

RoboCup Rescue 2016 Team Description Paper

iRAP Robot

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Info

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 RoboCup Rescue 2016 TDP collection:
<https://to-be-announced.org>

Abstract—This paper describes construction and operation of the iRAP Robot who has a long history in the 1st Runner up the award of rescue robot competition in Thailand from many years ago. The team is the next generation of iRAP PRO, iRAP JUDY and iRAP FURIOUS who have taken the 1st place three times accordingly in the World RoboCup Rescue Robot competitions (2009 - 2013). And, in the World Robocup Rescue 2015 in Hefei, China, We had participated in the competition again. Our team has two similar high mobility teleoperative robots and one autonomous robot. The teleoperative robots have front arms that driven by a Caterpillar. They can identify victims very well with commodity sensors and able to move autonomously in the radio drop-out zone. The difference between two teleoperative robots that is the one has used in the industrial rubber as a track wheel, and another one used the chain with the garden hose. The autonomous robot has good mobility to move up the inclined surface and identify victims by using vision system with image processing and thermal sensor. All of the robots can create explored map automatically and able to detect the QR code. Another robot is the new challenge in the competition. It is an autonomous robot that will be used in the outdoor mission. Therefore, we have developed a new aerial robot that can travel and search for the victims. The team has prepared for different scenarios that present in the World Robocup Rescue 2016 in Leipzig, (Germany).

Index Terms—RoboCup Rescue, Cooperative Robot, Aerial robot

I. INTRODUCTION

IRAP which stands for Invigorating Robot Activity Project is the team of students from King Mongkut's University of Technology North Bangkok, Thailand

iRAP ROBOT is the new generation of rescue robot for the competition. The team members are the next generation of the legendary student teams who have got the 1st place three times in the world RoboCup Rescue Robot competition (2009-2011 and 2013). The team has good experience and knowledge through these competitions. The paper introduces our approach

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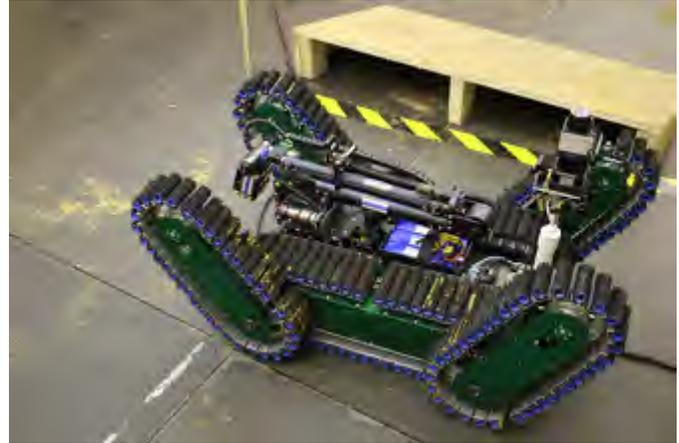


Fig. 1. Teleoperative robot locomotion

to Rescue Robotics. The team has designed and developed them for six years. The team has four robots, consisting of two similar teleoperative robots See figure 1, an autonomous robot See figure 2 and an autonomous aerial robot See figure 3.

The rescue robot for this competition is designed based on proficiency robots. Therefore, the team designed a robot that can motivate roaming around rough terrain by using Caterpillar wheel. The team designed stable cameras mounted arm on our robots and on the robot body to help identify the possible victim. The team uses the high-quality motor and sensory abilities. The full sets of affordable sensors are put on to the system to measure temperature, CO2, distance, to create a map and two-way communication. Our preliminary goal of this activity is to achieve a practical rescue robot for a real situation such as disaster, earthquake and building destroy. The team expects that all we did can help peoples life in a real disaster situation.

