# RoboCup Rescue 2017 Team Description Paper iRAP Robot

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**Info**

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

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

***Abstract*—In this paper, we would like to describe the new 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 2016 (Leipzig, Germany), we had participated in the competition again. We develop our robotics system every year to improve our skill. In this year, the team has prepared for different scenarios that present in the World Robocup Rescue 2017 in Nagoya (Japan). We have two similar high mobility teleoperative robots 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 robots have used the chain with the garden hose, which has good material to move up the inclined surface. In addition, the robots can create explored map automatically and can detect 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 seven years, the team has designed and developed. The team has two robots that consists of a teleoperative robot and a flying robot as shown in figure 1-3 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.

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

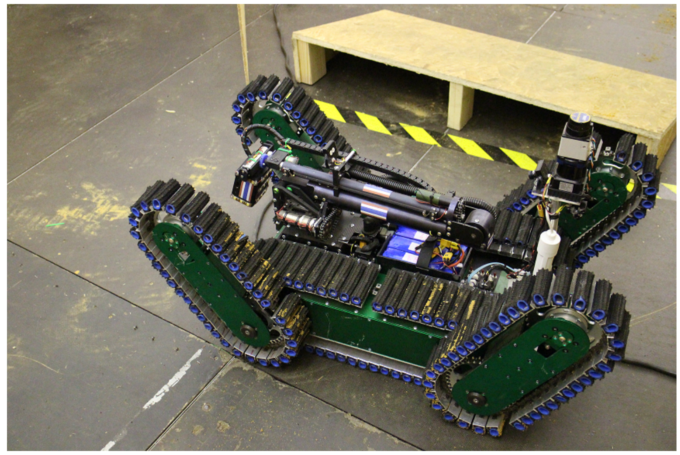

Fig. 1. Teleoperative robot locomotion

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

## II. Overview System

Our robots have developed in the mechanical parts, electronic circuits and also software for controlling the robot as shown in figure 6. The best mobility awards in the World Robocup Rescue competition can guarantee the capability

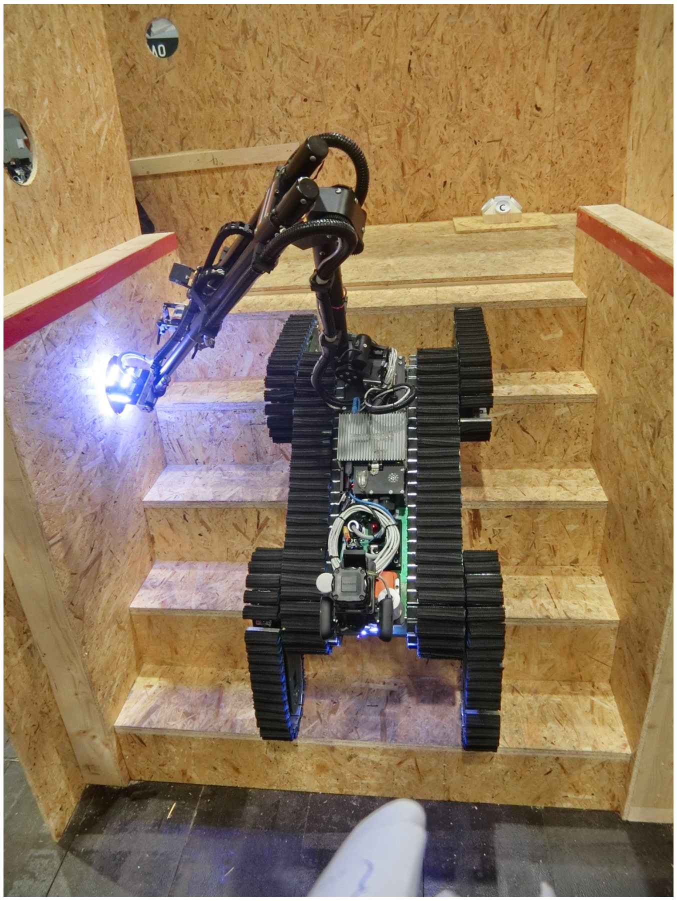

Fig. 2. Teleoperative robot climbs the ladder.

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

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 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_FURIOUS that have gained experiences from many competitions. In this competition, our team improved the two robots consisting of the teleoperative robot and the flying 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.

