RoboCup Rescue 2018 Team Description Paper iRAP Robot

Amornphun Phunopas, Wisanu Jitviriya, and Aran Blattler

Info

Team Name:	iRAP Robot
Team Institution:	King Mongkut's University of Technology North Bangkok
Team Leader:	Aran Blattler
Team URL:	http://www.kmutnb.ac.th/en/

RoboCup Rescue 2018 TDP collection:
https://to-be-announced.org

***Abstract*—In this paper, we would like to describe the improved construction and operation of our robot (iRAP ROBOT), which has a long history in the first place awards of World RoboCup Rescue Robot competitions such as iRAP PRO, iRAP JUDY, iRAP FURIOUS, iRAP JUNIOR and iRAP ROBOT teams. And also, in the World RoboCup Rescue Robot 2017 (Nagoya, Japan), we had participated in the competition again. The robot was serverely damaged by heavy workload exceeding specified limits in the final round, as a result of significant adjustments of the original policy regulations. The maximum driving mode operation and power consumption beyond robot restrictions produced thermal effects on the components. We have worked on the issue. Basic troubleshooting steps to resolve the issues involve these issues: designing the new proper electrical driving system for heavy workload and testing competition robotic system for RoboCup Rescue 2018. We have one high mobility teleoperative robot, one outdoor autonomous navigation robot and one autonomous flying robot. The teleoperative robot can move by a caterpillar module. They can identify victims very well with multi-sensors (Carbon sensor, Array temperature sensors, and cameras) and able to move autonomously in the radio drop zone. The teleoperative robot has used the chain with the garden hose, which has good material to move up the inclined surface. In addition, the robot can create explored map automatically and can detect the Hazmat and the QR code.**

***Index Terms*—RoboCup Rescue, Cooperative Robot, Aerial robot**

I. INTRODUCTION

INVIGORATING ROBOT ACTIVITY PROJECT (iRAP) is the teams of students from King Mongkuts University of Technology North Bangkok, Thailand. In this year, our robot is developed from **iRAP ROBOT** for the competition. The team members are the next generation of the legendary student teams who got the 1st place many times in the RoboCup Rescue Robot competition [1]. In this paper that introduces our approach to the rescue robot. More than eight years, the team has designed and developed. The team has three robots that consists of a teleoperative robot, an outdoor robot and a flying robot as shown in figure 1-4 respectively. Our rescue robot for this competition is designed based on proficiency robot by the agility test. Therefore the robots can motivate roaming around rough terrain by using caterpillar module. Four cameras are installed on the robot to help identify the victims. And the end effector of the robotic arm is designed to install the temperature camera and CO2 sensor. In addition, the laser range finder is used to create the map for marking the victims autonomously. Our 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 people life in a real disaster situation.

A. Improvements over Previous Contributions

The robot came to its limitation in the previous contribution. It was damaged by taking heavy workload continuously. The new teleoperative robot has been designed to extend the robot's performance beyond the new competition rulebook. The electrical motor driver has been analyzed to a new design for balancing the power consumption and workload. The robot body's temperature is monitored with ventilation. The other functions 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. 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. We have changed the thermal sensor then the autonomous robot succeeded in the previous competition because the thermal sensor worked well to detect the victims. Although, we have focused on the main competition of the indoor mission. The outdoor autonomous navigation robot and autonomous aerial robot are developed for promptly use in the future. The outdoor autonomous navigation robot uses the base platform of the teleoperative robot without flippers in figure 3. The robot is simply tested the autonomous navigated locomotion from point to point using IMU and GPS [2]. Basically, the aerial robot can fly and explore the victim in searching area using the thermal camera and CO2 sensor in figure 4. It has a function to navigate itself and avoid the obstacles using GPS and guidance sensor. It quite difficult to estimate the position of the flying

---

Amornphun Phunopas is with the faculty of Engineering, King Mongkut's University of Technology North Bangkok, e-mail: amornphun.p@eng.kmutnb.ac.th.

W. Jitviriya and A. Blattler are with the same University.


Fig. 1. Teleoperative robot locomotion


Fig. 2. Teleoperative robot climbs the ladder.

robot that has 6 DOF. The new technique is the source of visual odometry for localization. The quadrotor has a camera that point tilt down 45-degree referenced to horizontal line that use to estimate the trajectory by k-nearest neighbor visual odometry techniques [3] as shown in figure 5.

