RoboCup Rescue 2015 - Robot League Team <BART LAB Rescue Robotics Team (Thailand)>

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Abstract. BART LAB Rescue Robotics Team, a RoboCup Rescue Robotics team from Thailand, has participated in regional robot competitions since 2006. Since 2006, the team has received various awards for its robots. The team has also received acclaim during its participation in various international events. The team consists of three robots; two tele-operative robots and one autonomous robot. Their highly mobile attribute is a result of the four independently controlled flippers of the robots. The tele-operative robots are controlled using a controller while the autonomous robot navigates itself through the arena using a laser-scanner. The robots have similar physical structures and systems. The system used for mapping is SLAM whereas the one used for locomotion is the fuzzy logic algorithm. On the other hand, the physical structures consist of a platform and manipulator, where the manipulator contains the sensors required for victim detection. The main goal of our research and development team is to produce reliable rescue robots to employ in a real disaster situation around the world.

Introduction

'BART LAB Rescue Robotics Team' is a one of rescue robotics team from Thailand and presently consists of fifteen members and two robots. The two robots are composed of one Tele-Operative robots (TeleOp V) and one autonomous robot (AutoBot III). We constantly researching and developing robots and has participated in regional robot competitions since 2006.

In 2008, Thailand Rescue Robot Championship (TRR 2008), we were one of the 8-finalist teams from 80 plus participating teams and received the Best-In-Class award for its autonomous robot. In early 2009, we attended the RoboCup Japan Open 2009 in the Rescue League with ten Japanese teams, where the team received second place. Additionally, we were awarded the 'SICE Award" for data collection and management of the autonomous robot.

Figure 1: The Tele-Operative robots in BART LAB Rescue Robotics Team. These robots employ a track locomotion system with four independent flippers and are equipped with a manipulator which is controlled using inverse-kinematics to improve the robot's ability to search and retrieve victim information, similar to other robots in [1,2].

At the 2009 Thailand Rescue Robot Championship (TRR 2009), we were the Winner and awarded Best-in-Class for its autonomous robot. TRR 2009 was one of the most competitive Rescue Robot League in the Work with more than 100 exceptional teams, consisting of six international teams from four countries (Australia, NuTech-R: Japan, NIIT-Blue: Japan, Jacobs University: Germany, Pasargard: Iran, and Resquake: Iran). In early 2010, the team attended RoboCup Japan Open 2010 was awarded 1st Place Rescue Robot Award. After commendable performance at these two competitions, we participated at World RoboCup Rescue 2010, Singapore as the official representative team. There, the team was awarded the 1st runner-up for its Rescue Robot.

In 2011 and 2012, the our team continued to receive awards, 1st Place Rescue Robot Award and 1st Runner-up Rescue Robot Award at RoboCup Japan Open 2011 and 2012, respectively. Furthermore, the team was awarded the Best Autonomy Award at Thailand Robot Championship 2012 in the Rescue Robot League.

Tele-operative robots similar in their design yet have different performance, since TeleOp IV has better driving components. Tele-operative robots are highly mobile robots with tracking locomotion systems, making the robots more mobile in orange and red arenas. The robots consist of four flippers, which are controlled independently to improve their mobility in various terrains (two flippers at the front end and two more at the rear end). The robots also employ manipulators which are controlled using inverse-kinematics. The victim-sensing unit is attached to the end-effector of this manipulator, to improve the ability to sense victims and retrieve information. The victim-sensing unit contains various life-signal detecting sensors, for example, heat sensors, real-time motion image detector, carbon dioxide sensor, and a two-way voice communication system. The manipulator has multiple degrees of freedom with both rotational and prismatic joints, giving the robot a compact folding-size with a highly efficient workspace. The autonomous robot of the team is designed for victim identification using image processing and heat imaging technology. AutoBot III, the autonomous robot, navigates by employing a laser-scanner system and an efficient algorithm which allows the robot to navigate in the yellow arena without hitting walls. The tele-operative and autonomous robots are equipped with SLAM system to generate 2-D maps to guide the responders after the rescue robots raid the disaster area.

Figure 2: Autonomous robot of BART LAB Rescue Robotics team. This robot has a track-based locomotion system with sensors for the victim identification system, which uses image processing and heat imaging technology.