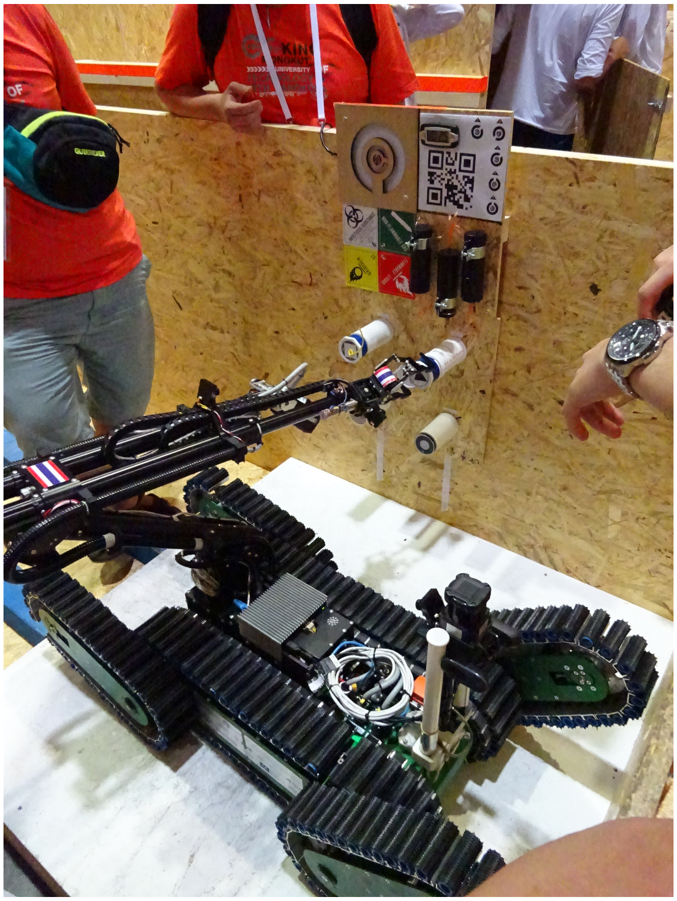

Fig. 4. Robot manipulator arm has a camera and a gripper at the end effector.

- 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. 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 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 [2], [3] 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.

### D. Human-Robot Interface

The main control is based on one CPU (PIC microcontroller 80 pins). Figure 6 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 7 (Quad-video and sensors information) and create 2-D map automatically as shown in figure 5. 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 UPS as in figure 8. Once all the tasks are completed, the report and the generated map can be quickly printed out.

Fig. 5. Automatic map generated by iRAP ROBOT in the world robocup 2016 competition.

### 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 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.

### C. Hazmat recongnition

The robot has a camera at the manipulation arm to detect the hazmat tags as shown in figure 9. In this year, our success is to detect the hazmat tags using the image processing method in figure 10. All 12 tags are used in the competition. Our model for recognizing the hazmat tags is shown in figure 11. The results of the model can be confirmed in figure 12.

## 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 team gained many experiences. Importantly, the team knew that The great competition is not practicable, if you do not have a good teamwork.

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 |

## Appendix A
## Team members and Their Contributions

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

- Mr.Thanapon Sorndach Mechanical design and Structure
- Mr.Yatip Auarmorn Mechanical design and Structure
- Mr.Bannawit Butdi Mechanical design and Structure
- Mr.Thanapon Sondach Mechanical design
- Mr.Thanawat Pongsathornpisuth Mechanical design
- Mr.Pongthana Laongaiem Maintenance
- Mr.Netinan Kuttanan Electronic design and system
- Mr.Theerawath Phetpoon Electronic design
- Mr.Patipan Taewmor Teleoperative robot hardware
- Mr.Porn-anan Raktrakulthum Communication system
- Mr.Poommitol Chaicherdkiat Network system
- Mr.Noppadol Pudchuen Software and Control system
- Mr.Aran Blattler Team manager (Team Leader)
- Mr.Sai-yan Primee Advisor
- Asst.Prof.Chatchai Sermpongpan Advisor
- Dr.Wisanu Jitviriya Advisor
- Dr.Amornphun Phunopas Advisor

