RoboCup Rescue 2016 Team Description Paper RRT - Robo Rescue Team FH Wels

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Info

Team Name: Robo Rescue Team FH Wels
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RoboCup Rescue 2016 TDP collection: https://to-be-announced.org

***Abstract*—This paper describes the work of the RRT - RoboRescueTeam FH Wels developing and building mobile rescue robots. The team consists of research associates and students at the University of Applied Sciences Upper Austria. This paper includes the preliminary results which are achieved so far about map building, localization and autonomous victim identification. Furthermore the implementation of SLAM and victim detection and a novel mechanism with a dynamic drive system for locomotion is described. Additionally the construction of a modular robotic arm is introduced.**

***Index Terms*—RoboCup Rescue, Team Description Paper, tracked robots, SLAM, mobile manipulation.**

Fig. 1. RRT - RoboRescueTeam FH Wels

I. Introduction

THE RRT-Team includes members which already have achieved experience by building autonomous robots for competitions and has been established in late 2007, see figure 1. These robots were able to win competitions such as the Robot-Challenge in Vienna (AUT) the Robot SM in Gothenburg (SWE) and the RoboGames in San Francisco (USA). The robots also started at the Eurobot in La Fert Bernard (FRA), Rapperswill(CH) and Heidelberg (GER) and the team won the Eurobot 2011 in Astrakhan (Rus). The RoboCup Rescue League is a competition where autonomous robots navigate through an arena with different level of difficulty such as uneven underground, obstacles and stairs. According to those requirements the development of the robots is very complex and combines multiple disciplines such as mechanical engineering, electrical engineering and programming. The team participated for the first time in RoboCup Rescue 2009 improving every year. The team won the Best in Class Manipulation competition at the RoboCup German Open 2013 and 2014. At RoboCup 2013 in Eindhoven the 9th place of overall, 2nd place in Best in Class Manipulation and the qualification for the finals in Best in Class Mobility. This year the team won the 2nd place of overall in the RoboCup German Open. The RoboCup Rescue League requires the highest demands on the motor and sensory abilities of the robots. The robot is developed specially for the use in the field of security and emergency application. The preliminary aim is to build autonomous and tele operated robots which are able to drive through an unstructured environment and search for victims. This includes generating a map of the environment and characterizing and locating victims as well as recognizing dangerous situation caused by fire and gas. Building a robot which is supposed to attend the RoboCup Rescue League requires high degree of versatility and experience which makes it difficult to start in this competition from scratch. The mechanical systems of the robot including the robotic arm are assembled so far. Also the single modules such as the controller board and the peripheral system such as cameras and sensors are tested successfully of our UGV robots, called MARK, RED SCORPION and SAFIR. The main focus concerns the exploration of all different areas of the competition by generating a two-dimensional map and the detection of victims. The autonomous navigation on rough terrain is a challenging problem for mobile robots because it requires the ability to analyze the environment and make decision which parts can be traversed or need to be bypassed. Due to the developed design, the robots are very fast and agile so it is able to handle all of the arenas.

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A. Improvements over Previous Contributions

The locomotion of mobile robots in uneven terrain is one of the most difficult demands on the system. On one hand,

Fig. 2. MARK - tracked robot

Fig. 3. Scorpion - omni directional drive

as an outdoor robot it has to be fast and flexible on the other hand the vehicle has to deal with rough underground such as stones, gravel or stairs. Other important requirements are that the whole system is robust and consists of light weight construction to reduce the energy consumption. As shown in figure 2 MARK15 UGV has four active flippers, where every flipper is driven by two brushless motors, one motor drives the main pulley wheel, the second one is supporting the cantilever. The drive system basically consists of four pulley belts which are driven separately. Additionally the two belts (left and right side) and the middle belts can rotate individually. This is important for tasks like driving over uneven underground and climbing stairs. The body of the vehicle basically consists of an aluminum frame and the gaps, which are for reducing weight, are covered with carbon composite sheets.

