SmokeBot

Mobile Robots with Novel Environmental Sensors for Inspection of Disaster Sites with Low Visibility

Project start: January 1, 2015

Duration: 3.5 years

Deliverable 7.1

Initial Requirement Analysis and Use Case Definition

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Main Authors:

Werner Mastny (TAUR)
Erik Schaffernicht (ORU)

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0.1: initial version, wm, Feb 2015
0.2: first iteration, wm, Mar 2015
0.3: second iteration, es, Mar 2015

Contents

A Introduction and purpose of this document

The SmokeBot project will develop a new tele-operated robotic platform for supporting fire brigades for search and rescue missions with a special focus on operation environments with limited visibility. In order to showcase the developments made during the project a challenging and realistic demonstration scenario is required.

The document at hand defines the demonstration scenario for the final version of the low visibility explorer robot. Derived from the scenario, detailed requirements for the robot and the sensors will be outlined.

B Scenario Specification and Use Cases

This sections will specify the scenario itself and additional uses cases from an end-user perspective. In the following sections these requirements are discussed and translated into functional and technical specifications from the perspective of the robot manufacturer and the scientific users.

To prove the robots capabilities one or more scenarios should be defined. By creating a realistic real-life scenario all achievements and the usability of the robot and its sensors shall be demonstrated. The scenarios shall be set up at real life test facilities of Fire Brigades to get reasonable results.

The Scenario should provide the possibility to validate all developments.

B.1 Kick-Off and Workshop

During the Kick-Off Meeting on February 3rd and 4thwe had an initial discussion on the use cases. Based on the experience of the usage of the current robot of taurob a possible scenario was primarily sketched. One major aspect is that the scenario should not be time critical and/or there should be no humans in danger. In time critical scenarios disaster relief units will enter the disaster site themselves anyway to proceed as fast as possible to the victims. A further aspect is that the robot will be needed in cases where the relief units not want to endanger their own personnel to probable risks. These risks can include hazardous gases, high temperature and low visibility.

On March 10th, 2015 we had a further discussion with prospective end users, the fire department Dortmund, the Fire Department Frankfurt and the Fire department Vienna. In this open discussion the participants were invited to freely talk about their expectations and requirements on a robot. During the discussion basic requirements concerning size, weight, temperature, speed and controlling the robot could be determined.

Additionally the scenario derived in the Kick-Off meeting was outlined. All participants agreed that this is a realistic scenario which furthermore happens quite often. Several additional remarks were made on the scenario from the user side of view.

All derivable information and requirements of this workshop influenced the following requirements and definitions.

B.2 Scenario Specification - Laboratory Accident

We want to set up a realistic scenario which is likely to happen in real life to make work for disaster relief units safer. Based on the discussions mentioned in B.1 a final Scenario taking place in a laboratory was defined. Chemical laboratories are very common in modern industry and accidents there are not uncommon.

As people working in laboratories are trained professionals it is realistic that they escape the building in the case of an accident in time. Furthermore all people working in a laboratory at a time are known and thus it is possible to check that all people have left the building. This would grant the scenario being not time critical. Also hazardous materials are used and stored in laboratories which set up unpredictable conditions for fire brigades in case of an accident.

Following Assumptions are made for the scenario:

- Caused by a chemical accident a fire was breaking loose – different hazardous materials are stored in various places – harmful and/or poisonous vapor are most likely to occur – a list of all stored materials is available.
- The fire has been put out by the sprinkler system in the lab or from the outside widely – Currently the laboratory is full of smoke and fog, possible some small hot spots have remained.
- All workers were able to exit the building safely. However there is a considerable health risk for the fire fighters due to the unknown conditions inside.
- The building is completely evacuated – the operation is not time critical

The low visibility explorer robot shall perform the following mission:

- The robot shall enter the disaster site semi-autonomously (control of the robot by waypoints) → Radar camera and thermal imaging necessary
- Identification and localization of gasses and remaining hot spots→ Thermal imaging and gas sensor needed

Additional conditions that have to be considered:

- The laboratory is not on the ground floor – the robot has to overcome the staircase.
- The journey to the laboratory is 500m long – repeaters have to be deployed
- The Wi-Fi connection is not stable – the available bandwidth of the standard Wi-Fi has to be improved, repeaters have to be dropped by the robot, the robot shall be able to recover to the last position of a good radio signal

- A sketch of the locations of possible hazardous materials is available → integration in the robots path planning
- The robot shall be controlled by high level commands (e.g. entering waypoints) and shall proceedsemi - autonomously through the disaster site.
- Acute hazards (flash over) might occur→ GDIM
- A user might give a command which is dangerous for the robot→ Self-preservation of the robot. (e.g. avoiding areas of high temperatures)

B.3 Additional Use-Cases

At this point some additional use cases shall be mentioned that might be carried out by the developed robot. Those use-cases where discussed in the end-user workshop in detail, since they were considered candidates for the demonstration scenario. We decided to keep them as additional use-cases in this document in order to show that the scenario and the derived specifications are broad enough to handle more than one specific scenario.