In conclusion, we comprises of highly mobile rescue robots in relation to those built by Thai teams for previous World RoboCup Rescue Leagues. Over the years, we have improved its autonomous robot and the quality of real-time map generation. The ultimate aim of our research and development team is to produce reliable rescue robots to be employed in real disaster situations around the world.

1. Team Members and Their Contributions

• Jackrit Suthakorn, Ph.D.	Advisor
• Choladawan Moonjaita	Main Coordinator
• Nantida Nillahoot	Coordinator
• Sakol Nakdhamabhorn	Operator, Programming
• Korn Borvorntanajanya	Programming Development
• Maria Chatrasingh	Algorithms and Computation
• Preedipat Sattayasoonthorn	Electronic System Development
• Chawaphol Direkwatana	Mechanical Designer
• Peerapat Owatchaiyapong	Mechanical Designer
• Suwipat Chalongwongse	Mechanical Development
• Rachot Phuengsuk	Controller Development
• Shen Treratanakulchai	Sensing Development
• Pittawat Thiuthipsakul	Sensing Development
• Syed Saqib Hussain Shah	Track Development
• Karat Thanaboonkong	Track Development

2. Operator Station Set-Up and Break-Down (5 minutes)

Our operator station is a suitcase-sized mobile unit. The operator system contains two laptop computers, robot controllers (joysticks), backup batter, power connection system, wireless access point system and a large monitor system. The system is placed in waterproof, wheeled, and tough suitcase, which allows for easy transport and setup. The system is utilized to control and communicate with the two robots (TeleOp V, and AutoBot III). One laptop is dedicated to the two tele-operative robots whereas one laptop is connected to the autonomous robot. The diagram below demonstrates the system for the operator station. Due to the simple and convenient design of our operator station, setup is almost immediate and ready to use.

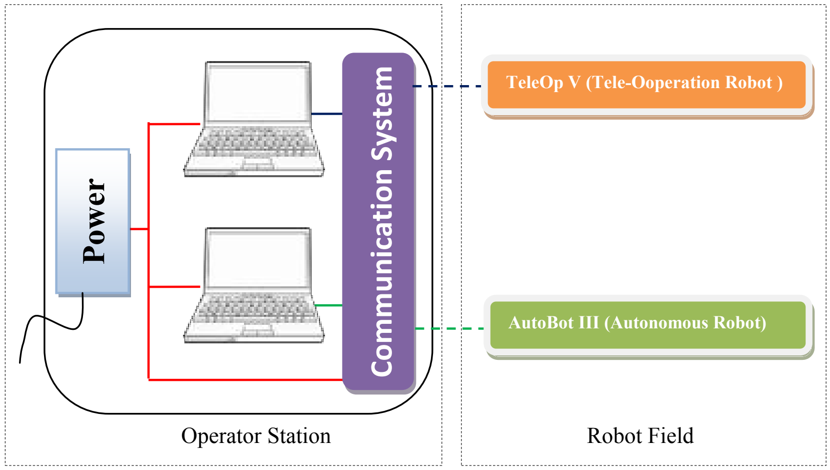


Figure 3: Diagram of the operator station

3. Communications

BART LAB Rescue Robotics team employs five access points connected via Wireless LAN 802.11A to communicate among the two robots. Each robots are designated an access point to communicate with the two access points at the operator station with bridging technique. The figure below demonstrates the communication system of our robot. The default setting in our communication system is Channel 36 which can be modified to any other requested channel in the available range. We don't utilize any RF or Analog wireless communication.

Figure 4: Diagram of the operator station

Table 1. Frequency, Channel/Band, and Power Table which describes the communication system of BART LAB Rescue Robotics Team.

Rescue Robot League		
BART LAB Rescue Robotics (Thailand)		
Frequency	**Channel/Band**	**Power (mW)**
5.0 GHz - 802.11a	36	To be determined

4. Control Method and Human-Robot Interface

Our control method and human-robot interface can be split into two groups: 1) Control and interface on tele-operative robot and 2) Control and interface on autonomous robot. These two groups are discussed in further detail below.