A novel tracked mechanism for sideways motion was developed, see figure 3. The robot can 'turn on a dime', or more correctly, it doesn't need to turn at all. The unique Omni-Ball drive enables it to move in any direction in its plane of operation, and can make those moves almost instantaneously. The Omni-Crawler approach will definitely be a significant benefit in some appli-cations that can be improved by its capabilities, and some applications that were previously impossible.

Both systems will be presented at RoboCup German Open

Fig. 4. SAFIR - basic configuration

2013, 2014, 2015 in Magdeburg (GER) and RoboCup World Championship 2013 in Eindhoven (NED) and 2015 in Hefei (CHN).

II. System Description

A. Hardware

All our robots are equipped with a chain drive. One has also a flipper system to overcome bigger obstacles as described in the rules. The robots are connected to the operator station via 5 GHz WLAN (SAFIR, MARK and RED SCORPION) and via 433 MHz (SAFIR) see figure 4. To generate a map from the scenario different 2D and 3D sensors are mounted on the robots.

1) Locomotion: The new rescue robot called SAFIR has been designed and built to be used in the first explora-tions of CBRN scenarios, major fires and technical assistance. Camera and measuring systems can be quickly and easily adapted or replaced. The data can be transmitted by radio or fiber optic cable directly to the head of operations. With an optional manipulator small and light objects can be manipu-lated and moved. SAFIR can remotely take samples and transport them out of the danger zone.

2) Batteries: The team is with commercial batteries such as batteries for drills (MAKITA). For the robot COBRA Bentronics BB250 batteries are used because of the higher pressures and demands.

3) Electronics and Computation: The complete hardware structure is shown in figure 5. The control board, a self-developed modular electronic system, controls all hard-ware components. This separation simplifies the testing methods and gives the structure more flexibility. The intrinsic actuators, all motors for locomotion and for the robot arm, and all intrinsic sensors, as ultra-sonic sensors, absolute encoders, CO2-Sensor and one IMU (ADIS16364), for leveling the pan/tilt system, are connected to the electronic board. Most of the extrinsic sensors are connected to a separate onboard computer (Zotac Z65 Mainboard), which is equipped with Intel i7-processor.

