Eurathlon 2013

Scenario Application Paper (SAP) – Review Sheet

Team/Robot Scentro
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

The robot is based on a Pioneer 3-AT. No pictures of the developed robot are provided and would be appreciated.

Processing

Different processing chain for navigation and image processing. Processor running Ubuntu for navigation and a i7 processor running Matlab for image processing. The idea of dividing the two tasks into two separate processing chains is appreciated.

Communication

A video transceiver transmitting at 5.8 GHz will provide a video stream between the vision computer and the Ground Station computer. Radio-to-Serial transceiver transmitting at 898 MHz to communicate navigation data with the ground station. No explicit means to deal with difficulties of communication.

Localization

Odometry and laser scanner for dead-reckoning. No explicit use of maps or SLAM.

Sensing

Laser for navigation and ultrasound sensor for obstacle avoidance. The team did not have decided which kind of vision system to use: stereo or mono and which kind of cameras. The issues caused by smoke are addressed by placing the sensors close to the floor. No other explicit means are considered.

Vehicle Control

Tele-operated with assistance for waypoint navigation/obstacle avoidance.

System Readiness

Hard to say from the paper. For hw/sw I will say 6-7.

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

From 0-5 I would say 3. No explicit tests are reported and the difficulties of the scenario are not fully addressed.

SCentRo's SAP for

"Search and rescue in a smoke-filled underground structure"

Abstract

The SCentRo team focuses on the scenario of searching a smoke filled indoor/underground environment as indicated by the photograph provided by Eurathlon. The emphasis of the development of team SCentRo is on the autonomous (robot) navigation of the underground structure and finding the Object of Potential Interest (OPI). The basic team comprises of doctoral students working on various aspects of robotics.

Team SCentRo distinguishes the navigation task from the task of finding the Object of potential interest (OPI) and has build the UGV architecture accordingly. A vision system scans continuously the environment for the OPI and provides a life video stream to the remote base station.

Contents

Introduction

The SCentRo team focuses on the scenario of searching a smoke filled indoor/underground environment, refer to Figure 1. The assumptions are that the structure

1. is filled with smoke, though the density of the smoke varies.
2. is considered relatively safe and accessible to a human fire fighter, meaning that the building's structure is mainly in tact and the floor is mostly unobstructed though some debris might be on the floor.
3. an overall map of the structure is available and waypoints can be indicated on the map though map details may not be reliable.

Figure 1, Underground Structure

The emphasis of the development of team SCentRo is on the autonomous (robot) navigation of the underground structure and finding the Object of Potential Interest (OPI). The team stays away from the problems of robot locomotion in fully unstructured environments (rubble and similar).

The SCentRo team consists of seven team members from different backgrounds and with a variety of expertise ranging from various levels of electronic hardware design to software engineering. The formal team leader Prof. Jacques Penders has been an integral part of robotics research for several years and was involved in various projects like Guardians, Viewfinder, REINS etc. The basic team comprises of doctoral students working on various aspects of robotics. Despite the fact that the team does not have any prior experience in robot competitions, it has the confidence to showcase its potential at the venue in front of the judges.

Navigation and searching for OPI

Team SCentRo distinguishes the navigation task from the task of finding the Object of potential interest (OPI). The system approach is to separate the functionality of the control and navigation system of the UGV and the vision system which acquire and identify the target OPI. Both systems running on different processor to optimise performance and reduce bottle nick system failure. The modular approach also enhances the system stability by dedicating each system its own processing power. Critically enough the vision system require much greater processing power to process the acquired stream of images and run the vision algorithm on the GUI software. This is critically important without interrupting the control and navigation processor performing obstacles avoidance and navigation task in real time. The vision system GUI software will run on Netbook powered by the inbuilt battery providing operation time for up to five hours without sharing the UGV on-board power supply, this will realise a reliable system operation. The vision system will only provide a life video stream of the GUI displayed on the vision computer desktop. The life video stream will be transmitted via the video link to the Ground Station operator computer. The vision system is using ISO9000 and ISO9001 standards.

Object of potential interest

In order to find the OPI a vision system (type of camera to be decided) continuously scans the environment of the robot and provides a life video stream to the Graphical User Interface module (GUI) positioned at the remote (ground or) base station (away from the area to be navigated). The data are displayed life on the vision desktop computer. The video stream will be transmitted via a video link to the Ground/base Station operator's computer. The vision data communication is using a dedicated (and separate) communication system which is based on the Wifi-Serial communication.

