RoboCup Rescue 2017 Team Description Paper YILDIZ

Sırma Yavuz, M. Fatih Amasyali, Erkan Uslu, Furkan Çakmak, Nihal Altuntaş, Salih Marangoz, M. Burak Dilaver, and A. Erkam Kırlı

Info

Team Name:	Yıldız
Team Institution:	Yıldız Technical University
Team Leader:	Sırma Yavuz
Team URL:	http://www.robotics.yildiz.edu.tr

RoboCup Rescue 2017 TDP collection:
https://to-be-announced.org

***Abstract*—This paper describes the improvements on robots, their operation and strategies developed by Team Yıldız. Since our last appearance in RoboCup in Germany, our team concentrated on full autonomy. As a result of experiences gained during the competition in 2016, the team especially worked on efficient navigation, mapping and victim detection strategies and developed its own algorithms. Our team decided to join this years competition with a single four wheeled robotic car. A new model of a tracked robot is also developed it will not be used during this years championship.**

***Index Terms*—RoboCup Rescue, Team Description Paper, Navigation, Exploration, Mapping.**

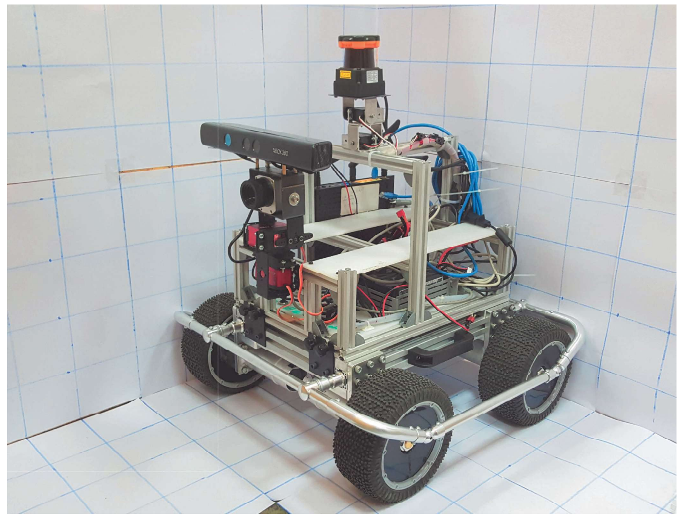


Fig. 1. Photo of the robot

I. Introduction

TEAM Yıldız is part of the robotics research group founded within the Computer Engineering Department of Yıldız Technical University. Our group is working on mapping, autonomous navigation and image processing algorithms and developing its own autonomous mobile robots since 2007. The group is focused on developing search and rescue robots and the algorithms required in search and rescue operations. Two teams; working with real robots and with simulation environment has emerged from the research group. Both of the teams work closely to develop algorithms and join RoboCup competitions since 2011. The virtual robot team won the second place in Mexico, Netherlands and Brazil and the first place in Germany world championships. Real robot team was awarded best in class small robot exploration in Germany world championship. Real robot team contains three undergraduate and two graduate students apart from three academics who act as team leader and advisors. Members of the team have a strong background in programming, electronic and mechanical design. Contributing towards the production of robust and more intelligent search and rescue robots is the most important goal of the group. We are planning to use only one skid steering differential drive robot during this years competition. Our robot is developed for autonomous navigation. This is an improved model of our previous robot. For the competition, our original model gone under some modifications; such as resizing, incorporating new sensors and changing the location and number of sensors. Final photo of the robot is shown in Figure 1.