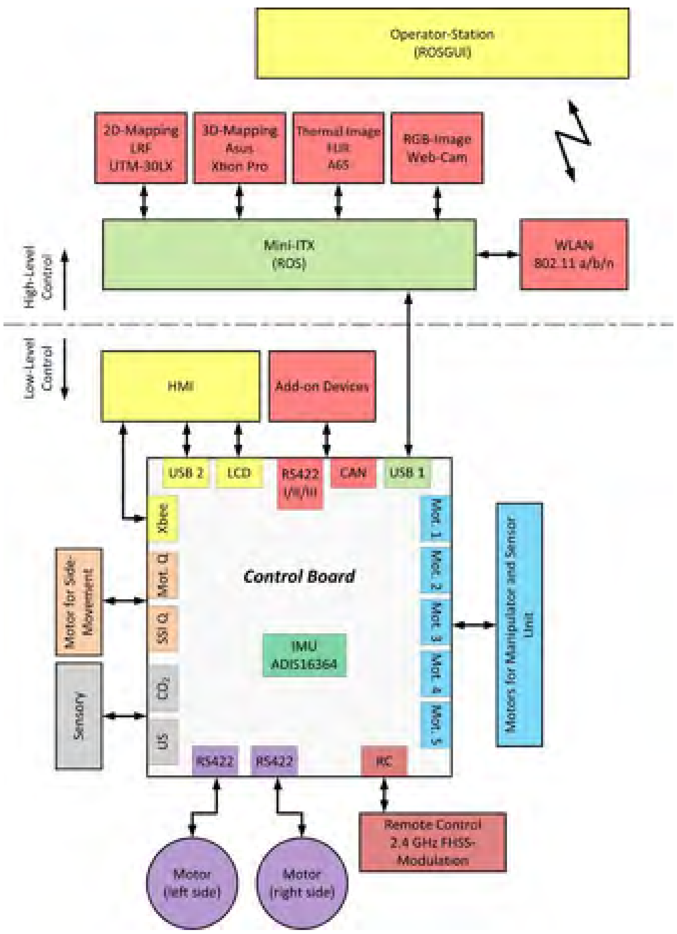

Fig. 5. Electronic hardware structure

Fig. 6. Inspection task

Fig. 7. 3D mapping of yellow arena at RoboCup German Open 2015

4) Manipulation: The main target of this project was to develop a robot arm for the rescue robot to grab and move things like small bottles or cubes with an approximately weight of 0.5 kilograms. The objects can be placed everywhere on the area and the arm should be able to get them also from plates in a height of up to 1.2 meters. To increase the stability and reduce the weight of the structure, materials like aluminum alloy and carbon are used. The three main parts are chosen as U-Shapes to have easy manufacturing and high reinforcement. To keep the flexibility of the robot we decided to construct the arm with three main axes, so the arm is really compact when it is not used. In complete the robot arm has 7 axes which include one linear gear, see figure 6. The axes are driven by Maxon engines and controlled by seven ELMO controllers. The arm and the robot can be easily assembled by a KIPP clamping tool for transporting the rescue robot. The robotic arm was also analyzed with the Finite Element Analysis. There we simulated the situation when the gripper picks up an object. It is possible that the gripper is not in the best position to grab the object, so we chose a diagonal force which we applied to the gripper adapter.When we apply a diagonal force of 10N to the gripper adapter, than we can see that the robotic arm is altered about 0.5 mm. So the robotic arm is easily capable of carrying items with a weight of 0.5 kg.

5) Sensors: The UGVs are equipped with different LIDAR systems from Hokuyo. For large scale mapping the Hokuyo UTM30-LX is used to map for example the University of Applied Sciences Upper Austria. For the RoboCup Rescue League the robots are equipped with UBG-04LX-F01 and the low cost URG-04LX-UG01 which are mounted on a pan/tilt unit in front of the robot chassis. For sensor fusion and robot localization an inertial measurement unit, so called IMU, is used. The IMU which is employed in the robot, is the MTi from the company Xsens.

Each rescue robot is equipped with the ASUS Xtion Pro live, which generates 3D point clouds, see figure 7. The RGB-D camera is used to obtain a complete 3D model from a set of point clouds or calibrated images. The environment perception is necessary for driving in uncertain terrain, to analyze, if the terrain is traversable and of course to rectify the position of the victims.

The core of thermo vision system is the FLIR infrared thermo camera A320 and TAU2 which works in a range of 7.5m up to 13m wavelength. The camera uses an uncooled micro bolometer to detect the infrared radia-tion which is emitted by the objects in the observed area. The A320 camera works at at 30 fps which also allows detecting the movement of objects precisely.

B. Software

The RRT-Team uses the release ROS Indigo. ROS - Robot Operating System is an open-source, meta-operating system for robots. It provides the services, which are expected from an operating system, including hardware abstraction, low-level device control, implementation of commonly-used functionality, tools for vis-ualization, message-passing between processes and package management. A basic ROS installation for RoboCup Rescue was developed at the workshop on Standard Robotic Software Architecture for RoboCup Rescue based on ROS in Koblenz, Germany (2011), ROS Robocup Rescue Summerschool in Graz, Austria (2012) and SSRR Summer School in Alanya, Turkey (2012). Refer to Table VI in the Appendix.

C. Communication

For the communication between robot and operator station a Bullet M5 is used which is operating on the 5 GHz band (802.11 a/n) with 300mW power and a bandwith of 54-300Mbit/s. The wireless communication is used for both, the autonomous modus as well as for the remote control modus.