4.1 Control Method and Human-Robot Interface of Tele-Operative Robot

The control system for the tele-operative robots is illustrated in the figure below. The onboard controlling system communicates with the operator station via Wireless LAN 802.11A access points. The onboard access on the robot is connected to an onboard laptop. Various USB devices and sensors, for example, cameras, microphones, speakers, and hokuyo ranging laser-scanner, are connected to the laptop. The laptop communicates with the Robot-CPU using a USB port through a USB-to-serial port. The Robot-CPU controls the platform, manipulator and other subsystems. Under the platform and manipulator subsystems are each of the joint and drive (motor) controller module which employees our speed/position PID control system. Feedback control theory is therefore used extensively in our robots. The robot also has an emergency resetting system which prepares and recovers the robot’s control system when it is operating in a remote area, far from the operator station.

TeleOp V have identical control systems therefore allowing more flexibility to add robots to the team in the future.

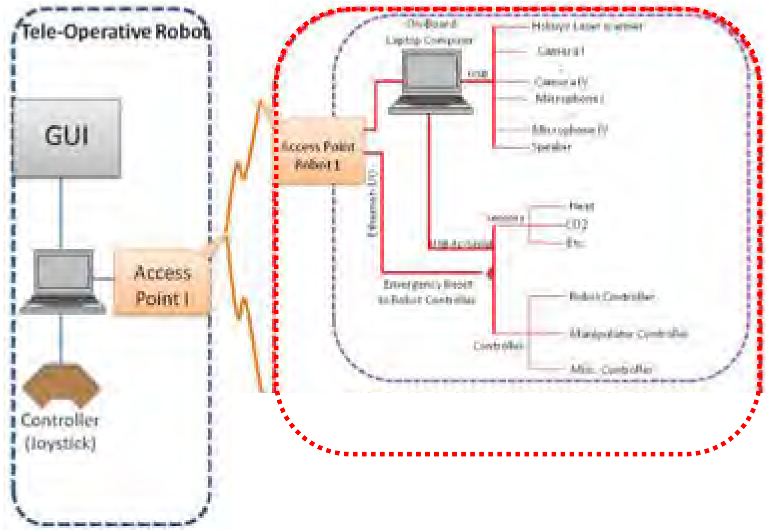
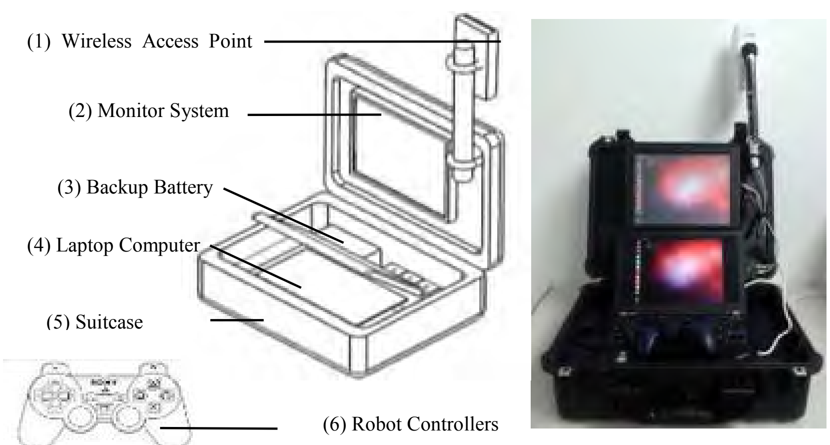


Figure 5: This diagram illustrates the control scheme for TeleOp V

At the operator station, the station's access point is connected to a laptop which is connected to a robot's remote controller (joystick) and a display monitor with GUI for the human-robot interaction. Information displayed on the GUI includes 4 viewing areas from 4 onboard cameras, sensor data display (heat, CO_2, etc.), robot heading, communication controller, configuration display of robot platform, pre-set robot configuration controller, and a controller for inverse-kinematic manipulator.