Sırma Yavuz, M. Fatih Amasyalı, Erkan Uslu, Furkan Çakmak, Nihal Altuntaş, Salih Marangoz, M. Burak Dilaver, and A. Erkam Kırlı are with the Department of Computer Engineeering, Yıldız Technical University, Istanbul, TURKEY, e-mail: sirma,mfatih,erkan,furkan,nihal@ce.yildiz.edu.tr, salih.marangoz@hotmail.com, mbdilaver@gmail.com erkamkrl@gmail.com

A. Improvements over Previous Contributions

Our team previously participated at RoboCup Rescue competitions. As a result of our experiences, we first migrated to ROS and improved our mechanical design. Electronic framework and sensors are also updated during time. Migrating to ROS and aiming only full autonomy has changed the mechanisms considerably. In terms of mechanics, we have decided to use only wheeled models and no tracked robot for this year. We have experimented on passive and active suspension systems and decided on a simpler suspension which will allow us to cover most of the area without experiencing too many mechanical problems. ROS allowed us to make use of drivers for Ardunio platform. Now we use Ardunio platform to receive input from our sensors and to control the motors. We have also started to use Asus RGBD sensor for victim identification, which has libraries available for ROS. In terms of navigation strategies, changes in sensors and full autonomy made our algorithm more reliable and faster. We have also built an arena

Fig. 2. The drawings and the picture of the robot platform.

very similar to the competition in our laboratory to test the algorithms.

II. System Description

Only one fully autonomous robot will be used per mission. It will try to cover the most of the area using the SLAM and exploration algorithms developed by our team. SLAM algorithms relying on sensor data will generate the map of the area automatically. Victim detection and annotation is planned to be fully autonomous as well. The robot will only send the necessary information to the operators computer.

A. Hardware

As the robot is skid steering differential drive robot, whole physical kinematics modeling is hard to reach as the parameters depend heavily on environment variables. Instead, kinematics parametrization is achieved according to experimental kinematics. This way required rotational radius, angular velocities and linear velocities can be realized without deep physical modeling.

The robot is equipped with different sensors including a RGB-D camera, one LRF and an inertia measurement unit (IMU) that may be used for exploration and mapping purposes. Additionally, thermal camera, RGB SD and HD cameras, microphone and carbon dioxide sensors are used to detect the victims and to determine their states.

LRF is the only required sensor to produce 2D map of the environment. The inertia measurement unit IMU is also utilized to control and stabilize the LRF. LRF is fixed to a base on top of a pan/tilt unit and the angles of the unit are controlled to be equal to the negative of the angles measured by the IMU. As a result, the LRF direction is stabilized to always be level and pointing in the same direction. This eliminates the requirement of identifying and removing any noisy or invalid range scans within the algorithm.

Initial drawings of the robot showing the placement of li-po batteries and the on board computer, are given in 2.

Final appearance of the robot is as given in Figure 1. Also important components of the robot and operator station specifications are given in Table II and Table I, Appendix C.

B. Software

All relevant software packages used by the team is listed in Table III, given in Appendix C.

