Proceedings of the OAGM&ARW Joint Workshop 2017 DOI: 10.3217/978-3-85125-524-9-11

Concept and Implementation of a Tele-operated Robot for ELROB 2016*

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***Abstract*— The current use of mobile robots in search and rescue scenarios like natural or man-made disasters is often required to protect emergency response personnel from dangerous situations and support them in their work. At the same time the localisation and rescue of victims has to be achieved fast and reliable. However, a fully autonomously controlled robot is highly sophisticated and needs many sensor components whose data has to be combined. Due to this fact, mostly a combination of a tele-operating system and a fully autonomous system is implemented.**

This paper focuses on developing a concept for a taurob robot for participating in the European Land Robot Trials 2016 (ELROB). The aim is to integrate suitable sensors into the robot system and to implement a tele-operating mode. The selection of the sensors is based on criteria's of the competition's scenarios. For the implementation of the tele-operating mode, the Robot Operating System (ROS) is used. Two variants, a keyboard and an Xbox Controller, are tested to steer the robot.

The obtained results show that operating the robot by the Xbox controller is easier and more precise than by the keyboard. Combined with the sensors, the system shows an overall solid performance and provides a good basis for further development.

I. INTRODUCTION

Disaster control and its dangers are a big topic, that can be covered by robots to protect rescuers from hazardous environments [5]. The European Land Robot Trial is a convention for showing the abilities of different unmanned systems in realistic scenarios [2]. The aims are headed towards the greatest possible autonomy and strong performance. To participate at ELROB 2016 the servicerobot Robbie was designed to fulfill the requirements of three different scenarios [3]. This robotic system is based on an Austrian robot platform from the company taurob [1] and was developed to compete in the challenges of three scenarios. Reconnoitring of structures (e.g., mapping), search and rescue (find and drag a dummy body) and Reconnaissance and disposal of bombs and explosive devices (EOD/IED). To achieve results in these challenges, several sensors and a controlling system were integrated to the robot. In the following, these systems are specified and their performance is discussed.

II. SYSTEM OVERVIEW

The system consists of the robot vehicle and its selected sensor components.

A. Robot Vehicle

The basis of this project is a Taurob robot [1]. It is a rugged mobile service robot, which is driven differentially and has capabilities to handle rough terrain. The robot structures itself into the base, the wheels and the wheeled driven rubber tracks. For a better climbing performance, it is also possible to adjust the latter ones in height by the robot's driving motors. This function makes it able to climb slopes and stairs up to 45 degrees and obstacles up to 35cm in height. The robot is waterproof and designed for harsh environments, too. Interaction with its environment is achieved by the robot arm, which has the strength to pull a body with 20kg in weight. Additionally, the robot is equipped with Ethernet ports to allow easy integration of various hardware components like the robot arm and sensors.

Moreover, the upper side of the robot base includes a voltage supply socket. It provides two voltage levels, one stabilized 12V (max. 4A) and a 24V (max. 5A) battery voltage. These two voltage levels make it possible to power all used hardware components. The robot's integrated WLAN router achieves a wireless communication between the robot and a laptop. Fig. 1 shows an example of the Taurob robot with all integrated sensor components.

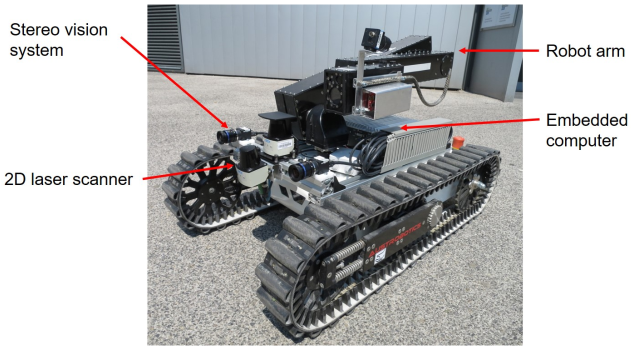

Fig. 1. Sensor setup of Robbie

B. Robot Periphery

For participating in all ELROB scenarios, a stereo vision system, several Cameras, two laser scanners, a robot arm including a nuclear sensor and a hook, a GPS module and an embedded computer are integrated to the robot's periphery. All hardware components are essential for the tele-operator

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*This project has been partly funded by MA23 - City of Vienna within the Project Call 16-02 ”Photonics: Foundations and industrial applications”.