(a)

(b)

Figure 6: Image shows the framework of (a) Our Operator's Station and (b) GUI

4.2 Control Method and Human-Robot-Interface of Autonomous Robot

The control scheme utilized for the autonomous robot is similar to that of the tele-operative robot. The difference in this control system is that the robot navigates itself autonomously and can also detect a victim automatically. Aspects of the autonomous robot's navigation, for example, map generation, navigation and robot localization, are discussed in further detail in Sections 5 and 6. Along with that the mechanism used to automatically identify victims is discussed in Section 7. At the starting point, the autonomous robot has to be launched manually after which it travels autonomously. This autonomous robot will continuously report to the laptop at the operator station which is dedicated to the autonomous robot (GUI of the autonomous robot discussed in detail in Section 5).

5. Map generation/ printing

Our robot is mainly governed by ROS operation. The software package used to generate a map is G-Mapping package from the open SLAM community. Firstly, the map is defined by an occupancy grid, which has a high resolution, of about 0.05 meter per pixel. There are two inputs that create the map, which are: 1) the laser range finder which is used to measure the distance of objects or structures around the robot at 180 degrees and 2) the odometry of the robot which is used by the wheel encoder to calculate the distance the robot has traveled in the axial direction. The robot's orientation is measured using the inertia measurement unit (IMU).

Figure 7: A map generated at Thailand Robot Rescue Championship

The figure above shows the map generated at a previous competition using G-Mapping algorithm. Maps have a resolution of about 0.05 meters per pixel and the red mask shows the location of victims using heat detection whereas the blue mask shows the victim using QR code detection.

6. Fuzzy Logic Algorithm for Autonomous Running with Obstacle Avoidance

Our autonomous robot uses the fuzzy logic algorithm to run and avoid obstacles. The fuzzy logic algorithm uses input range information collected by a laser range finder. The laser range scanner provides data from ten directions following the pan scan direction. Ten directions are chosen with the aim to reduce the amount of data and computation period within the algorithm. A filter is applied to reduce the error before the data is turned into the membership function for Fuzzy sets. The membership function is a range from zero to one and is used as the fuzzy input in the algorithm. This function is defined by the range of the distance collected by the laser range finder device. For the fuzzy rule design, obstacle avoidance and distance decrease as the robot moves around the area, therefore the robot reduces its speed at each side of the driving system. The fuzzy set is divided into three categories: low, medium and far. These fuzzy categories correspond to obstacles and choose the minimum distance for obstacle avoidance. The fuzzy outputs using the If-Then Rule based on the orientation of the robot and the velocity of each driving motor. The output is computed in real-time based on the environment and sent to the driving unit of the robot, to respond with the environment immediately.

7. Sensors for Victim Identification

The Our robots are equipped with a victim sensing unit which contains various necessary sensors to detect victim life-signals. The sensors utilized in our system are listed below:

1. Cameras (for Victim Form and Motion Detection)
2. Heat Sensors (for Victim Temperature Detection)
3. Microphone/Speaker (for 2-way Voice Communication)
4. CO_2 Sensors
5. QR code
6. Motion