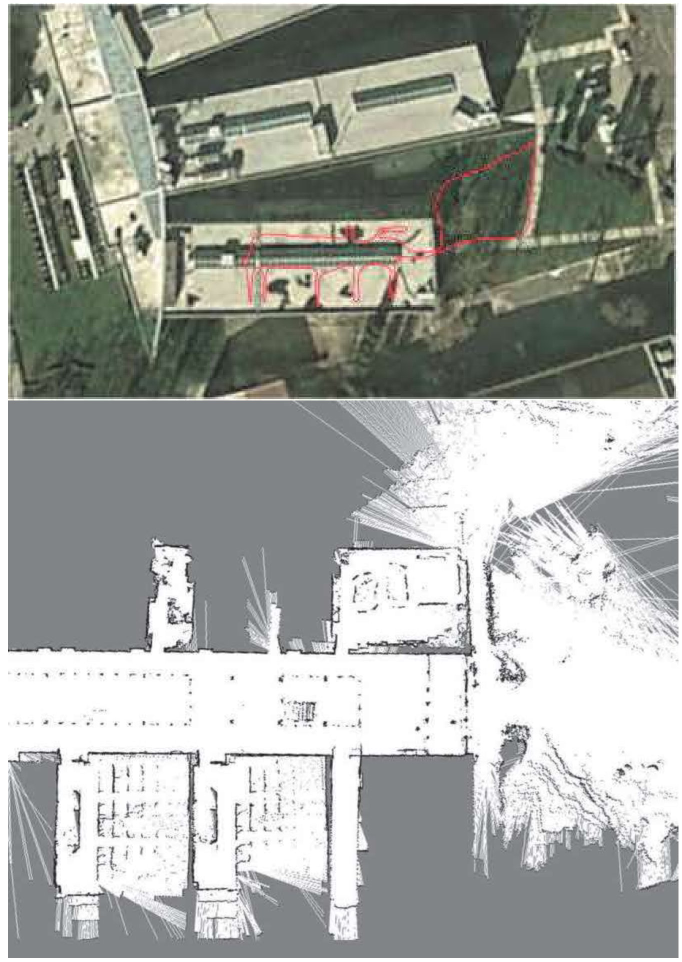


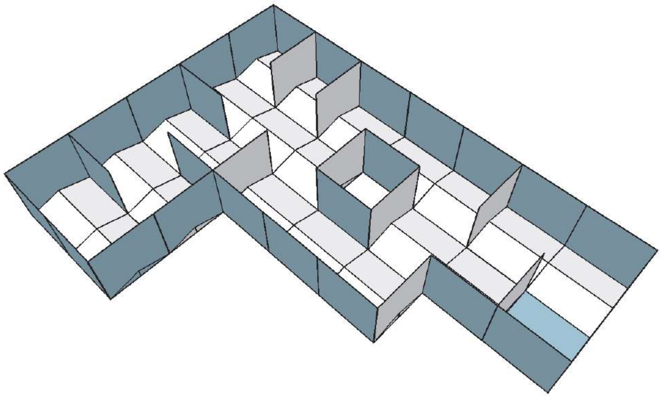
Fig. 3. Sample sensor-based map for the faculty building.

C. Map Generation

We use ROS frame-work which allowed us to use various tools and libraries. Recently we have developed new R-SLAM Mapping software to generate a 2-D map of the environment. We will be using our own navigation software which requires data from both victim detection and mapping algorithms. Operator can follow the landmarks and victims found by the algorithm on the screen. We will extend the software, to provide an information sheet for each victim found, to allow operator to edit the victim information.

We are able to produce reliable sensor-based maps using our own R-SLAM algorithms, and it is fully adapted into ROS. Sample sensor-based maps generated in our faculty building and in laboratory environment, using R-SLAM are given in Figure 3 and Figure 4.

Our previous work on SLAM algorithms primarily rely on LRF and encoder data for mapping and localization. Since the competition site is more complicated, including ramps, stairs or holes on the walls we are currently incorporating IMU and Asus data into our software. In our application we aim the operator to add few annotations to the information sheet provided by the software and not to interfere with automatic map generation at all.



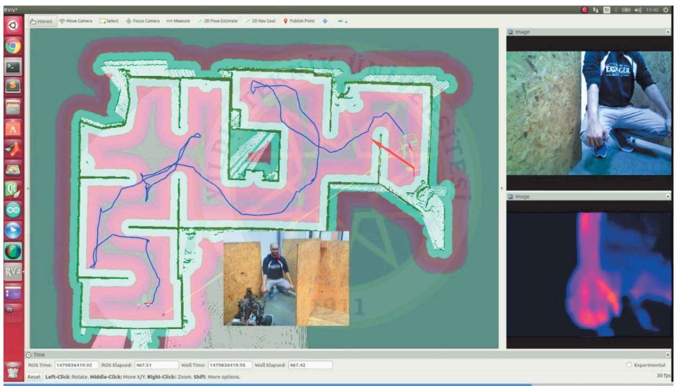


Fig. 4. Sample sensor-based map for the area constructed in the lab.

D. Navigation and Localization

Exploration method of the robot is established on frontier based approach and potential target detection and navigation studies [1]. Our exploration strategy is based on finding the frontiers having the greatest potential. Potential frontiers are defined proximity of the unexplored neighbor grids. This definition depends on the distance of the paths which is calculated with A* algorithm between robot and its target. Minimum and optional path is selected and robot is navigated during this selected path. Navigation is based on global and local planners. Global planner determines the path according to Dijkstra algorithm. Local planner uses the dynamic window approach [2], [3].