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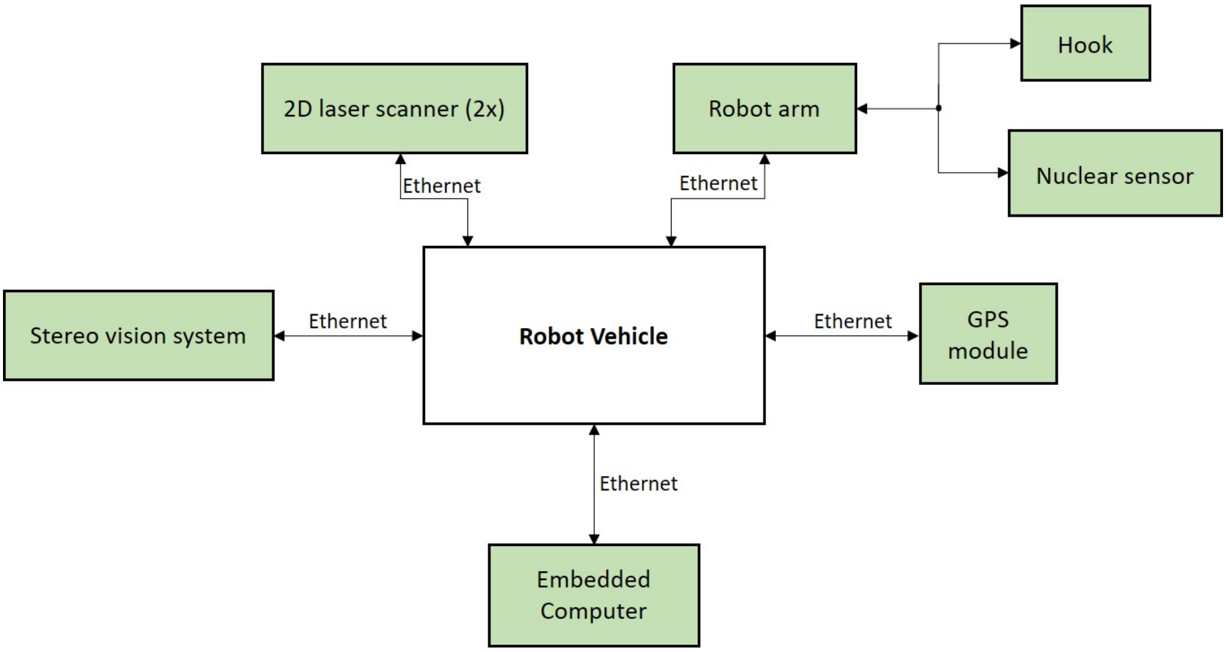

Fig. 2. Connections between robot and hardware components

to operate the robot through rough terrain, detect objects of interests and interact with them. The following block diagram (Fig. 2) shows connections between sensor components and the robot.

The single cameras of the Robot are located on different points, giving the operator the possibility to obtain a broad view around the robot. Two cameras on the front and rear are placed in the body between the tracks, each giving a view in the needed driving direction. Another camera is positioned either on the left or right side of the front, giving the possibility to reconfigure and choose the needed side view before operating manually. A last camera is mounted to the last joint of the robot's arm providing a view from the hooks position (e.g. view top-bottom, to see the tracks and the driveway in overview).

Two laser scanners placed in the front are needed for generating maps and position in the operation via SLAM-algorithms. The nuclear sensor and the GPS module are applied for positioning and obtaining radiation heat maps.

The stereo vision system is installed on the front of the robot. Its purpose is dedicated to future development of 3D map generation and autonomous operation.