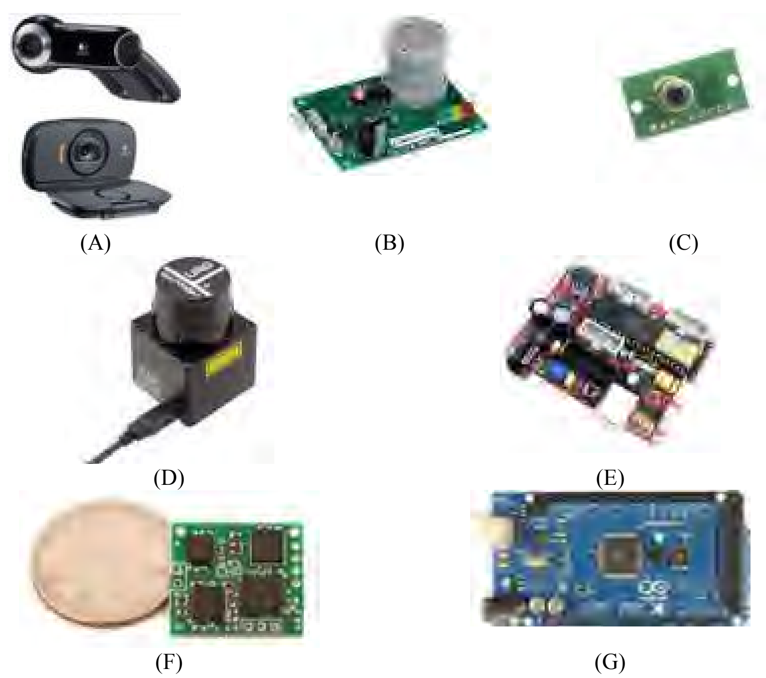


Figure 8: Electrical components of our robots

The autonomous robot detecting system is divided into 2 types: 1) image detection from camera is used to monitor and analyze the data from victim such as motion detection, QR code detection, and reading the text in an image and 2) heat sensor detection to determine the heat of the victim inside the arena. Heat sensors are mounted on a servo motor to allow for the sweep to search the heat of a victim. The image below shows the range of these two victim searching mechanisms, where the red zone represents the image detection area and the blue zone represents the heat detection area.

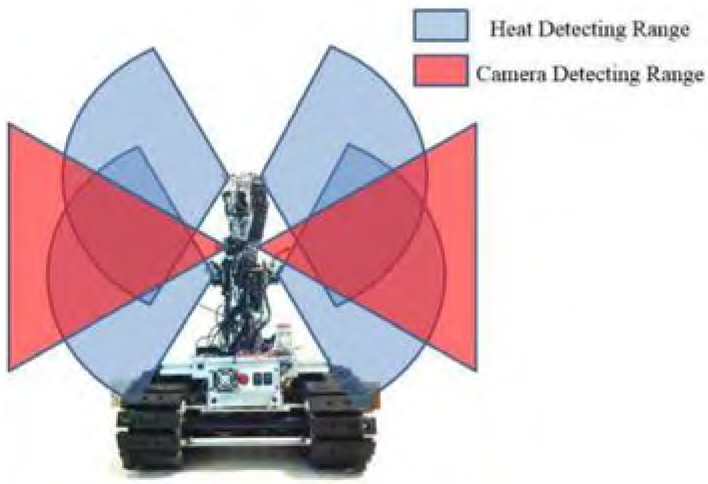


Figure 9: This figure shows the swing-sweep search algorithm used to detect and identify the victim.

The autonomous robot is divided into two main physical structures, the platform and the manipulator. The platform of the robot has the driving system whereas the second part consists of the manipulator and sensors. The sensors that are attached to the manipulator include: camera, heat sensor, carbon dioxide sensor, and the laser range finder. Special properties of the manipulator are: rotation and extension. The manipulator works with the sensors shown in figure 10.

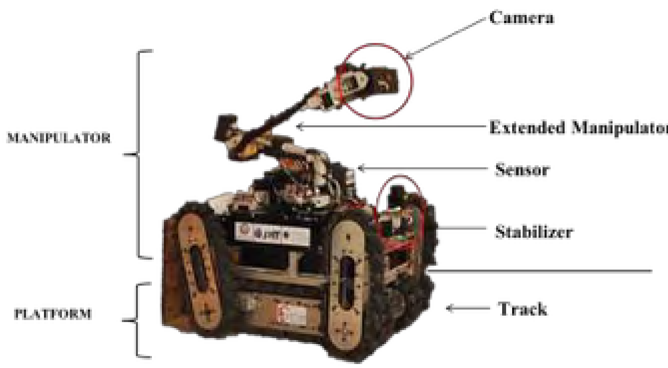


Figure 10: Components of autonomous robot

QR code detection is a task, achieved by the autonomous robot by moving during the mission, therefore the input data is video type and detection is achieved through image processing. The QR code detection flow chart is shown below (in figure 11).

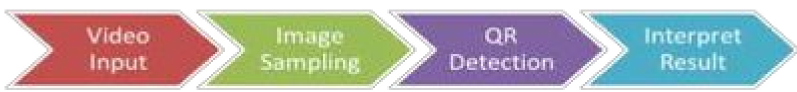


Figure 11: Diagram shows the process for QR code detection

Image processing allows for the detection of QR code throughout the different zones of the arena and is divided into multiple steps. The first step is, to import the video and sampling data into the image processing program. Second, the image goes through pre-image processing such as noise reduction and exposure calibration. The third step is, searching for QR code, therefore the program searches for three main points in the QR code for the purpose of alignment. The final step, the QR code is interpreted into data information that matches the QR code.