Sensors used for navigation and localization are listed as follows:

- Inertia Measurement Unit (IMU): It provides 3D orientation, acceleration, 3D rate of turn and 3D earth-magnetic field data.
- Laser Range Finder (LRF): The field-of-view for this sensor is 240 degrees and the angular resolution is 0.36 degrees. It can measure distances up to 30 meters.
- RGB-D Camera (Asus): Our navigation algorithm uses Asus data to head towards the possible victims. Although, the Asus data is not originally used as a part of the localization software, we intent to use it to correct the IMU data in future to increase the reliability in real disaster areas.

Starting with Robocup 2016, preliminaries are split into task specific suites. One interesting test suite was Exploration 4, in which teams were unable to score any points, where the robot should autonomously avoid holes while navigating. As an improvement over previous year, our implementation on Exploration 4 is given in Figure 5. The results are obtained by using 2D mapping together with octomap method [4].

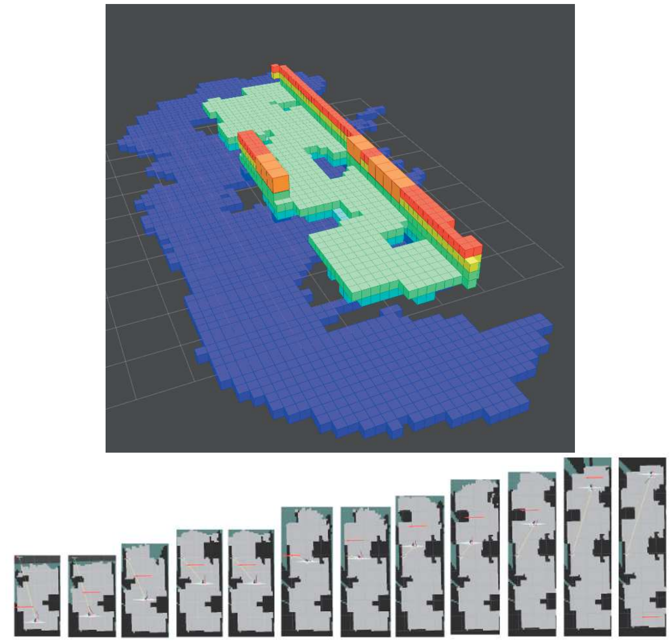


Fig. 5. Exploration 4 implementation: 3D map of the full exploration 4 arena (top), step by step exploration of the arena (bottom).

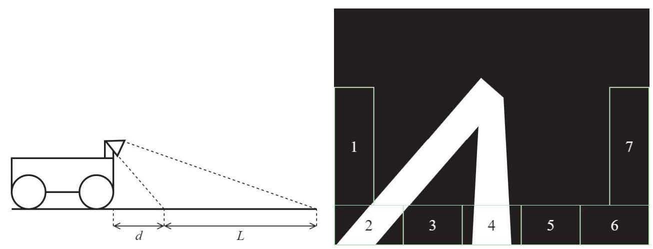


Fig. 6. Outdoor competition implementation: Robot and the camera position (left), processed camera frame on line following (right).

As a new challenge, outdoor competition is also introduced in 2016. Our implementation on line following task using a RGB camera, is given with Figure 6. The algorithm tries to keep the near end of the line on area marked as 4 while keeping last areas where the far end of the line passes.

E. Victim Detection

Main sensors used for victim detection are as follows;

RGB-D Camera (Asus): We primarily relay on RGB-D data to identify any possible victims. While depth information provides information to identify possible victims, RGB data is used to confirm the presence of victims. Thermal Camera: Measures the absolute temperature on FOV at 320×240 pixels. CO2 Sensor: It is used to check the breathing for the victim found. Microphone and speaker: These are used to detect the sound of the victim.