III. TELE-OPERATING MODE

To control the robot manually, a tele-operating mode is implemented using ROS. One criteria is to provide two variants for the operator, which can be chosen later. These two steering variants are:

- Keyboard controlled steering
- Steering by Xbox controller

For realisation of both steering variants various ROS packages were integrated in the software environment.

TABLE I

KEYBOARD BUTTON CONFIGURATION

Button	Function
u	Left rubber track forwards (right turn)
i	Go forward
o	Right rubber track forward (left turn)
j	Left rotation
k	Current command stop
l	Right rotation
m	Left rubber track backwards (right turn)
,	Go backward
.	Right rubber track backwards (left turn)

A. Keyboard control

First approach is to control the robot by a keyboard. To realise this variant, the teleop_twist_keyboard package [4] was integrated into the ROS environment. This allows the operator to control the vehicle with the input buttons shown in Table I.

To quit operating the robot by the keyboard, CTRL-C has to be entered. After that the robot stays in safety state and cannot be controlled by keyboard as long as the teleop_twist_keyboard package is restarted.

B. Xbox controller

Alternatively, ROS also provides controlling the robot by Xbox controller [7]. Therefore, the joy package [6] is used for implementing the controller into the ROS environment. After implementation, every steering command of the robot can be used to configure it to one of the Xbox controllers or joysticks buttons. In Fig. 4 the wired Xbox controller and its buttons are demonstrated.

Since there are only a few of control commands, not all

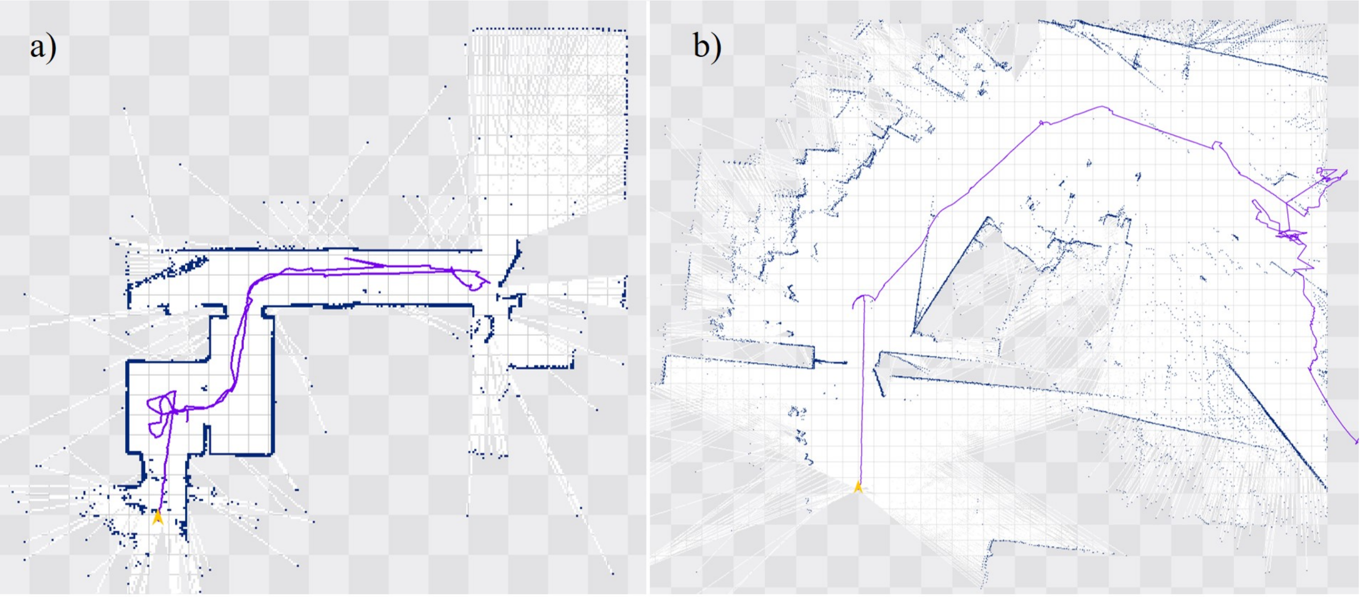

Fig. 3. Mapping results a) small indoor rooms b) disrupted map in a big open area at ELROB 2016

Fig. 4. Xbox Controller for operating the robot

buttons are used for steering the robot. The following table II shows which of them are implemented for which function.