Vison data collection

The vision system sensing element will be provided via mono or stereo camera system (still to be determined). The purpose of the camera is to acquire images for Matlab vision algorithm to process and identify the target OPI. The cameras will not provide any sensing feedback to the UGV control system. In case of identifying the target OPI sign rectangle shape the vision computer will issue I/O high on the first I/O port connected to the UGV control computer bringing the UGV to a stop. Once the UGV stopped the vision system will attempt to identify the characters printed on the OPI sign post. If the correct OPI is found the vision computer will issues I/O high on second I/O port instructing the UGV control computer to fully stop and the vision computer GUI software will display an image of the target OPI on the Ground station computer via the video link. If no target OPI is found both I/Os are low commanding the UGV to continue driving and searching for the next target OPI. For a heavy smoke environment a SWIR camera and collimated laser illuminator will be utilised to penetrate the smoke. The suggested laser peak wavelength is 1550 nm. Experiment will be conducted to verify the ability of this wavelength to penetrate heavy smoke with visibility of less than half a meter.

Vision data link

A video transceiver transmitting at 5.8 GHz will provide a video stream between the vision computer and the Ground Station computer. The video transceiver will have a maximum range of 4 km line of sight and 1 km in urban area. The actual range would have to be determined experimentally. The vision system logs all images on the on-board vision computer. In case of communication drop out the vision computer will keep acquiring and analysing images attempting to identify the target OPI. Once communication established the vision system will continues sending video stream to the ground station computer.

Vision data processing

The processing power for the image processing will be provided via class i7 processor Netbook provided with a battery life at full load up to 5 hours. The Netbook will run Matlab vision algorithm graphic user interface (GUI) which will be viewed by the Ground station operator computer via a HDMI video radio link. The UGV's complete vision system contains a Netbook computer, mono or stereo camera with USB or composite video output (still under investigation), video(HDMI) to USB converter, and video transceiver operating at (5.8Mhz). The system be will power sufficient and does required any power supplier from the UGV power supply system. This approach has solved many power reliability problems. The operating system running on the Netbook is Windows 7 (64bit). Matlab software includes (computer vision, image and acquisition tool boxes) will be installed on Windows platform to execute an especial vision algorithm. The vision algorithm will provide a character recognition GUI to identify the text character of the target OPI and alert the UGV control and navigation computer to stop the vehicle then notify the Ground Station operator by capturing a still image of the target OPI.

Matlab GUI vision algorithm will be configured to execute automatically upon Windows operating system starts. Windows operating system will be configured to run on medium resource and it will run script to overwrite windows desktop errors messages during starting and operation. The vision system will not require a real time operating system at this point as the i7 processor will be more than sufficient to provide an adequate processing power to run the vision algorithm and override any operating system interrupt in real time. This was proved experimentally. Matlab GUI will also have an error override code to prevent the GUI software from freezing during operation (due to video USB converter drives interrupt) this approach will provide reliable algorithm execution on non-real time operating system. Matlab GUI software will run under university licence. The algorithm code and execution is the property of Sheffield Hallam University.

Navigation

Below we first discuss the robot and additional components required for the navigation task. After that we discuss the integration of the components and the resulting navigation capabilities and functionalities.

Vehicle

As the team assumes that the floor is mostly unobstructed, we apply a wheeled vehicle. The vehicle is a commercially available system from *Adept MobileRobots* called **Pioneer 3-AT** which is skid steering drive (see Figure 2). The physical characteristics of the vehicle are provided in Table.1. The construction is durable and rugged. Easily handles the small gaps, minor bumping, jarring, or other obstacles that hinder other robotic platforms. Some Pioneer robots have been in service for over 15 years. The vehicle is fully assembled and integrated with its accessory packages so it is Technology Readiness Level (TRL) 9.

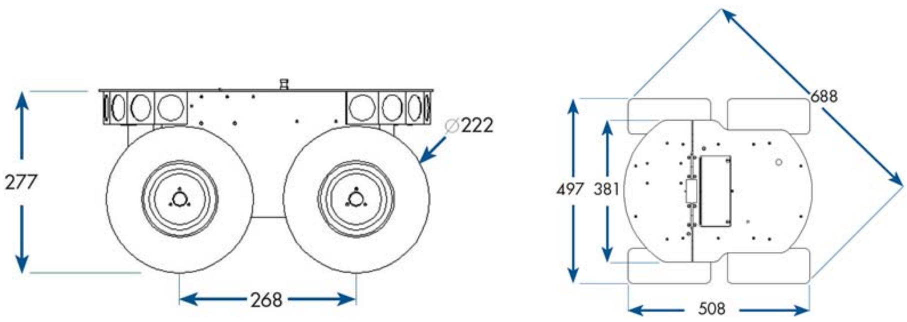

Figure 2, The pioneer vehicle Schematically

Processing for navigation

The robot is equipped on board with a 2.26 GHz Intel Dual-Core processer and it uses Ubuntu 12.04 as operating system with ROS as middleware. The sensory data such as Odometry and Ultra sounds data is being transferred through serial connection. Data publications are being handled using Python and C++ software.

characteristics	Value	characteristics	Value
Turn Radius:	0 cm	Max. Traversable Gap:	15 cm
Swing Radius:	34 cm	Traversable Terrain:	Asphalt, flooring, and, and dirt.
Max. Forward/Back. Speed:	0.7 m/s	Robot Weight	12 kg
Rotation Speed:	140°/s	Pay load	12 kg (Tile/Floor), 10(Grass/dirt), 5(Asphalt)
Max. Traversable Step:	10 cm	Power	3-lead-acid batteries, 2-4 hrs (just robot)

Table 1, Vehicle Characteristics

Navigation Communication link

A Radio-to-Serial transceiver transmitting at 898 MHz will provide UTM coordinates and sensory data stream between the robot and the Ground Station computer. The communication interface on the robot only transmits the data when it receives acknowledgement from the operator. In case the communication link is lost (acknowledgement did not received) the interface on the robot log the data until the communication link is re-established. Once the communication is re-connected, first the logged data will be transferred. The data communication system is using standard serial protocol.