In a scenario in a tunnel or underground station the robot could perform investigation tasks for following units. Assuming a fire in a spacious metro station the robot could proceed through the smoky areas and identify possible risks or victims. Localizing people would be essential in this scenario – on one hand to be able to assist them as fast as possible and on the other hand to ensure that the usage of heavy equipment for distinguishing the fire and blowing out smoke can be used safely. Furthermore the robot could provide measurements on temperature and gases defining the safely accessible area for following units.

The robot could also support fire brigades in outdoor scenarios – especially work fire services at chemical industries. In case of an accident the robot could identify the hazard and furthermore again can define the safely accessible area.

Thinking further earthquakes can cause very dusty conditions. The low visibility explorer robot could therefore be used for the localization of persons. However in the case of an earthquake disaster relief units are faced with heavily destroyed buildings meaning the robot would need to have an outrageous mobility to be able to proceed through the collapsed buildings.

C Platform Functional Specification

While the previous section specifies the use-case and lists its requirements to the SmokeBot platform from an end-user perspective, this section translates those requirements into a functional description of the robot platform.

The platform has to serve two purposes. It has to serve as a demonstration platform for the deployment at a fire brigade training site and as a research platform to carry out all the scientific work in SmokeBot. Thus, specifications are derived from the scenarios defined above and from the requirements of a flexible research platform.

C.1 Discussion of Scenario Requirements and Use-cases

In general, we expect the requirements presented in the scenario definition of Section B.2 to be feasible – subject to unforeseeable events. Yet, not all aspects mentioned in the additional use cases will be handled in the limits presented by the SmokeBot project. Most prominent is the detection and localization of people, which is outside the scope of the project. The assumption here is that the operator of the robot will identify people and via the different sensor inputs available, after which he decides further actions.

Furthermore, not all parameters that are fully explored yet, for example heat resistance duration is a subject the end users expressed different opinions (prolonged exposure vs. short term heat spikes). We expect clarification on those issues at latest with the second iteration of this document in form of deliverable D7.2.

C.2 Scenario requirements

Stairs: The robot shall be able to climb standard stairs up to an inclination of 45°.

Robot Speed: The speed of the robot should be 5km/h at least. For long journeys (up to 500m) to disaster sites a faster speed of at least 10km/h or an additional faster transportation method has to be fulfilled.

Operation Time: The operation time shall be at least 1 hour with all sensors active permanently.

Ambient Temperature: The robot shall be able to permanently operate at a temperature of -20°C to +60°C. Additionally it shall withstand 120°C for 30 minutes.

Self-Preservation – Limit values:

Following conditions shall trigger the self-preservation behavior:

- The robot is exposed to a temperature between 60°C and 120°C for at least 30 minutes
- The robot is exposed to a temperature between 120°C and 600°C for at least 5 minutes
- The robot is exposed to a temperature of more than 600°C
- The robot loses its remote connection to the operator

Self-Preservation – User commands: The robot shall alert the operator if a command would lead the robot to areas with conditions that could damage the robot.

Self Preservation – change of conditions: If the conditions change to be critical for the robot the user should be alerted and the robot shall suggest moving to a safe area by user choice.

User Interface - Information: The User Interface shall display the following information by user choice.

- Live feeds of color cameras
- Live Feed of thermal camera
- Gas sensor response
- Radar camera visualization
- LIDAR visualization
- Generated map
- 3D model of robot in current pose

The User Interface shall display the following information permanently

- Battery status
- Radio Signal strength
- Overturn prevention

User Interface – Control Commands: The robot shall have two operation modes – a tele-operated mode and a Semi–autonomous mode.

Tele – Operated mode: The robot shall be controllable with joysticks by the user.

Semi-autonomous mode: The robot shall be controlled by the input of waypoints on a map.