II. OVERVIEW SYSTEM

Our robots have developed in the mechanical parts, electronic circuits and also software for controlling the robot as shown in figure 7. The best mobility awards in the World Robocup Rescue competition can guarantee the capability of our robot. We have experimented the robot motion to confront the difficulties in the different terrains. Moreover, we have developed software, which is parallel with the proper hardware. And, we try to start it up more advanced. The details of our robot will be described as follows:

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

Fig. 3. Outdoor autonomous navigation robot.

Fig. 4. Autonomous flying robot in outdoor mission, as quadrotor model.

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. Refer to the Tables I and following as well as Table IV in the Appendix.

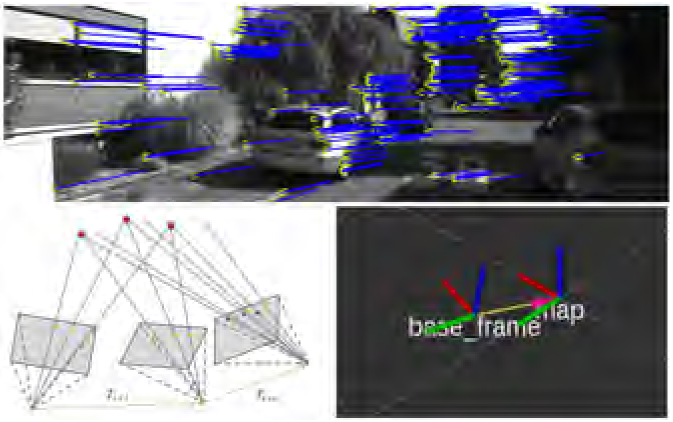


Fig. 5. The k-nearest neighbor visual odometry the process that use to estimate quadrotor motion in 6 DOF.

Fig. 6. Robot manipulator arm has a camera and a gripper at the end effector.

- Locomotion
  Regarding designing the robot locomotion system, the team has learned and has improvements through our team advisors iRAP PRO, iRAP JUDY and iRAP FURIOUS that have gained experiences from many competitions. In this competition, our team attentively improved the teleoperative robot. The team is looking forward to 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 motors-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 microcontrollers, etc.
  The electronics systems are low-level systems. The micro-controllers are used to interface with motor-driven