A. Improvements over Previous Contributions

The new robots have been designed by solving problems occurred from the last competition and improved the easiness in robots control and QR code detection. Our main focuses are exploring all areas, detecting all victims, motion detection, generating a map in 2-D and map merging. The simulated situation included many rough surfaces, hard terrains, rolling floor, stairs, and inclined floor; therefore, the rescue robot should be fast enough, light-weight and strong to circulate and explore. We have developed the autonomously outdoor robot that is the aerial robot. It can fly and localize itself by GPS sensor. Besides, the essential sensors for searching the victim

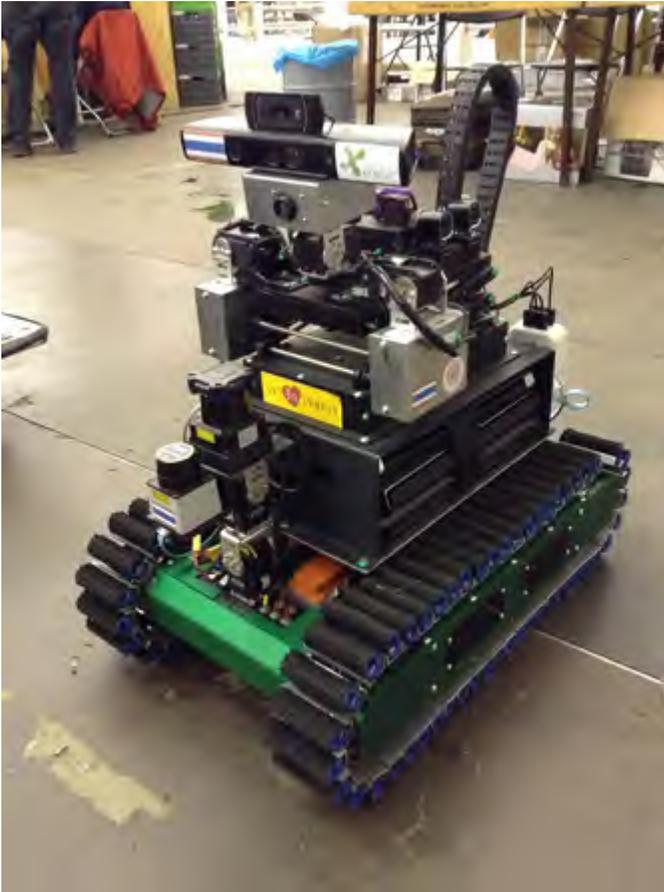


Fig. 2. Automatic robot locomotion



Fig. 3. Autonomous flying robot in outdoor mission, as quadrotor model.

are also installed into the aerial robot, such as temperature and camera sensor.

II. SYSTEM DESCRIPTION

Our robots have mainly developed in the mechanical durability. We have experimented the robot motion to confront the difficulties in different terrains. Moreover, the robot can proof

for the best mobility in the World Robotic Rescue competition many times. The advantages are: the good hardware and robot mobility. We have a software that is good enough to complete the missions in the competition. We realize that the software should be developed parallelly with the good hardware. And, we try to start it up more advanced. Comparing to other teams, our members are young and be mostly the undergraduate students. They eager to win the competition. The team attempts to develop more researches in advanced technology in near future.

A. Hardware

The teleoperative robot comes in at 70 kg, 1 m long, 60 cm wide, 60 cm high which can reach up to 2 m when standing up fully (or it is in doggie style). The teleoperative robot has four flippers to give him balance to go through all kinds of obstacles. It also has an ability to flip itself back. The flippers are module design meaning that it can still run with just one or two or three flippers, or even no flipper at all. It has a 1.5 m detachable arm with 360-rotation and a shakable hand with servo motor to reach small space. It is equipped with four cameras two at the base, one front camera, one back camera. Two at the arm as the main search cameras. It has three sensors - two in the front for CO₂ detection and 1 laser-scanner in the back to map out the surrounding within 30 meters radius. It is equipped with flash light for navigation, microphone and speaker allowing the rescuers to communicate with the survivors. All of these - It took us many years to develop the teleoperative robot to achieve the highest robotic mobility. There are plenty ups and downs but we have never gave up. We had to overcome several obstacles including developing the right design, and then convince a sponsor to provide us with materials. We converted a readily available commercial converter belt to continuous track for the robot. With this design, the robot is able to navigate through various terrain including rocks, sands, debris and other surfaces.

The autonomous robot moves and explores the map automatically. It has four cameras to detect QR code, CO₂ sensor and thermal camera to detect the victims. However, the autonomous robot did not succeed in the previous competition because the thermal sensor did not work well to detect the victims. We have learned the mistakes from the previous competition and attempt to solve the problems.

The autonomous aerial robot is the new development in the competition. Basically, the aerial robot can fly and explore the victim in searching area using the thermal camera and CO₂ sensor. It has a function to navigate itself and avoid the obstacles using GPS and guidance sensor. Refer to the Tables I and following as well as Table IV in the Appendix.

