open source GMapping library to perform 2D SLAM. For this purpose, EKF outputs will be used as a priori pose estimates, and roll/pitch corrected laser scans (laser scans projected into the horizontal frame). This approach has been previously demonstrated by the robotics group at Jacobs University Bremen during the RoboCup Rescue Virtual League.

This will be complemented by the creation of local elevation maps from 3D data for local navigation.

Corrected pose from the 2D SLAM will be used to generate 3D maps. The 3D scans and 6DOF pose estimates will be transmitted to the base station where a 3D map will be built in an off line manner for use by the operator.

5.2 Navigation

Navigation is considered as two separate platforms – global navigation and local navigation.

Global navigation is addressed on the base station, where potential routes to a distant target location (potentially set by the operator) are broken down as a traverse graph – a directed graph with potential straight line paths between vertices. Nominally, this will be done by the operator though it might be done in an automated manner if sufficient implementation time is available.

Local navigation represents motion to the next waypoint using the local elevation map. A path to the local goal is planned using D*, with trajectory fitting used to generate drive commands.

5.3 Exploration

Apart from operator generated goals, frontier exploration based on the 2D map will be used for exploration of unknown environments.

6 Scenario Specific Challenges

Mobile manipulation for handling hazardous material adds a number of specific challenges for a robotic system. Some of these are identified and addressed here.

Manipulation Capabilities: The robot platform will have an Invenscience ARM2.0 manipulator (described in Section 2.2). Control will primarily be done through a haptic capable teleoperation interface (Section 3.1), with some autonomous grasping behaviours currently being validated. The manipulator has a reach of 2.7m – though it is restricted in the areas due to the configuration of the links. A pincer like gripper allows grasping of valves, and the screw linear actuators allow significant load to be lifted (exact force measurements have not yet been performed).

Mapping on non-level ground: The approach to SLAM, based on reprojection of laser scans, has been shown to be effective in uneven terrain in the Robocup Rescue competitions. Crossing of railway tracks should be possible, though has not specifically been validated.

High speed traverse: Human in the loop control associated with waypoint navigation, and the backup possibility of direct teleoperation should allow effective traverse speeds in unstructured outdoor environments.

Sensor information and visualization: The robot will have a sensor payload capable of acquiring 3D information of the environment. Along with sensor data enabling human in the loop navigation, full 3D scenes of the manipulation environments will be transmitted to the operator to allow effective telemanipulation.

7 System Readiness

Most of the hardware and software elements that comprise the proposed system are being developed and validated in ongoing FP7 projects, and have a basis in widely known technologies and concepts that have been previously validated. While some of the advanced perception and autonomy aspects might not perform as expected during the competition, a back-up operation schema of full tele-operation supported by onboard autonomy for communication recovery will always be available.