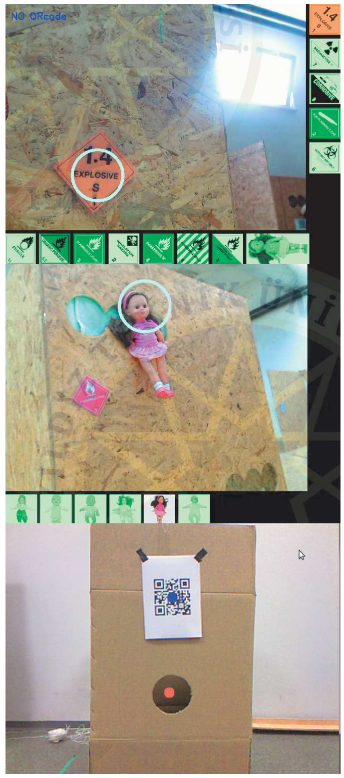


Fig. 7. The results of the developed system (top) hazmat chart detection, (middle) victim detection and (bottom) QR-code is marked by blue dot while the hole is pointed out by red one.

The holes located in different heights on the walls constructing the competition area are possible places for victims. In order to reduce computational load of complex image processing algorithms for victim detection, we first use Asus depth data to identify possible victim locations by detecting the holes. Two steps are used for hole detection. First, a kind of median filter that is developed by our team is applied to remove noise and convert the greyscale depth data into black/white image as seen in Figure 7. At the second step, OpenCV library is used to find segmented hole location.

Alongside the hole and depth detection process, RGB images are used to check if there is a victim in the hole. For visual victim detection, DPM (Deformable Part Models) approach is used [5]. Two of the sample results obtained in our laboratory is shown in Figure 8.

F. Communication

There are two access points in our system, one on the robot side and the other on the operator station. These access points support 802.11a/n and 802.11g/n; however we plan to use 802.11g/n to communicate between our main robot and the operator station. The computer used on our robots supports 802.11a/n and 802.11g/n will be connected to the access point via Ethernet cable. General setup of our system is shown in Figure 9. The wireless communication is between the access points require a selectable 802.11a/n or 802.11g/n band.

Fig. 8. Victim detection using DPM.

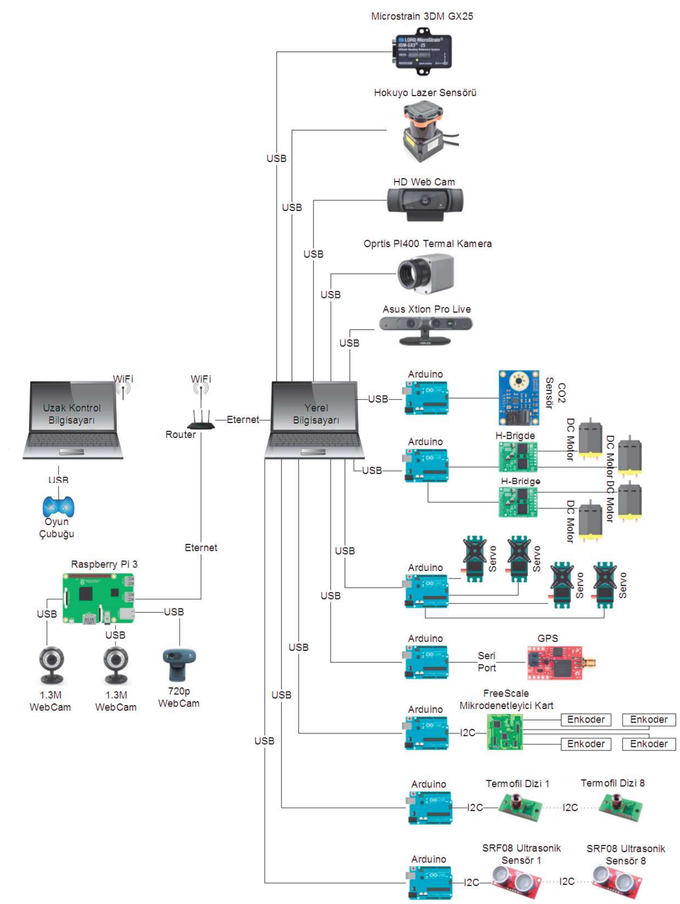


Fig. 9. The general setup of the system.