- Locomotion

Regarding designing the robot locomotion system, the team has learned and has improvements through our team advisors iRAP PRO, iRAP JUDY and iRAP FURIIOUS that have gained experiences from many competitions. In this competition, our team improved the three robots consisting of two teleoperative robots and one autonomous robot. The team is looking forward to



Fig. 4. Robot manipulator arm

researching the better locomotion system. The locomotion of all teleoperative robots made of the conveyor belt system that the team examined from different surface characteristics of the terrain. Many parts of the robot have been improved in order to be tough, light weight and easy for maintenance as much as possible. Each drive system consists of two motor– 24V, 95 rpm DC with gear-boxes for the movement on the left and right. The structure of the drive system is made of aluminum. The synthetic rubber is used to make the belt. The robots have a pair of flipper that can be rotated 360 degrees.

- Power (Batteries) The all robots consume the LiPO batteries because they are light and have high power.
- Electronics, including micro-controllers, etc. The electronics systems are low-level systems. The micro-controllers are used to interface with motor-driven system and data acquisition.
- Manipulation/ directed perception The teleoperative robot can extend its arm from the doggy style standing up to 2 metres to search the victims around the disaster area as in figure 5. The checkable arm consist of temperature sensor, CO2 sensor. The robot arm can navigate itself by knowing the end-effector position in cartesian coordinate system.
- Sensors For victim identification, the team will analyse information from different kinds of sensor that located at the robot surveying arm. For preliminary step, the team will check the status of the victims through the CCTV camera and measure the victim body temperature by utilizing temperature sensor. In some circumstances, this victim informed by the temperature will be incorporated with data from CO2 sensor and the surrounding sound, which will be received via microphone, to analyse the situation of the victim.

B. Software

Several kinds of sensors are installed on each robot to gain the data for processing and creating an automatically 2-D map on the operators computer monitor. The map is



Fig. 5. The teleoperative robot is standing in doggy style to search to the victims.

generated by using the information from the distance of the robot movement from encoders, the inclination of the robot and direction of the robot sensed by Inertia Measurement Unit, and the distance between the robot and obstacles from laser range finder. However, when the robot moves on different kinds of surface, the slipping problem is unavoidable. This slipping is a major problem for designing and constructing the robot. Therefore, SLAM algorithm [1], [2] is utilized to help generate the map in addition to the information from the encoders and assign position on axis x, axis y and axis z from the camera with lidar scan. Refer to Table V in the Appendix.

C. Communication

There are two communication systems used between the operator and the robots. The first one is wireless LAN based on IEEE 802.11a standard which functions as the main communication system. That is, it controls robots, receives video streaming from cameras on robots, and checks sensors feedback for locating the status of robots on a computer monitor as well as for the map automatic generation. The second one is the RC controller with the radio frequency of 72 MHz as the backup communication system for an emergency situation. The range of the working distance is 400 m for outdoor and 200 m in the building.



Fig. 6. Automatic map generated by iRAP ROBOT.



Fig. 8. Operator console illustrated the real time quad videos and the information of robots sensors.

D. Human-Robot Interface

The main control is based on one CPU (PIC microcontroller 80 pins). Figure 7 shows the diagram of the control system which has two main tasks as follows:

- To receive the data for identifying the status of the robots as shown in figure 8 (Quad-video and sensors information) and create 2-D map automatically as shown in figure 6. This information will be shown to the robot operator via a second computer monitor.
- To send the data for controlling the movement by sending the signal to the drive control for controlling DC motor at various locations on the robots. The RS-232 communication system will be used for sending and receiving the data of CPU. Therefore, there must be a serial server to convert RS-232 system to Ethernet system.

III. APPLICATION

A. Set-up and Break-Down

The speed of the set-up and break-down process of each task is very crucial. The team realizes that the faster for set-up and break-down, the better time for other tasks. The team uses aluminum case as the station. When needed, just open this aluminum case and turn on the switch. The operations can be started within 1 minute. Inside this aluminum case, there are three monitors, a notebook, an access point, a printer and a



Fig. 9. The operator station

UPS as in figure 9. Once all the tasks are completed, the report and the generated map can be quickly printed out.