D. Human-Robot Interface

During the remote controlled modus the motion of the robot is con-trolled by a Microsoft Xbox 360 controller, which is connected to the operator station. Several cameras are mounted on the robot, one at the front and the other one at the rear side of the robot which gives images of the environment. Furthermore a thermo camera and standard cameras are mounted on the top of a robotic arm and provide live stream for the operator. The figures shows RCU 3000 includes four standard 19 inch LCD screens. These screens illustrate the map, the video signals and also the console of the Ubuntu system for teleoperated and autonomous robots. A UPS (Uninterruptible Power Supply) is also included to avoid casualties of the server. The communication takes place via wireless LAN or with a LAN wire. A new remote control unit was developed (RCU 2000) which provide longer operation runtime and the unit is easy to handle and transport, see figure 8.

E. User Interface

The tool rqt is a software framework that implements the various GUI tools in the form of plugins. One can run all the existing GUI tools as dockable windows within rqt. The tools can still run in a traditional standalone method, but rqt makes it easier to manage all the various windows on the screen at one moment, see figure 9. The graphical user interface (ROSGUI) is about to be developed which is supposed to display current information of the terrain and en-vironment. This includes the pictures of the thermo camera and the RGB-cameras as well as the data of the CO2 sensor, laser range finder and several other sensors. Additionally the operator gets important information about the robots battery status and warnings for the obstacle avoidance.

Fig. 8. RRT Remote Control Unit (RCU 2000 and RCU 3000)

Fig. 9. View of RGB and thermal camera for victim detection

F. Mapping

One of the most important tasks at the RoboCupRescue is to explore an unknown terrain and create a map of this terrain. This leads to the common known SLAM (Simultaneous Localization and Mapping) problem. As described the robot has to build a map while it is localizing itself. To solve the SLAM problem hector slam is used. Hector slam consists of several ROS (Robot Operating System) packages. One node of these packages is the hector mapping node. Hector mapping is a SLAM approach that can be used without odometry as well as on platforms that exhibit roll/pitch motion (of the sensor, the platform or both). It leverages the high update rate of modern LIDAR systems like the Hokuyo UTM-30LX and provides 2D pose estimates at scan rate of the sensors (40Hz for the UTM-30LX). While the system does not provide explicit loop closing ability, it is sufficiently accurate for many real world scenarios. The system has successfully been used on Unmanned Ground Robots, Unmanned Surface Vehicles, Handheld Mapping Devices and logged data from quadrotor UAVs.

It creates an occupancy grid map using a LIDAR (Light Detecting and Ranging) System. The grid consists of cells

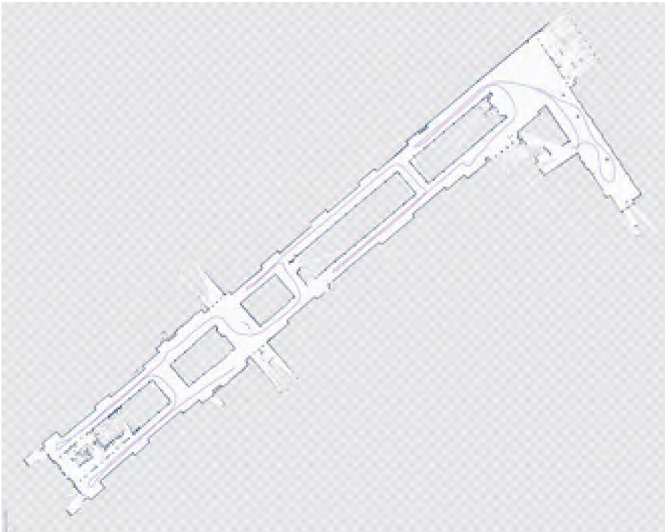

Fig. 10. Large scale GeoTIFF Map from the 3rd floor of the University of Applied Sciences Upper