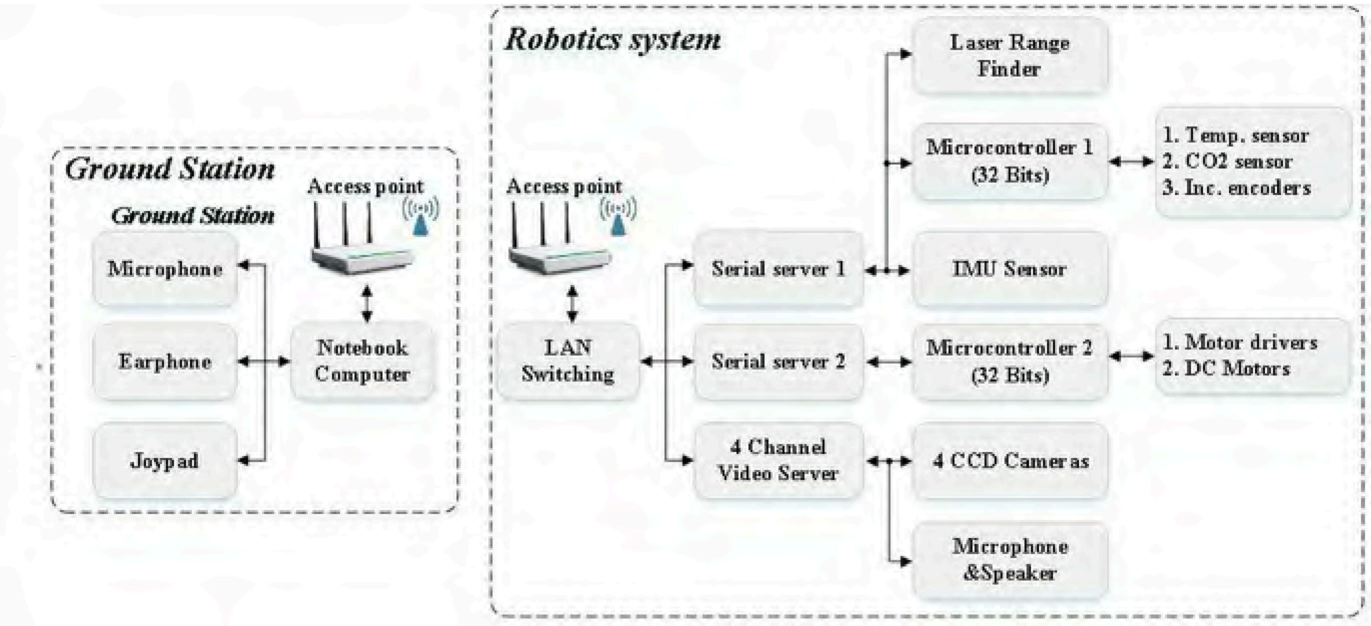


Fig. 7. The control system diagram.

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. 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 crucial information regarding the environment around the robot. Thermal camera and CO2 detectors were mounted at the end-effector of the robot manipulator to detect a heat signature and CO2 level of the immediate environment. The position estimation for the robot is determined by fusing pulses from encoders, the inclination from IMU and current distance from LiDAR sensors, which are used to generate the 2D occupancy grid map of the environment by utilizing SLAM library available on Robot Operating Systems. Moreover, to detect the visual clues of the immediate environment such as Hazmat sign, QR code or motion, the auto-detection algorithm of these clues was also implemented, as for 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.

D. *Human-Robot Interface*

The operator can quickly get familiar to control the robot by using typical gaming joystick, two information displays, and communication headset. Especially, the gaming joystick is used as an input to control the robot, which can be easily configurable by the different operator preference. The primary display is used to visualize the quad-channel video feed from the robot, the robot orientation, CO2 level, Thermal camera video feed and other essential information as shown in figure 8. The second display is used to visualize the visual clue detection (Motion, Hazmat, and QR code) as shown in figure 9.

The main control is based on one CPU (32-bit microcontroller). 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 10. This information will be shown to the robot operator via a second computer monitor.

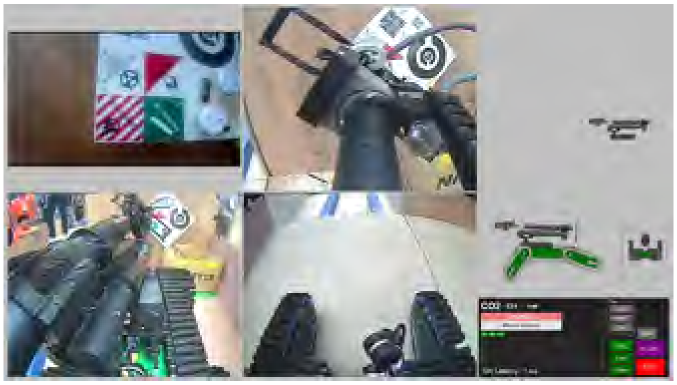
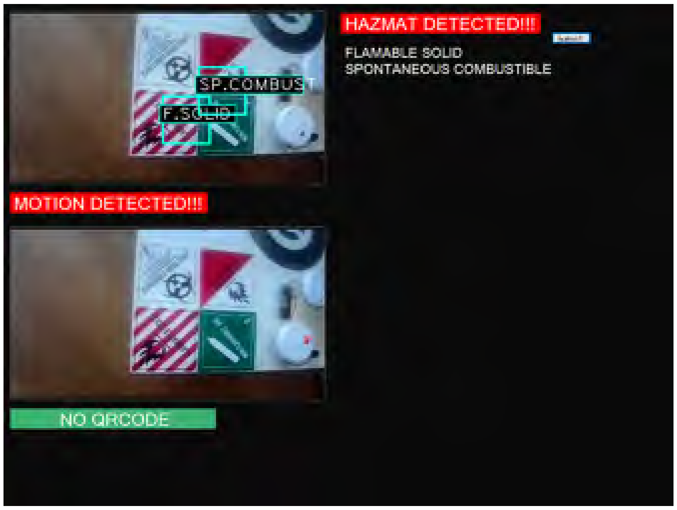


Fig. 8. Primary operator display illustrated the real time quad videos and the information of robots sensors.