Obstacle avoidance: The robot shall avoid obstacles during navigation. The obstacle avoidance shall also be active in the tele-operated mode and prevent to robot of colliding into obstacles caused by user commands.

Integration of existing maps: The robot shall be able to extract pertinent information from a map image and fuse that with map data generated during operation. The initially extracted map should be of sufficient quality for specifying a navigation task.

Generation of maps: The robot shall be able to generate a consistent structural map of the environment and provide an estimate of its pose in the map, also in a smoky environment.

Protection class: The complete robot including sensors shall be rated IP67.

Transport: It shall be easily possible for two persons to handle the robot.

LED light: LED lights shall be included in the robot.

Color Cameras: Color Cameras shall be integrated in the front and back of the robot.

Gas Sensor Placement: At least two sensors shall be placed on the robot – one as far to the ground as possible, the other approximately 1 meter above (+/- 10cm).

Gas sensor Protection: The gas sensor needs to be protected from dust.

Gas sensor change: The Gas sensor module shall be changeable within 1 minute for different gases.

Decontamination: It shall be easily possible to decontaminate the robot.

Temperature Sensors: Temperature sensors shall be placed inside and outside of the robot.

D Platform Technical Specification

D.1 General Setup and mobility

Drivetrain: The robot shall have two tracks, each track providing at least 40Nm.

Arm: The mounting Arm for the sensors shall provide 3 DOF.

Weight: The overall weight of the system must not exceed 60kg.

Measurements: The robot must not exceed horizontal measurements of 1000x600mm. The mounting Arm for the sensors shall be at least 800mm long.

Batteries: The robot shall have a rechargeable battery which grants the minimum operation time of one hour.

Change of Tracks: The tracks shall be changeable in less than 5 minutes by a trained person.

Safe state: When losing the connection to either a sensor or the remote control the robot must stop all movements.

Loss of power: The robot must not perform any movement in case of loss of the supply voltage.

Visibility: Camera and sensor windows shall be protected against fogging and rain.

D.2 Sensor Suite

Sensor integration: All sensors shall be protected against shocks, vibration and be rated IP67 – either the sensor itself or an additional housing.

Sensor Range: The sensors shall enable to capture an area of 20 meters around the robot for safe navigation.

Smoky conditions: The sensors shall enable the robot to identify its surrounding in smoky conditions.

Weight: The overall weight of the sensor suite shall not exceed 6kg.

Further requirements for the sensors will be outlined in the Deliverable "D7.2 - Second iteration of the requirement analysis and use case definition". Based on the results from the first tests and demonstrations the requirements will be set to meet all necessary functionalities.

D.3 Computing power and communication

Data Link: Gigabit Ethernet shall be used as backbone between all components.

Interfaces: Following interfaces shall be provided on the robot: 12V/1A and RS232 for the gas sensor

- 5V/600mA (USB Power) and Gigabit Ethernet for the Radar camera
- 2-24V, 24W max, and Gigabit Ethernet connection for the thermal camera)
- 12V/1A and Gigabit Ethernet LIDAR

Cable Connection: All Ethernet connections shall provide Gigabit – speed.

Middleware: ROS, Version Indigo, shall be used.

ROS Messages and Nodes: A comprehensive list of ROS messages and nodes shall be defined as the software communication interface between all the different sensors and the main computers. This list will be created and maintained over the whole development cycle of the different sensors that developed and integrated throughout the SmokeBot project.

Droppable Repeaters: To enhance the wireless range 3 repeaters shall be stored on the robot and deployed autonomously. The robot therefor shall define the ideal spots for placing the repeaters during its mission.

Self-preservation of radio signal: On loss of signal the robot shall return to the last known position of good connection.

Bandwidth enhancement: For a better bandwidth the protocol of the radio connection shall be adapted to use several paths of transmission simultaneously.

Embedded PC: An embedded PC with following basic features shall be used: Core i7, RAM 16GB, Harddisk 256GB SSD

E Summary

The document defines the demonstration scenario for the low visibility explorer robot. Based on this scenario more detailed requirements for the robot and the sensors were derived.

The idea of the low visibility explorer robot was well appreciated and has awakened great interest by fire brigades. During the project we will get additional information and further input from prospective end users. According these inputs the requirements will be permanently adapted. Therefore the Deliverable “D7.2 - Second iteration of the requirement analysis and use case definition” will iterate this document in the beginning of 2017.