Localisation

The proposed system is being used in an underground structure meaning that no GPS signals can be received. Nevertheless the robot is using GPS coordinates updated with the Odometry data to approximate its location and represent them in UTM coordinates. By default, using GPS in any environment comes with collection of restrictions and it has been recommended that GPS should be used as first solution; however one must always have an alternative method for localisation. Therefore, in this system the GPS unit is only going to act as a correction mechanism and most of the localisation process is approximated using Odometry sensors combined with on-board motion detectors. The main objective of the localisation system is to reference robot's travelled distance with the coordinates of the starting point and to calculate current UTM coordinates at any given time (see Figure 3).

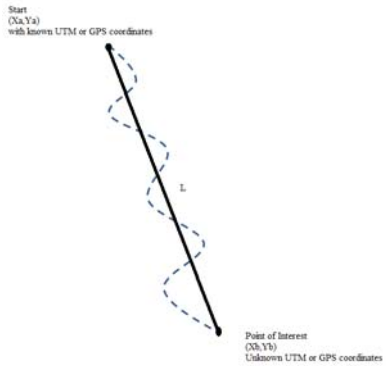

Figure 3, Localisation diagram

At any given time the robot's travelled distance can be calculated. The unknown UTM coordinates then can be approximated based on the initial coordinate and travelled distance.

Concurrently, the GPS module is requesting the current position, if by any chance the system has received any latitude and longitude at specific reading of odometry, the converted UTM coordinates (from GPS coordinates) will record the amount of error in odometry reading. In this localisation system "Adafruit Ultimate GPS Breakout" is going to be interfaced with the robot. The GPS module has a built-in antenna with -167 dBm sensitivity, and it can provide 10 updates upon location request in second from 66 different channels. However, in order to have better sensitivity, an external antenna with higher sensitivity also is going to be used.

Sensing

The external environment will be sensed using two main subsystems, namely a laser rangefinder system and an ultrasonic obstacle detection system. The laser system is mainly concerned with tasks of pose estimation for navigational purposes, it may or may not be utilised for obstacle avoidance purposes, and the ultrasonic system is dedicated to the obstacle avoidance task.

Laser rangefinder system uses the commercially available Hokuyo URG or UTM series, from prior experience with smoke filled indoor environments, the group noticed that such systems are affected by the smoke, however since the hot smoke rises up and tend to have low density closer to the floor, the system performs better when mounted close to the floor. The laser is mounted directly on the mobile base of the robot so as to compensate for the above smoke effect and provide an accurate description of the environment in the base horizontal plane.

The robotic platform used has an embedded ultrasonic sensing subsystem mounted near the top of the platform facing forward and providing a range of 100 to 5000mm and field of view of more than 200°. Ultrasonic is robust in smoke and therefore will be dedicated to collision avoidance, however due to low angular accuracy the system will not be incorporated within mapping or localisation systems. The embedded system may be enhanced by external ultrasonic rangefinder transceivers mounted higher above the floor along the overall system to avoid collision with protruding and hanging obstacles.

System displacement and velocity are observed by two independent subsystems, an internal odometry based system measures the vehicle speed and tracks the robot's displacement w.r.t its initial position, a parallel system utilises the difference between consecutive laser scans to estimate the relative 2D pose w.r.t initial position in terms of transition in XY axes and rotation about Z axis. The two systems provide redundancy in the system to compensate for real-world challenges facing each system.

Vehicle Control

Pioneer 3AT has durable and rugged body and it can handle small gaps, minor bumps or other obstacles that hinder other robotic platforms. Vehicle top speed is 0.7m/sec and rotational speed of 140 degree/sec, so abrupt braking and sharp turns can be controlled by it.

The system is working in semi-autonomous state. Obstacle avoidance is done using the programs implemented which uses 8 forward SONAR and LASER to successfully reach the destination. Waypoint following is done using referencing the initial coordinates from where the robot will start and giving the waypoint coordinates to the robot which it has to reach avoiding the obstacles.

Semi-autonomous – The technician will have the Nintendo-Wii remote with him to override the autonomous system in case of urgency and control it through the Nintendo-Wii remote. Provision will be given to the technician to switch it back to the autonomous mode whenever the urgency is finished.