HAZMAT DETECTED!!!

FLAMABLE SOLID
SPONTANEOUS COMBUSTIBLE

MOTION DETECTED!!!

NO QRCODE

Fig. 9. Secondary operator display illustrated the motion detection, QR code detection and hazmat detection.

- 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 UPS as in figure 11. 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 2017. During the competition, the objective is to find as many survivals 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.

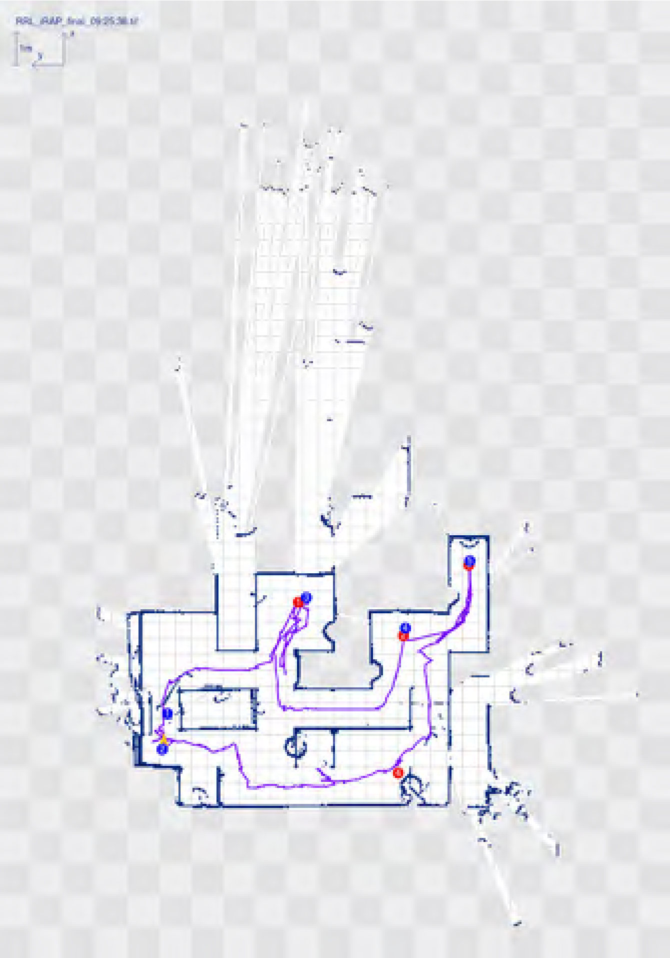


Fig. 10. Automatic map generated by iRAP ROBOT in the final round of world robocup 2017 competition.

C. Hazmat recongnition

The robot has a camera at the manipulation arm to detect the hazmat tags as shown in figure 12. We have our own software to detect the hazmat tags using the image processing method [4]. All 12 tags are used in the competition. Our model for recognizing the hazmat tags is shown in figure 13. The results of the model can be confirmed in figure 14.

IV. Conclusion

After the competition, the team knew how to make the better robots. The team learned the new technologies from other countries competitors, learned how to be a good team. The