G. Human-Robot Interface

Only one fully autonomous robot will be used per mission. It will try to cover the most of the area using the SLAM and exploration algorithms developed by our team. SLAM algorithms relying on sensor data and will generate the map of the area automatically. Victim detection is planned to

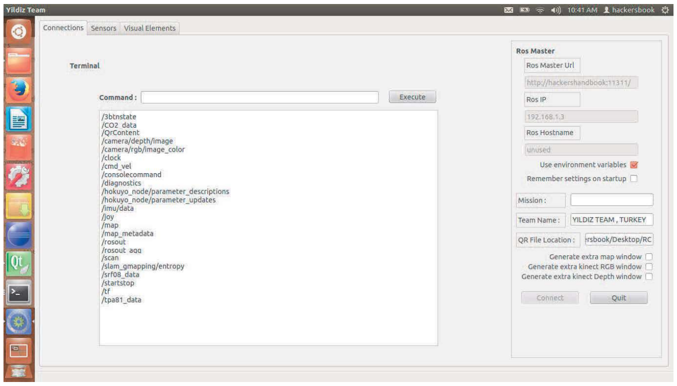


Fig. 10. Operator Interface Initiation.

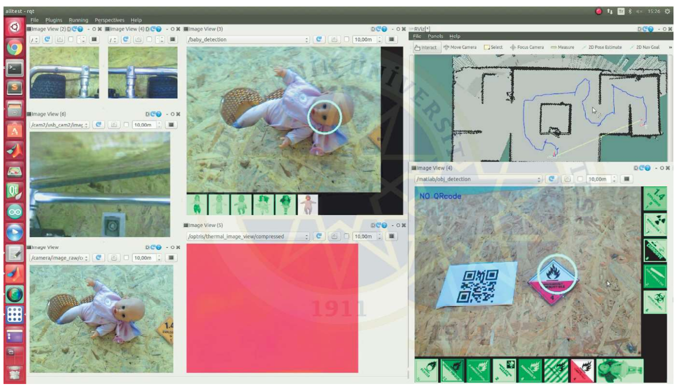


Fig. 11. Visual elements.

be fully autonomous as well. The robot will only send the necessary information to the operators computer for him to annotate and print the victim information and the map. Robot control interface consists of one form with three tab pages, namely Connections, Sensors and Visual Elements. Initiation or connection tab page shown in Figure 10 is divided to two parts; left side of the page is simulated as an external terminal capable of executing general Linux or specific ROS queries and the right side of the page is dedicated to ROS connections containing general startup configuration.

RGB-depth camera view and Mapping information are shown in another interface shown in Figure 11. Since all algorithms will run on the robots and only the automatically generated maps and video streams will be sent to the operators computer. Using the interface, where operator monitors the sensor based map generated by the SLAM algorithm and may eliminate points he considered to be faulty, he will also see the position of the robot as calculated by the SLAM algorithm. Mapping visual is generated by computing laser scan data although camera views are directly shared using raw camera data which are received from the network via ROS topics. Victims will be marked here as well.

III. Application

A. Set-up and Break-Down

Since we primarily plan to run for autonomous league, we have not changed the structure of the operator station too much. An aluminum wheeled case will be used to carry all necessary items for the operator station. The station will be powered up and powered down with one button. The operation case contains one laptop, one lcd monitor, one access point and a power unit. To carry the robot we have another movable chassis with wheels, it is constructed according to the size of our robot. Although other team members will assist the operator to carry the operation case we aim to have only one operator to set up and break-down the operator station within 10 minutes. Two people will be responsible of carrying the robots inside and outside the competition arena.

B. Mission Strategy

We are planning to use only one skid steering differential drive robot during this years competition. Our robot is developed for autonomous navigation. Although a new model of a tracked robot is also developed it will not be used during this years championship. We plan to test our algorithms thoroughly for this year and apply them into the new model afterwards.

C. Experiments

To test our robot and algorithms we have built a test area in our laboratory. To construct standard test methods we have utilized the ideas discussed in [6], [7], [8], [9], [10], [11], [12]. These tests and validations are also required in our ongoing projects which are supported by the government agencies and our University. Some details of these experiments are given in previous sections and in our publications [2].