B. Experiments

We took the teleoperative robot to the test, by participating in World Robocup Rescue Robot competition in 2015. During the competition, the objective is to find as many survivors as possible within a time limit. We were able to win those competitions due to the robot unsurprising ability to navigate through various terrain, camera and CO2 sensors capabilities to locate and identify whether survivors are alive. Moreover, as you can see the generated path on the map, the robot is able to automatically generate map and mark survivors locations so that the rescuer can compare it to the buildings blue print. We believe this feature is one of the key differentiators of the that takes us all the way to the best mobility.

C. Application in the Field

Accordingly, our teleoperative robot has the high-performance in mobility. Our main goal for this activity is used for a real application. We have cooperated with government and military department of Thailand to develop the EOD (Explosive Ordnance Disposal) robot. The team designed all the parts of the robot for real rescue application. We are confident that our robot is very useful for bomb disposal. The EOD robot uses the based mechanism from the teleoperative robot but it has water pressure cannon to destroy the bomb. It is installed instead of manipulation arm as shown in figure 10.

In the future, the team might improve and change a lot of robot parts for better results that may be able to prevent the water and fire. For example, the team will increase the toughness of some robot parts, create a weight-less robot, extend the effective range of WLANs signal, and improve the quality of video cameras. The team plans to make them in the real application soon.

IV. CONCLUSION

After the competition, the team knew how to make the better robots. The team learned the new technologies from other

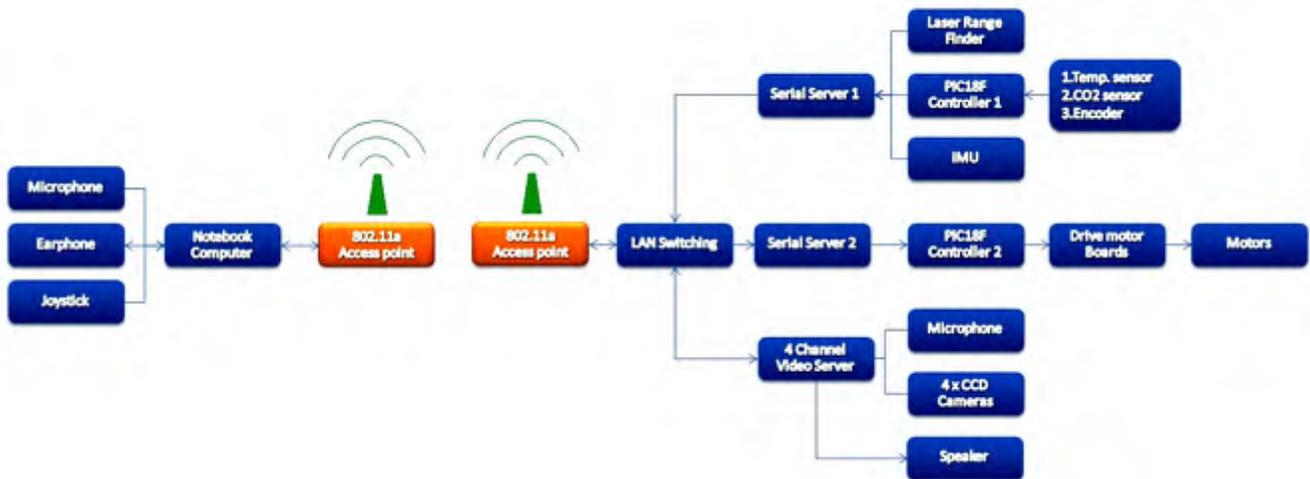


Fig. 7. The control system diagram.



Fig. 10. The EOD (Explosive Ordnance Disposal) robot.

countries competitors, learned how to be a good team. The team gained many experiences. Importantly, the team knew that The great competition is not practicable, if you do not have a good teamwork.

