RoboCupRescue 2015 - Robot League Team
<Yıldız (Turkey)>

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Abstract. This paper describes the improvements on robots, their operation and strategies developed by Team Yıldız. Since our last appearance in RoboCup Open in Germany, team has decided to concentrate on full autonomy. This was the result of experiences gained during the competition in 2013. The team especially worked on efficient navigation, mapping and victim detection strategies. Our team decided to join this year's competition with a single four wheeled robotic car. Although a new model of a tracked robot is under development it will not be used during this year's championship.

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 real robot team was not able to join the competitions every year, partly because of financial reasons, but the virtual robot team won the second place in Mexico, Netherlands and Brazil world championship. Real robot team contains one undergraduate and three graduate students apart from four 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 year's competition. Our robot is developed for autonomous navigation. This is an improved model of our previous robot PARS. For the competition, our original model gone under some modifications; such as resizing, incorporating new sensors and changing the location and number of sensors.

1. 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
- M. Fatih Amasyalı Advisor, responsible of victim detection and image processing software development
- Erkan Uslu Electronics, controller programming
- Muhammet Balcılar SLAM software development
- Furkan Çakmak Navigation Algorithm, ROS, Control algorithms
- Attila Akıncı Exploration Algorithms, operator interface
- Nihal Altuntaş Image processing software, victim detection
- Bedir Yılmaz Image processing software, victim detection

2. Operator Station Set-up and Break-Down (10 minutes)

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.

3. Communications

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 Fig. 1. The wireless communication is between the access points require a selectable 802.11a/n or 802.11g/n band. There is a headset to be used by the operator requiring Bluetooth communication.

Table 1. Communication requirements of the team

Rescue Robot League		
YILDIZ (TURKEY)		
Frequency	**Channel/Band**	**Power (mW)**
5.0 GHz - 802.11a		32mW
2.4 GHz - 802.11g		32mW
2.4 GHz - Bluetooth	spread-spectrum	

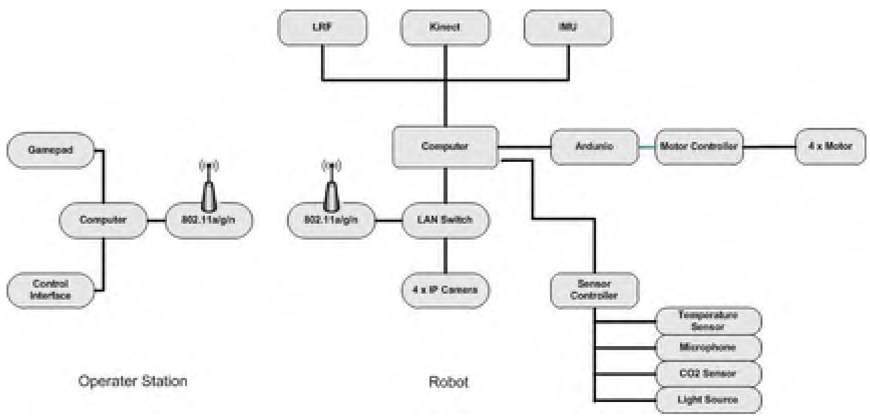

Fig. 1. The general setup of the system.

4. Control Method and 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 be fully autonomous as well. The robot will only send the necessary information to the operator's 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 Fig. 2 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.

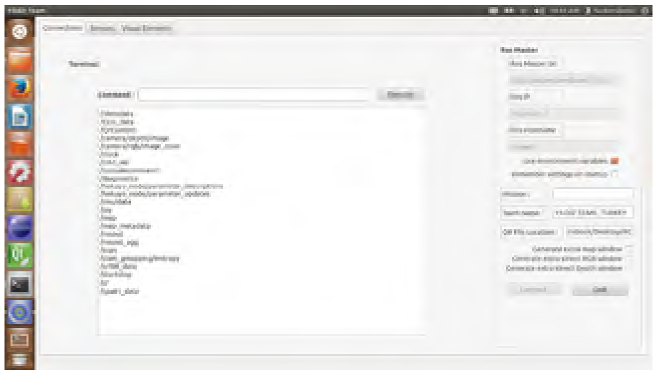

Fig. 2. Operator Interface Initiation.

Sensors tab page is shown in Fig. 3. On the left side of this page IMU, Ultrasonic and Carbon dioxide sensor values are shared part by part in the diagonal corners and also RGB camera view and basic robot management command group is presented. QR code details and retrieval information in QR codes is extracted and shared in right side of the page.

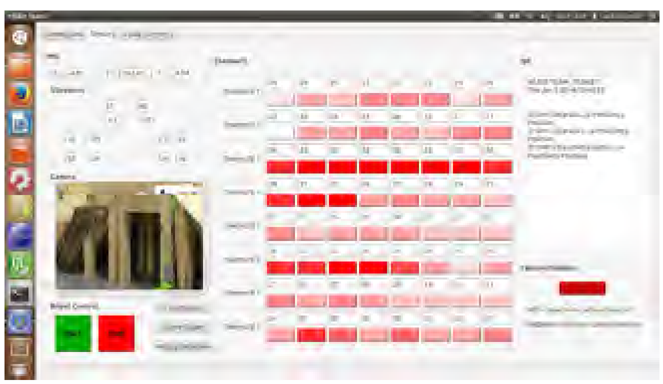

Fig. 3. Sensor Value Tracking.

The heat map is used to visualize the temperature information which is represented with colors changing between red and white. Thermopile sensor values can be seen on the heat map as well. Heat map source will be replaced with thermal camera by the competition.

Finally, RGB-depth camera view and Mapping information are shown in visual elements tab page shown in Fig. 4. Since all algorithms will run on the robots and only the automatically generated maps and video streams will be sent to the operator's 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. System history is logged and shared in this tab. Rviz and OpenNI initiation can be done using application shift buttons. Operator will be using this tab to watch the video stream and draw a map. Victims will be marked here as well.