## 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

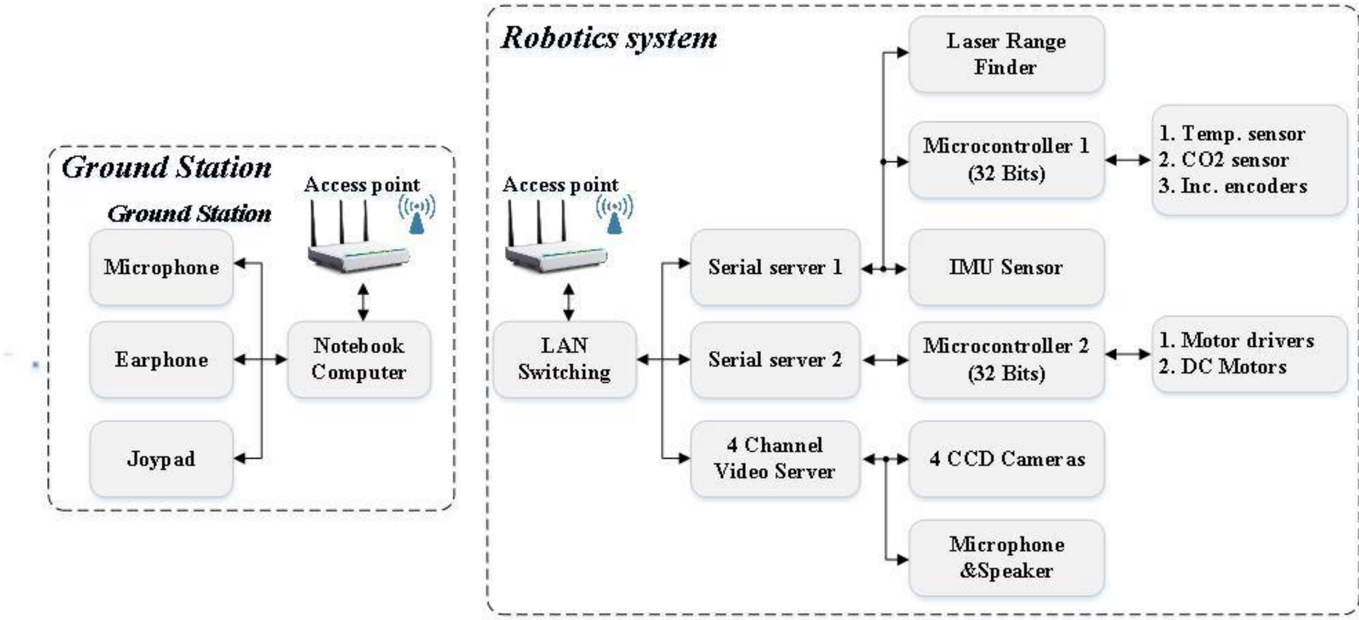


Fig. 6. The control system diagram.

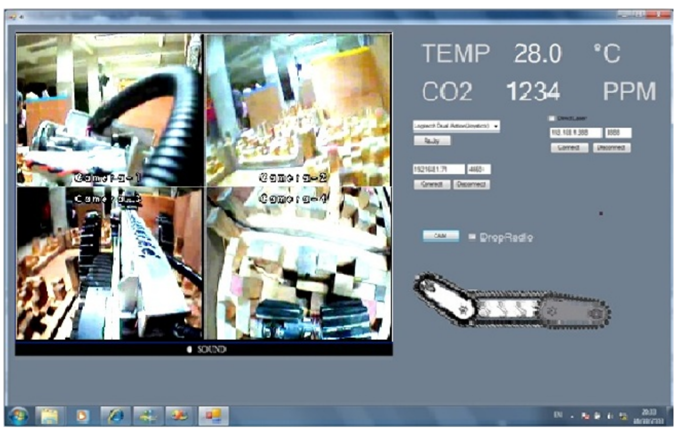


Fig. 7. Operator console illustrated the real time quad videos and the information of robots sensors.

Fig. 8. The operator station

## ACKNOWLEDGMENT

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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 |

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 | Utility |
| ROS | indigo | BSD | Utility |
| OpenCV [4], [5] | 2.4.8 | BSD | Haar: Victim detection |
| OpenCV [6] | 2.4.8 | BSD | LBP: Hazmat detection |
| Hector SLAM [7] | 0.3.4 | BSD | 2D SLAM |
| iRap 3D Mapping | - | closed source | 3D Mapping |
| Proprietary GUI | 0.7 | KMUTNB | Operator Station |

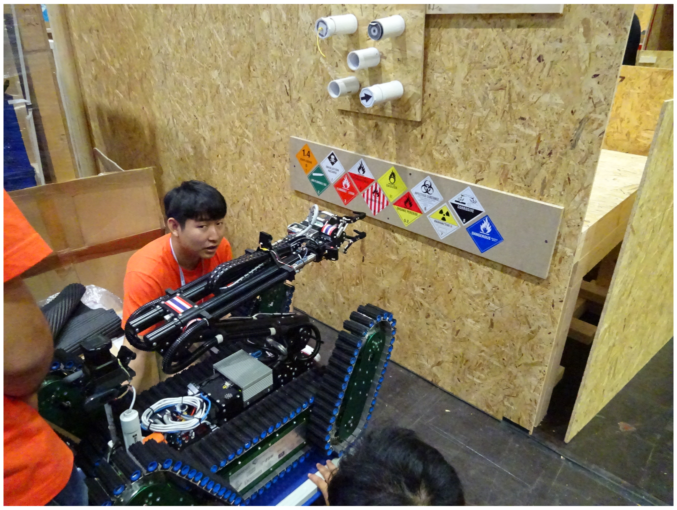

Fig. 9. The robot has read the hazmats.