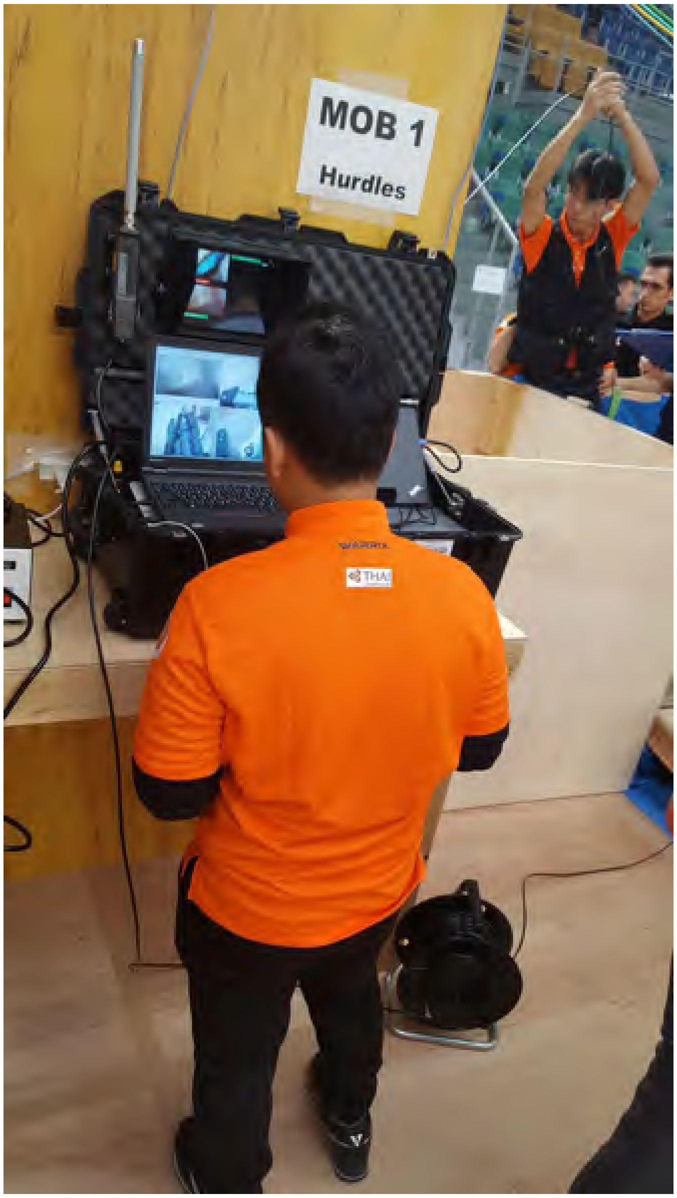


Fig. 11. The operator station

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 13 members and three advisers. The names and responsibilities of each member are listed as follows:

Mr.Thanapon Sorndach	Mechanical design and Structure
Mr.Bannawit Butdi	Mechanical design and Structure
Mr.Thanut Vibutr	Mechanical design and Structure
Mr.Chinnawut Ngiamngamsri	Mechanical design
Mr.Peeyaphoom Thanawutthianan	Mechanical design
Mr.Patipan Taewmor	Driver and Programmer
Mr.Nonthawat Danwiang	Electrical design
Mr.Natinan Kuttanan	Electronic design
Mr.Pubadee Bunjing	Electronic design
Mr.Poommitol Chaicherdkiat	Network systems
Mr.Tanawit Sinsukudomchai	System interface
Mr.Noppadol Pudchuen	Map programmer
Mr.Theerawath Phetpoon	Embedded systems
Mr.Aran Blattler	Team manager (Team Leader)
Mr.Sai-yan Primee	Adviser
Asst.Prof.Chatchai Sermpongpan	Adviser
Dr.Amornphun Phunopas	Adviser

TABLE I
MANIPULATION SYSTEM

Attribute	Value
Name	iSMILE
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	0.8kg
Weight including transportation case	2kg
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	0.5 kg
Any other interesting attribute	-
Cost	4000 USD

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

The authors would like to thank the King Mongkut's University of Technology North Bangkok for regularly supporting