APPENDIX A

TEAM MEMBERS AND THEIR CONTRIBUTIONS

The iRAP ROBOT has twelve members and three advisers. The names and responsibilities of each member are listed as follows:

- Mr.Thanapon Sorndach Mechanical development
- Mr.Pattaraphon Boonchai Controller development
- Mr.Yatip Uarmorn Mechanical design and Structure
- Mr.Jirath Sorndach Mechanical design and Structure
- Mr.Chatpong Rattanapan Mechanical design
- Mr.Yodsanon Chusanatas Teleoperative robot Hardware
- Mr.Tanawat Pongsathornpisuth Autonomous development

- Mr.Arphakorn Kunha Electronic design
- Mr.Anon Makchareon Electronic design
- Mr.Patipan Amnajsung Software and Control development
- Mr.Poommitol Chaicherdkiat Network system
- Mr.Noppadol Pudchuen Software and Control development
- Mr.Sai-yan Primee Advisor
- Asst.Prof.Chatchai Swrmpongpan Advisor
- Dr.Amornphun Phunopas Advisor(Team Leader)

APPENDIX B

LISTS

A. Systems List

There are four main systems:

- The manipulation System in the Tables **I**
- The Aerial Vehicle (quadcopter) in the Tables **II**
- The Operator Station in the Tables **III**
- The Hardware Components List in the Tables **IV**
- The Software List in the Tables **V**

ACKNOWLEDGMENT

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TABLE I
MANIPULATION SYSTEM

Attribute	Value
Name	Somwhang
Locomotion	tracked
System Weight	70kg
Weight including transportation case	100kg
Transportation size	0.8 x 1.35 x 0.8 m
Typical operation size	0.6 x 1.2 x 0.6 m
Unpack and assembly time	180 min
Startup time (off to full operation)	15 min
Power consumption (idle/ typical/ max)	ND
Battery endurance (idle/ normal/ heavy load)	ND
Maximum speed (flat/ outdoor/ rubble pile)	ND
Payload (typical, maximum)	5 kg
Arm: maximum operation height	2 m
Arm: payload at full extend	15kg
Support: set of bat. chargers total weight	ND
Support: set of bat. chargers power	ND
Support: Charge time batteries (80%/ 100%)	ND
Support: Additional set of batteries weight	1.3kg
Any other interesting attribute	-
Cost	23000 usd

TABLE II
AERIAL VEHICLE

Attribute	Value
Name	iRapFly
Locomotion	quadcopter
System Weight	3kg
Weight including transportation case	6kg
Transportation size	0.6 x 0.6 x 0.5 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
Any other interesting attribute	-
Cost	2000 USD

TABLE III
OPERATOR STATION

Attribute	Value
Name	iRAP STATION
System Weight	15kg
Weight including transportation case	30kg
Transportation size	0.8 x 1 x 0.4 m
Typical operation size	0.8 x 1 x 0.4 m
Unpack and assembly time	30 min
Startup time (off to full operation)	20 min
Power consumption (idle/ typical/ max)	ND
Battery endurance (idle/ normal/ heavy load)	ND
Any other interesting attribute	-
Cost	2000 USD

TABLE IV
HARDWARE COMPONENTS LIST

Part	Brand & Model	Unit Price	Num.
Robot structure	-	2500 USD	2
Drive motors	Maxon	1200 USD	2
Drive gears	Planetary Gearhead GP 62	-	2
Drive encoder	Omron rotary encoder	120 USD	2
Motor drivers	ND	-	2
DC/DC	Regulator	-	1
Battery Management	ND	-	1
Batteries	LiPO	-	1
Micro controller	Arduino, Pic	-	1
Computing Unit	Mini PC, Embedded	-	1
WiFi Adapter	Access point IEEE 802.11a	190 USD	1
IMU	xsens	-	4
VDO Cameras	Microsoft	320 USD	4
PTZ Camera	ND	-	1
Infrared Camera	ND	-	1
LRF	ND	-	2
CO ₂ Sensor	ND	125 USD	1
Temperature Sensor	Lepton	2400 USD	1
Battery Chargers	ND	100 USD	10
6-axis Robot Arm	ND	23000 USD	1
Aerial Vehicle	ND	2000USD	1
Rugged Operator Laptop	ND	2000USD	1

TABLE V
SOFTWARE LIST

Name	Version	License	Usage
Ubuntu	14.04	open	
ROS	indigo	BSD	
OpenCV [3], [4]	2.4.8	BSD	Haar: Victim detection
OpenCV [5]	2.4.8	BSD	LBP: Hazmat detection
Hector SLAM [6]	0.3.4	BSD	2D SLAM
iRap 3D Mapping	-	closed source	3D Mapping
Proprietary GUI from KMUTNB U.	0.7	closed source	Operator Station

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