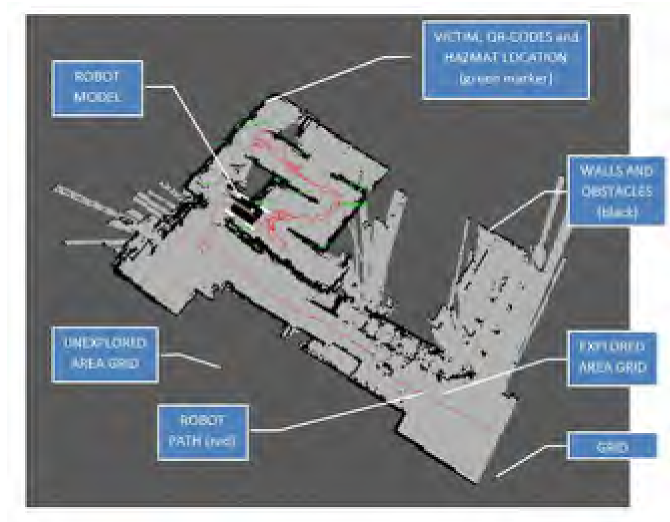

Fig. 11. Exploration of test arena; the planner will generate a path from the robot's current position (red) to a desired goal pose (green)

which store the infor-mation if they are free space, an obstacle or unknown terrain. If the Robot starts exploration the map consists of only unknown terrain cells. If after a few scans the robot detected obstacles it remarks the infor-mation in these cells.

G. Exploration and Path Planning

The black marked cells are obstacles, the light grey cells are free space and the dark grey cells are unknown terrain. If there are obstacles in the map the Robot is able to estimate its position and its moving velocity relatively to these obstacles. Due to the precision of the laser scanner there is no odometry from the Robot required. If the Robot is not remote controlled a second problem has to be solved. The Robot has to choose autonomously where to go next. To solve this problem the hector exploration planner is used. The planner generates goals and paths to these goals. The hector exploration planner package is a library that can be used inside a ROS node. As described a path will be generated by calculating the cost to reach a close frontier. A frontier is a cell in the occupancy grid map that is marked as free space and has a neighboring cell that is marked as unknown terrain. Costs are the distance to the frontier and the safety of reaching the frontier. With a weighting factor it can be adjusted how much a safer path is preferred over a shorter one.

The map submitted after each mission will generated with the hector geotiff ROS package. It provides a node that can be used to save occupancy grid map, robot trajectory and object of interest data to RoboCupRescue compliant GeoTiff images.

H. Victim Detection

The main task in the Rescue League is to detect victim, draw a map of possible ways into and out of the building and send important information to search and rescue teams. The victims are simulated by dolls which show signs of life as moving, body heat, speaking or least breathing. Closed to the victims hazmat labels and eye charts are placed. So the robot should be able to detect them and send the infor-mation to the rescue team. For the detection of these hazmat labels and QR-Codes the robots are using simple USB cameras and a database with different hazmat labels was created. With the use of the OpenCV library and other open source tools it is possible to try out many different algorithms for computer vision.