D. Application in the Field

On a real disaster site, the main advantage of our system is being able to move autonomously. Communication would arise as an important problem in most disaster sites. If the robot is not able to get back where it has started, the information it gathered inside the ruins becomes completely useless. Although we still have a long way to go in terms of mechanics, the strongest feature of our system is its autonomy. In terms of mechanical design, we are working on a design that can cope with rough terrain better, besides having financial problems we will probably need much more work to be successful on a real and completely unknown disaster site.

IV. Conclusion

After our first competition the main conclusion we draw was we had to see it to really understand it. It was a great experience in many ways:

- We realized that very simple mistakes or not having enough training time may finish the run at the first moment,
- We had a chance to get to know each other far more better under the pressure and tried to establish the team accordingly,
- We realized that we have aimed much more than what we can achieve for the first time; trying to have different kind of robots caused us not being good enough at anything. For that reason, this time we have decided to concentrate

Fig. 12. Drawings of the Robot.

on full autonomy and work on other aspects such as manipulation in future. Going step by step is proven to be important.
- We have had the disadvantage of working on the algorithms up to the last moment and did not run the robots on areas similar to the competition site. As a result, on the set-up day we realized that our wheeled-robot was too close to the ground which prevents it to move even in a simple ramp. Also for the tracked robot, we only realized an electronic design mistake after burning few motor controller cards, when robot got stuck. Now we have an arena where we constantly try our robots.

Appendix A
Team members and Their Contributions

The list of the team members and their main responsibilities are as follows:

- Sırma Yavuz Team leader, responsible of mechanical design, electronics and SLAM software development, SLAM software development
- M. Fatih Amasyali Advisor, responsible of victim detection, image processing software development and exploration algorithms
- Erkan Uslu Electronics, controller programming
- Furkan Çakmak Navigation Algorithm, ROS, Control algorithms
- Nihal Altuntaş Image processing software, victim detection, 3D mapping
- Salih Marangoz Image processing software, victim detection, exploration algorithms
- M. Burak Dilaver Image processing software, victim detection, outdoor competition
- A. Erkam Kırlı Image processing software, victim detection, outdoor competition

Appendix B
CAD Drawings

Some drawings of the robot are given in Figure 12.

Appendix C
Lists

A. Systems List

For the Operator Station, specifications are given in Table I.

TABLE I
Operator Station

Attribute	Value
Name	YildizOp
System Weight	3.5kg
Weight including transportation case	6.3kg
Transportation size	0.5 x 0.5 x 0.3 m
Typical operation size	0.5 x 0.5 x 0.5 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)	3 / 1 / 0.5 h
Cost	$3000

TABLE II
Harware Component List

Part	Brand & Model	Num.
Robot Base	Custom Made	1
Electronics for motor control and sensor readings	Arduino Uno, Motor Driver Shield	2
Motors	Maxon Motor	4
IMU	Microstrain 3DM-GX2	1
LRF- Laser Range Finder	UTM-30LX	1
Access Point	TPLink	1
Asus RGB-D Camera	Asus Xtion Pro Live	1
Computer	Toshiba Sattelite	1
Thermal Camera	Optris Thermal Camera	1
Battery	Li-Po	4
Total Price		**$30000**

B. Hardware Components List

Main components of our Robot used by the team is listed in Table II.

C. Software List

Software packages used by the team is listed in Table III.

Acknowledgment

This research has been supported by Turkish Scientific and Technical Research Council (TUBITAK), EEEAG-113E212 and Yıldız Technical University Scientific Research Projects Coordination Department (Project Numbers: 2015-04-01-GEP01 and 2015-04-01-KAP01).

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TABLE III
Software List

Name	Version	License	Usage
Ubuntu	14.04	open	
ROS	Indigo	BSD	
OpenCV [13], [14]	2.4.8	BSD	Victim detection
OpenCV [15]	2.4.8	BSD	Hazmat detection
SLAM	0.1	Closed Source	2D SLAM
Proprietary GUI from Yildiz U.	0.7	Closed Source	Operator Station

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