8. Robot Locomotion

Our robots utilize tracked locomotion systems. Moreover, the tele-operative robots are equipped with four independently controlled flippers to enhance their mobility. The locomotion of these robots is similar to a tank-like system. When the left and right tracks are moving in the same direction, at the same speed, the robot moves either forward or backward. Once the left and right tracks start moving at different speeds the robot will make a turn with respect to the velocity of each track. The maximum speed of the tele-operative robot is almost 0.5 m/sec. On the other hand the robot has a maximum angular velocity of 1.8 rad/sec. To maintain stability during movement up/down a ramp or stairway, the robot has to move at an appropriate speed. Figures 12 and 13 compare the CAD and real image of the robot.

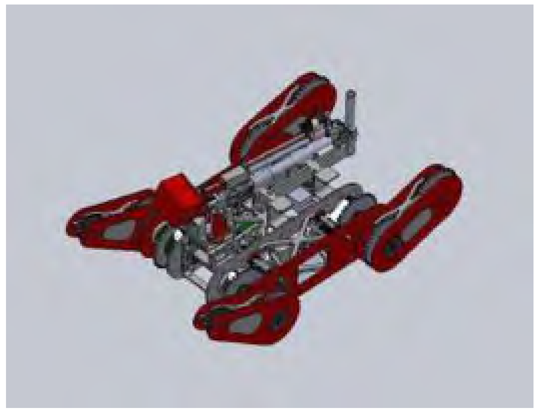


Figure 12: CAD of TeleOp V platform

Figure 13: TeleOp V in step field

9. Other Mechanisms

In this section, we discuss the six degrees-of-freedom manipulator that can be found on the tele-operative robots. The manipulator is designed to perform in a high vibration environment with strong shock absorption during movement along a rough-terrain. The manipulator is relatively light-weight and strong based on its structure. The folding size of this robot is very compact while the workspace is optimized by using both rotation and prismatic joints. The victim sensing unit is attached to the end-effector of the manipulator, which improves the ability to search and identify the victim's conditions. Figure 14 shows the manipulator's degrees of freedom.

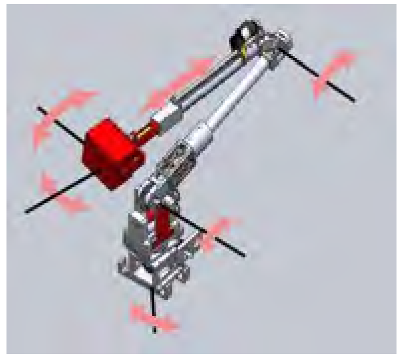


Figure 14: CAD representation of the six degrees-of-freedom manipulator

10. Team Training for Operation (Human Factors)

A year-round setup of the rescue robot arena is constructed for practice and training at Mahidol University, Salaya, Thailand. The arena consists of all the zones of the rescue arena; red, orange, yellow and blue zones. Therefore, BART LAB Rescue practices and conducts experiments frequently. The QR code task is also a part of the arena, as shown in figure 15.

Figure 15: QR Code task in the practice arena.

11. Possibility for Practical Application to Real Disaster Site

Our ultimate goal is to produce a reliable rescue robot, through research and development, for application in a real disaster site around the world. We strongly believe that our team robots are prepared to perform a rescue task in the real world.

12. System Cost

The table below shows the approximate cost of a tele-operative rescue robot in our team.

Table 2. Cost for each part on a Tele-Operative Robot

BART LAB Rescue Robotics (Thailand)			
Item	**Quality**	**Unit Price (USD)**	**Price (USD)**
Laser-Scanner	1	1,500	1,500
Laptop	2	800	1,600
Camera	4	100	400
Sensor (system)	1	-	500
DC Motor (Locomotion system)	6	1,200	7,200
DC Motor (Manipulator system)	7	800	5,600
Electrical Components	-	-	1,000
Mechanical Parts	-	-	1,000
Part Machining/Misc.	-	-	2,500
Total			21,300

13. Lessons Learned

Teamwork and real world applications.

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