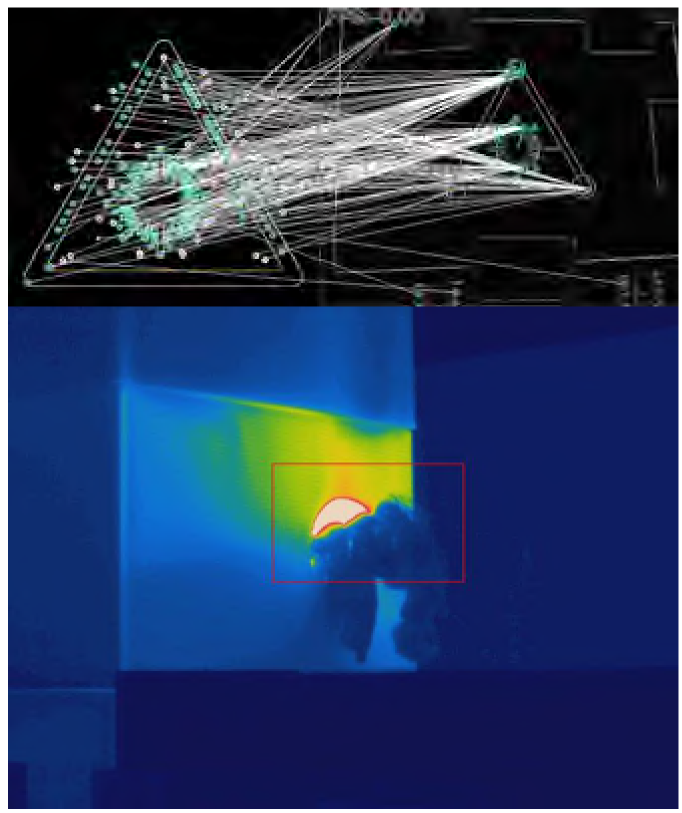

Fig. 12. Detection of Hazmat Labels and Victims)

It is planned to implement a smart algorithm which is supposed to de-tect interesting objects such as victims automatically. Therefore the picture is scanned for conspicuous areas. The objects in the picture should be found using the temperature information. On one hand victims can be classified by a certain body temperature on the other hand dangerous heat sources can be localized. The next step in the development process will be acquiring detailed information about the location of the object and to mark it as an interesting point in the created map. The distance between the robot and the detected object will be calculated using a depth of focus algorithm. For the final solution algorithms are supposed to combine the pictures and their information of the different cameras.

III. Application

A. Set-up and Break-Down

For transporting the robot itself it can be packed into a moveable case with wheels. All sensitive and expensive sensors such as thermo camera or laser range finder are packed separately in a case. The whole setup and breakdown procedure can be accomplished within less than 5 minute. The procedure includes starting up the operation station, controlling the network status, checking if the sensor are working properly and to make sure that all actuators in the initial position takes only one minute. For starting the mapping, autonomy and victim detetion mode the robots are ready in three minutes.

B. Mission Strategy

Our team wants to participate with land and air robots. For the air competition an AR-Drone from Parrot will be used. For the new NIST arena the team can decide between two robots. As mentioned before the robot SAFIR have a modular platform. So for the autonomy competition a sensor modul will be equiped. The team also develop a new tracked vehicle which will be presented at RoboCup 2016 in Leizig.

C. Experiments

The navigation of the rescue robot in our real disaster environment, which is shown in figure 19Fehler! Verweisquelle konnte nicht ge-funden werden., requires full knowledge of the function of the robot. So the remote controlling system requires a special training and practice for the operator to navigate the robot through the arena. Furthermore a large amount of practicing is necessary to control the 4 chain disk drives. Also the manipulation of the robot arm has to be learned by the operator. The team members are responsible for their contributions and to guarantee an accurate function of the developed algorithms. In the last month competitions are planned between the team members to in order to train operators for the RoboCup Championship. In the next few weeks, the RRT-Team will get a new test arena, where all missions (yellow, orange, red, blue and black arena) can be tested.

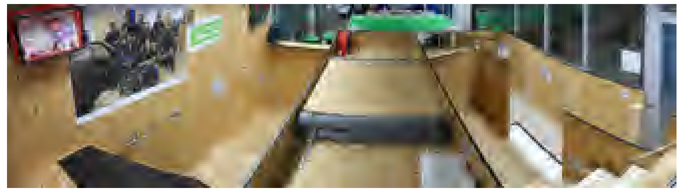

Fig. 13. Team training area

Fig. 14. Pipe inspection with MARK and iRobot 310 SUGV

Fig. 15. Outdoor training at EURATHLON 2013

D. Application in the Field

For mobile rescue robots it is very important to be able to maneuver through rough and uneven terrain. Especially during rescue missions or outdoor use the robot has to deal with hard environmental conditions, see figure . Therefore these rescue robots need a good drive concept to support the rescue units. At the moment usually chain or belt drives are used for teleoperated rescue robots. To improve the mobility these robots uses additional flippers. Such flippers are sometimes part of the drive and in a few cases only for stabilization. There are also drive concepts which consists out of rotatable and powered flippers. But these flippers rotation is limited due to the mechanical design in the most cases. The work deals with a novel drive concept for a high mobility rescue robot called COBRA. The COBRA uses four flippers equipped with a own chain drive. The novel idea is that every flipper is able to rotate full 360 degree.