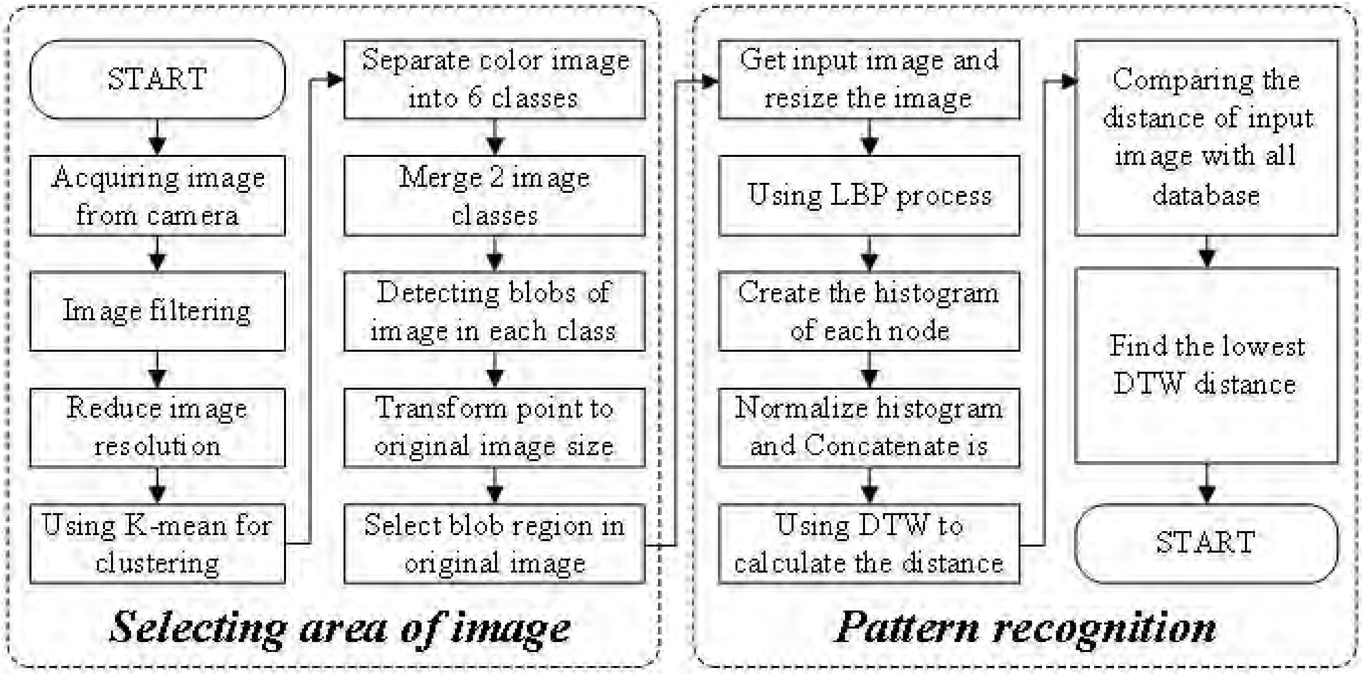


Fig. 12. The flowchart of hazmat recognition.

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

Fig. 13. The selected hazmat tag for inputting to the program.

the iRAP Robot in participating the World Robocup Rescue Robot Competition.

REFERENCES

[1] A. Phunopas, A. Blattler, and N. Pudchuen, "Rap robot: World robocup rescue championship 2016 and best in class mobility award," *Robot World Cup. Springer, Cham*, 2016.

[2] A. Blattler, A. Phunopas, W. Jitviriya, S. Yamana, and S. Keita, "The tracked robot for explosive ordnance disposal (eod) mission, performance test and navigated locomotion using imu and gps," in *The fourth Asian Conference on Defence Technology (ACDT)*, 2017.

Fig. 14. The result of pattern recognition shows the post-processed image and histogram.

TABLE V
SOFTWARE LIST

Name	Version	License	Usage
Ubuntu	16.04.3	open	Utility
ROS	Kinetic	BSD	Utility
OpenCV, EMGU	2.4.8	BSD	QR Code detection, Motion Detection,
Hector SLAM [5]	0.3.4	BSD	2D SLAM
iRap 3D SLAM	-	closed source	3D SLAM
Hazmat Detection[4]	1.0.2	KMUTNB	Hazmat sign Detection

[3] N. Pudchuen and C. Deelertpaiboon, “Visual odometry based on k-nearest neighbor matching and robust motion estimation,” in *International Electrical Engineering Congress (iEECON)*, 2018.

[4] W. Jitviriya, P. Chaicherdkiat, N. Pudchuen, and E. Hayashi, “Development of automatic recognition of hazmat marking chart for rescue robot,” in *International Conference Artificial Life Robot (ICAROB)*, 2018.

[5] S. Kohlbrecher, J. Meyer, O. von Stryk, and U. Klingauf, “A flexible and scalable slam system with full 3d motion estimation,” in *Proc. IEEE International Symposium on Safety, Security and Rescue Robotics (SSRR)*. IEEE, November 2011.