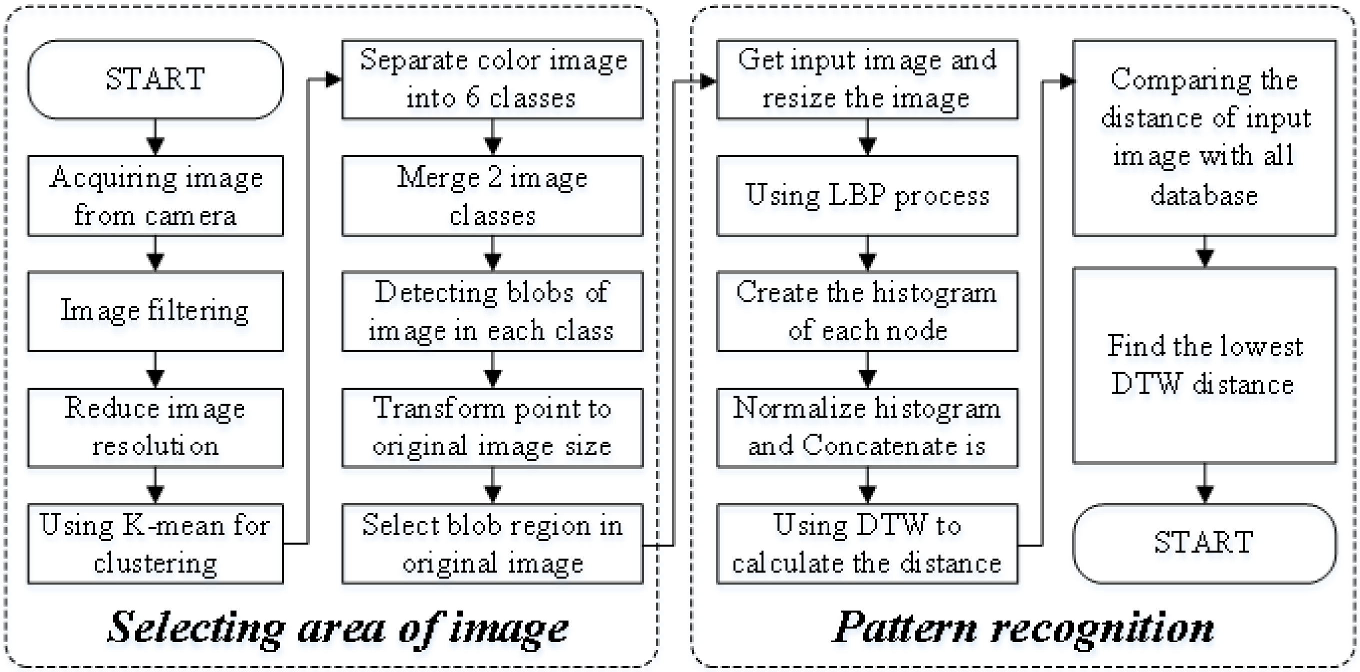


Fig. 10. The flowchart of hazmat recognition.

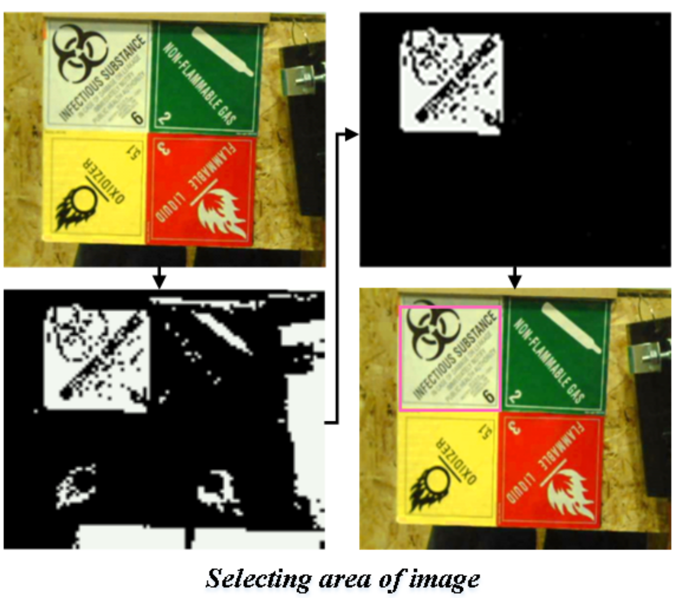


Fig. 11. The selected hazmat tag for inputting to the program.


Fig. 12. The result of pattern recognition shows the post-processed image and histogram.