Fig. 4. Visual Elements with external video streams.

5. Map generation/printing

Since our last appearance in the competition, we have started to use ROS framework 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. Operator will be able to print the victim information and the final map using the print button on the software.

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 Fig. 5 and Fig. 6. 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 Kinect 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.

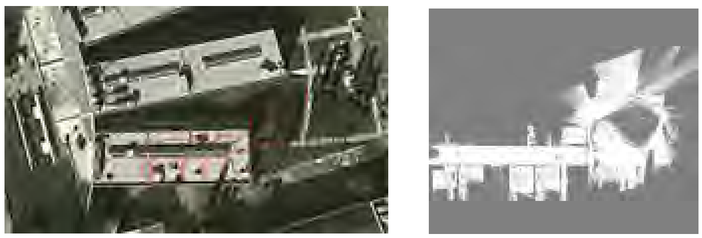

Fig. 5. Sample sensor-based map for the faculty building shown on the left.

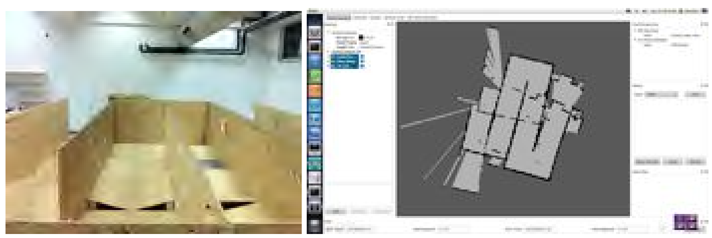

Fig. 6. Sample sensor-based map for the area shown on the left.

6. Sensors for 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.
- Ultrasonic Range Finders: Although these sensors are not crucial for mapping or localization, they are used to sense any obstacles close to the ground and are not detectable by LRF.
- RGB-D Camera (Kinect): Our navigation algorithm uses Kinect data to head towards the possible victims. Although, the Kinect 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.

7. Sensors for Victim Identification

Main sensors used for victim detection are as follows;

- RGB-D Camera (Kinect): 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 Array Sensor: Measures the absolute temperature of 8 adjacent points in its field-of-view simultaneously. Number of sensors is located on the robot at different heights.
- CO_2 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.

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 Kinect 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 Fig. 7. At the second step, OpenCV library is used to find segmented hole location.

(a) **(b)**

Fig. 7. Test Results of the developed system (a) QR-code is marked by blue dot while the hole is pointed out by red one and (b) black/white image obtained by medianization in the first step of hole detection

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 [4]. Two of the sample results obtained in our laboratory is shown in Fig. 8.

Fig. 8. Victim Detection using DPM.

8. Robot Locomotion

For the competition, our original model gone under number of modifications; during the process different types of models are produced. The final drawings and the picture of the four wheeled, differential drive robot platform is given in Fig. 9.

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 parameterization is achieved according to experimental kinematics. This way required rotational radii, angular velocities and linear velocities can be realized without deep physical modeling.

Fig. 9. The drawings and the picture of the robot platform.

9. Other Mechanisms

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

10. Team Training for Operation (Human Factors)

All members of our team are trained to have basic knowledge in using ROS to be able to develop their algorithms in this platform. Although, it is relatively simple to get our robots running, it took some time to build a platform for them to notify each other from the developments, so every one of them will know what to do to run the robots without having problems. We have documented the steps required to run the robot and it is updated regularly. The team still needs some time to finalize their work and experience in the arena which has built in our laboratory. We expect to test our system fully in German Open competitions.
Since the robots run autonomously, no extensive training of the operator, but to make sure the set-up and break-down procedures to be completed in time and the operator can evaluate the results produced by the robot correctly or make any annotations when needed, there he still needs to be trained.

11. Possibility for Practical Application to Real Disaster Site

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.

12. System Cost

System Cost		
Name	Brand - Model	Web
Robot Base	---	---
Electronics for motor control and sensor readings	Ardunio Uno, Motor Driver shield	http://www.arduino.cc/
Motor	2KE-2032 Series	http://www.zhengke.cn
IMU	Microstain 3dm-gx2	http:// http://www.microstrain.com/inertial/3DM-GX2
LRF - Laser Range Finder	UTM-30LX	http://www.hokuyo-aut.jp
Access Point	Airties	http://www.airties.com
Kinect RGB-D Camera	Microsoft	http://www.xbox.com/en-US/kinect
Computer		
CO2 sensor	MG811 for Ardunio	http://www.arduino.cc/
Thermopile	Devantech TPA81 8x1	http://www.acroname.com
Ultrasonic	Devantech SRF08	http://www.acroname.com
Battery	Li-Po	
TOTAL PRICE = Approximately $ 15000		

13. Lessons Learned

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 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.

References

1. Visser, A., and Bayu A. S.: Including communication success in the estimation of information gain for multi-robot exploration, Proceedings of the 6th International Symposium on Modeling and Optimization in Mobile, Ad Hoc, and Wireless Networks, (2008)
2. Çakmak F., Uslu E., Yavuz S., Amasyalı M. F., Balcılar M., Altuntaş N.: Using Range and Inertia Sensors for Trajectory and Pose Estimation, Signal Processing and Communications Applications Conference, (2014)
3. Fox D., Burgard W., Thrun S.: The dynamic window approach to collision avoidance, In Proceedings of the IEEE/RSJ International Conference on Intelligent Robots and Systems, (1996)
4. Felzenszwalb, P., McAllester, D., Ramanan, D. : A discriminatively trained, multiscale, deformable part model. In Computer Vision and Pattern Recognition, (2008)