TABLE II
XBOX BUTTON CONFIGURATION

Button	Function
Left joystick (up/down)	Drive (forward/backward)
Left joystick (left/right)	Rotate (left/right)
Right joystick (up/down)	Height-adjustment rubber tracks (up/down)
Right bumper	Release button
Left bumper	Turbo button

Due to safety reasons the enable button have to be pressed all time for steering the robot by the joystick. Speed can be controlled depending on how strong the stick gets pushed. That means if the joystick gets only half pushed, the robot will also drive with half the speed. Alternatively, the left bumper can be used for enable the robot's full speed mode. In this mode, Robbie drives with around $5km/h$ full speed. As mentioned before, it is possible to overcome obstacles by adjusting the robot's rubber tracks up or down. This is done by moving the right joystick up or down respectively. Safety state is achieved when all buttons are not pressed.

IV. RESULTS AND DISCUSSION

Compared to the keyboard variant, the Xbox controller is the better decision for operating the robot in all ELROB challenges. The results of both variants compared are shown in Table III. While the Xbox controller obtains mostly excellent results, the keyboard is improvable in most criteria. Since all buttons of the keyboard are closely packed together, steering the robot becomes more complex. Moreover delay times of the sent commands were detected during tests with the keyboard, which also effects sensitivity and accuracy of steering the robot. Additionally, increasing speed by the keyboard needs to push and hold one "drive-button" and push the "speed-up-button" at the same time. In contrast, the Xbox controller varies speed by inclining the joystick, which results to more sensitivity and accuracy.

TABLE III
EVALUATION OF BOTH STEERING VARIANTS (+ ... EXCELLENT, ∼ ... AVERAGE, • ... BAD)

Evaluation Criteria	Keyboard	Xbox Controller
Handling	∼	+
Accuracy	•	+
Sensitivity	•	+
Flexibility	∼	∼
Feasability	+	+
Safety functions	+	+

Mainly, there are several aspects coming out of this development. The tele-operated operation was a great success at the ELROB event. While the video stream is slightly delayed due to transfer limitation, the analogue joysticks are able to compensate that with nearly stepless motion, giving the option not to lose time by having to stop and wait for movement transmission on the screen. The map presented in Fig. 3 was generated in two different areas. The left part (a) shows a testrun inside a building with small rooms. The right part of the picture (b) shows the generated map of the reconnoitring of building structures challenge in big rooms during the ELROB competition. In (b) it can be seen that the system tends to lose orientation and fails by generating a solid map of the area.

V. SUMMARY AND OUTLOOK

The aim of this paper was to develop a concept for the taurob robot to participate at the ELROB 2016. One part was to integrate two Pointgrey cameras for a stereo vision system, two Sick 2D laser scanners, one Garmin GPS module and one embedded computer into the robot system. The selection of these sensors was based on the criteria of the ELROB scenarios. Additionally, a tele-operating mode was implemented by the open source program ROS for steering the robot by a keyboard or an Xbox controller. To check reliability of the robot system for the ELROB, trials in specific test scenarios were carried out. The obtained results of the test scenarios show that operating the robot by the Xbox controller is easier and more precise than by the keyboard. Furthermore, it is possible to build a 2D map of indoor areas by the 2D laser scanner. Moreover, a dummy body with a length of 1,80m and a weight of 20kg can be dragged by the robot's arm. Although there is still some potential for improvement in different fields, the system achieved a 3rd rank in the Reconnoitring of structures part of competition.

The next step will be the upgrade to a more autonomous state of operation including navigation and full support of visual data processing as well as 3D Mapping including radiation and visual integration of Points of interests (POIs). Also, an advanced controlling system for the arm is planned. The project is in further development and will be featured on schedule for EnRicH 2017 in Austria and the next ELROB 2018 in Riga.

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