IV. Conclusion

The robotic system is suited to support rescue team for allocating human victims, fire and gas in the case of a real disaster. It is supposed to replace humans in dangerous situations. The motion system, the robotic arm and the new rescue robots, which are mentioned above, allow to explore the operational area and detecting victims and dangerous situations The team is in contact with fire fighting stations in the City Wels and with the company ROSENBAUER Group which is one of the worlds largest manufacturers of fire fighting vehicles and after the competition we have to present the prototype of our rescue robot. With its wide range of municipal fire fighting vehicles we expect to force the development of our robot. The team got practical application at RoboCup German Open, RoboCup Championships, EURATHLON and ELROB.

Appendix A
Team members and Their Contributions

- Raimund Edlinger Team leader, Mechanical design and SLAM algorithm
- Michael Zauner Team leader, Electronic and Path planning
- Thomas Penkner Computer vision
- Walter Rokitansky Advisor and C programming
- Christian Krenslehner Electronic and C programming (COBRA)
- Andreas Leitner Electronic and C programming (SAFIR)
- Thomas Mairhuber Electronic and uC programming (Robot arm)
- Bernd Fuchs Mechanical design (Robot arm)
- Josef Guertl Mechanical design (COBRA)
- Florian Karer 3D Mapping
- Dominik Bauerl Mechanical design (COBRA)
- Iris Andrea Grininger SLAM algorithm, path planning
- Reinhard Daum robot model design
- Iris Andrea Grininger SLAM algorithm, path planning
- Patrick Feichtinger Object detection
- Armin Pointinger UAV
- Juergen Buchner Semi autonomous robot control

Appendix B
CAD Drawings

Appendix C
Lists

A. Systems List

B. Hardware Components List - SAFIR

C. Software List

Acknowledgment

The authors would like to thank the contribution of the University of Apllied Sciences Upper Austria who is sponosring this research.

TABLE I
Unmanned ground vehicle I

Attribute	Value
Name	SAFIR
Locomotion	tracked
System Weight	23kg
Weight including transportation case	28kg
Transportation size	0.5 x 0.8 x 0.4 m
Typical operation size	0.4 x 0.7 x 0.3 m
Unpack and assembly time	10 min
Startup time (off to full operation)	1 min
Power consumption (idle/ typical/ max)	60 / 200 / 400 W
Battery endurance (idle/ normal/ heavy load)	240 / 120 / 60 min
Maximum speed (flat/ outdoor/ rubble pile)	1.5 / 1 / 0.5 m/s
Payload (typical, maximum)	5/ 20 kg
maximum operation height without arm	50 cm
Arm: maximum operation height	120 cm
Arm: payload at full extend	1kg
Support: set of bat. chargers total weight	0.5kg
Support: set of bat. chargers power	1,200W (100-240V AC)
Support: Charge time batteries (80%/ 100%)	15 / 25 min
Support: Additional set of batteries weight	2kg
Cost	25000 USD

TABLE II
Unmanned ground vehicle II

Attribute	Value
Name	COBRA
Locomotion	tracked
System Weight	60kg
Weight including transportation case	70kg
Transportation size	0.6 x 0.9 x 0.7 m
Typical operation size	0.5 x 0.8 x 0.6 m
Unpack and assembly time	180 min
Startup time (off to full operation)	10 min
Power consumption (idle/ typical/ max)	100 / 300 / 800 W
Battery endurance (idle/ normal/ heavy load)	240 / 120 / 60 min
Maximum speed (flat/ outdoor/ rubble pile)	1.5 / 1 / 0.5 m/s
Payload (typical, maximum)	15/ 40 kg
Arm: maximum operation height	170 cm
Arm: payload at full extend	2kg
Support: set of bat. chargers total weight	5kg
Support: set of bat. chargers power	1,200W (100-240V AC)
Support: Charge time batteries (80%/ 100%)	90 / 120 min
Support: Additional set of batteries weight	2kg
Cost	50000 USD

TABLE III
Aerial Vehicle

Attribute	Value
Name	ARDrone
Locomotion	quadcopter
System Weight	3kg
Weight including transportation case	6kg
Transportation size	0.6 x 0.6 x 0.4 m
Typical operation size	0.6 x 0.6 x 0.2 m
Unpack and assembly time	10 min
Startup time (off to full operation)	2 min
Power consumption (idle/ typical/ max)	100 / 150 / 300 W
Battery endurance (idle/ normal/ heavy load)	30 / 20 / 15 min
Maximum speed	12 m/s
Payload	0.15 kg
Cost	500 USD

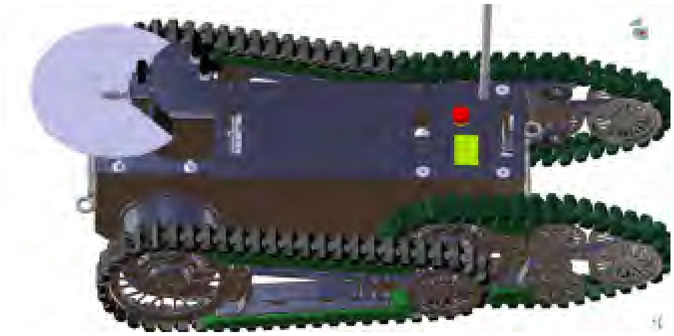

Fig. 16. COBRA - new tracked vehicle

TABLE IV
OPERATOR STATION

Attribute	Value
Name	RCU 2000
System Weight	5kg
Weight including transportation case	5kg
Transportation size	0.4 x 0.5 x 0.3 m
Typical operation size	0.4 x 0. x 0.3 m
Unpack and assembly time	1 min
Startup time (off to full operation)	1 min
Power consumption (idle/ typical/ max)	60 / 80 / 90 W
Battery endurance (idle/ normal/ heavy load)	10 / 5 / 4 h
Cost	3000 USD

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TABLE V
HARDWARE COMPONENTS LIST

Part	Brand & Model	Unit Price	Num.
Drive motors	Maxon RE 45 150 W		2
Drive gears	Planetary Gearhead GP 52		2
Drive encoder	Encoder HEDS 5540		2
Motor drivers	self developed		2
DC/DC	self developed		1
Batteries	MAKITA	70 USD	1-2
Micro controller	ARM 7 controller		1
Computing Unit	ZOTAC with i7	500 USD	1
WiFi Adapter	Bullet M5	150 USD	1
IMU	self developed		4
Cameras	Genexta	500 USD	4
Infrared Camera	FLIR Tau2	2.500 USD	1
LRF	Hokuyo UTM-30LX	3.500 USD	2
CO_2 Sensor	self developed board		1
Battery Chargers	MAKITA charger	50 USD	4
Aerial Vehicle	ARDrone	250 USD	1
Rugged Operator Laptop			1

TABLE VI
SOFTWARE LIST

Name	Version	License	Usage
Ubuntu	14.04	open	
ROS	indigo	BSD	
PCL [8]	1.7	BSD	ICP
OpenCV [9], [10]	2.4.8	BSD	Haar: Victim detection
OpenCV [11]	2.4.8	BSD	LBP: Hazmat detection
Hector SLAM [12]	0.3.4	BSD	2D SLAM
Moon 3D Mapping	0.8	GPL	3D Mapping

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