RoboCupRescue 2009 - Robot League Team AVA (Malaysia)

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Abstract. This document introduces AVA rescue robot team and its work in developing functional rescue robots. Our main effort has been focused on efficient Human Robot Interaction (HRI) for a dynamically complex system and a Graphical User Interface (GUI) supporting adjustable autonomy. We implement the system on two identical tracked robotic platforms which are equipped with a range of state of the art sensors for autonomous navigation and victim detection.

Introduction

Research and Development (R&D) team at AVA Strategic Alliance Company works on a Human Machine Interaction (HMI) project using Virtual Reality (VR) systems to increase efficiency of training courses of personals in various required fields. To examine efficiency of our HMI system, we have decided to participate at RoboCup rescue robot field where teams are supposed to find victims as a target in a complex environment.

Our system is implemented on two identical high mobility tracked robotic platforms (Fig. 1) [1] which benefit state of the art sensors for autonomous navigation and victim detection. These robots use a complicated skid steering called Triangular Tracked Wheel (TTW) locomotion mechanism [2] which makes it possible to navigate in rough terrains like collapsed buildings.

Besides developing a friendly video centric User Interface (UI) we are working on adjustable autonomy [3] to reduce complexity of still complex multi robot controlling.

Fig. 1. Our robotic platform (ALPHA)

1. Team Members and Their Contributions

• Sharifah Azizah Sayeed A. Ghazali	Team leader
• AVA R&D team	Software
• Jimmy Lim Jit Whang	Logistical support
• Tan Sri Mohd Jamil Johari	Advisor

With our special thanks to Takin Robotics Company and their engineering team for technically supporting us.

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

Our robots are controlled by a lightweight rugged industrial computer using a game pad and a Head Mounted Display (HMD) (Fig. 2). All these equipments are included in a waterproof backpack and operator can easily transport it to the control station. The industrial computer used in the OCU is vibration resistive and the HMD has a transparent display therefore, operator can control robots even while he/she is running. Prior to each mission robots will be booted up to be transported to the arena by two team members (operator can also be one of these two people). As soon as they placed the robots in start point, operator can start control application to drive the robots.

At the end of each mission, operator will deliver mission data while two other team members will take the robots out of the arena. This will be done in less than 5 minutes.

Fig. 2. Our backpackable OCU

3. Communications

Each robot utilizes a 5 GHz IEEE802.11a Access Point/Bridge with a pair of external antennas to exchange data (e.g. high level control commands, sensor data and digital audio/video) with another one on OCU.
We use channel 44 as our default setting (Table 1) but it can easily be changed to any possible channel if it is needed.

Table 1. Used communication frequencies

Rescue Robot League		
AVA (MALAYSIA)		
Frequency	**Channel/Band**	**Power (mW)**
5.0 GHz - 802.11a	selectable	100

4. Control Method and Human-Robot Interface

As mentioned, we are implementing an adjustable autonomy approach to reduce complexity of multi robot controlling. Using this method, operator may enter to the robot control loop when it is needed. The available autonomy modes are:

- Teleoperation: *no sensors are used to help keep the robot from bumping into objects*
- Safe: *teleoperation with obstacle avoidance provided by the system*
- Shared: *semi-autonomous navigation with obstacle avoidance where the user communicates his desires at points in the route where a choice must be made or can otherwise bias the robot's travel direction*
- Follow: *robot follows its moving leader and avoids collision*
- Full autonomous: *robot chooses a goal point (based on Frontier Exploration algorithm [4]) to which it then safely navigates*

We will surely limit this capability to full autonomous mode for the robot exploring in yellow arena.

Although providing several autonomy options facilitates operator's task in HRI loop but, most operators don't take enough care to suggestions from this system [5]. To overcome this problem, we are implementing an autonomy mode suggestion system [6] in our GUI which is displayed on HMD.

Though using HMD to control rescue robots efficiently is not new to RoboCup rescue robot league [7] but our GUI benefits of special see throw capability of our high resolution HMD.

Furthermore, operator is alerted about critical situation via stereo headphone of the HMD and vibrating joystick.

5. Map generation/printing

Teams are proposed to represent a 2D map using occupancy grids in addition to information about victim locations. Our map generation module is based on recently well known GMapping software [8] which uses Grid-based SLAM algorithm with Rao-Blackwellized Particle Filters by Adaptive Proposals and Selective Resampling [9]. Practical experiments prove the robustness of this algorithm in USAR applications [10]. All we have done is just tuning parameters of this algorithm to have an optimum result with our hard/software architecture.

6. Sensors for Navigation and Localization

Our robots use Player framework [11] as control infrastructure which utilizes a TCP socket-based client/server model.

A built in Player module transfers IMU corrected encoder readings to the robot position vector (x, y, θ) which still is additively error prone and it is used only for a rough estimation about the robot location and orientation.
Each robot has a Hokoyo UTM-30 LX scanning Laser Range Finder (LRF). This long range (up to 30 m), wide angle (270°) and fast (25msec/scan) LRF helps us to drive the robot at a high speeds while mapping. Our experience shows that the pose vector can be completely neglected without worry about SLAM output using this LRF.
Also it should be noted that we use active sensing method [12] to mechanically stabilize LRF using outputs of IMU. We found in our practical experiences that built in IMUs of our robots are not fast enough and we use another fast IMU to remain LRF horizontal.
In addition to these sensors, our robots have a pair of cameras to provide fine images of robot surroundings and its own status. One of these cameras has optical zoom capability and it is mounted on a pan/tilting servo mechanism. This camera is controlled by operator's head orientation using built in Head Tracker of our HMD. Fig. 3 illustrates the navigation sensors used in our robots.

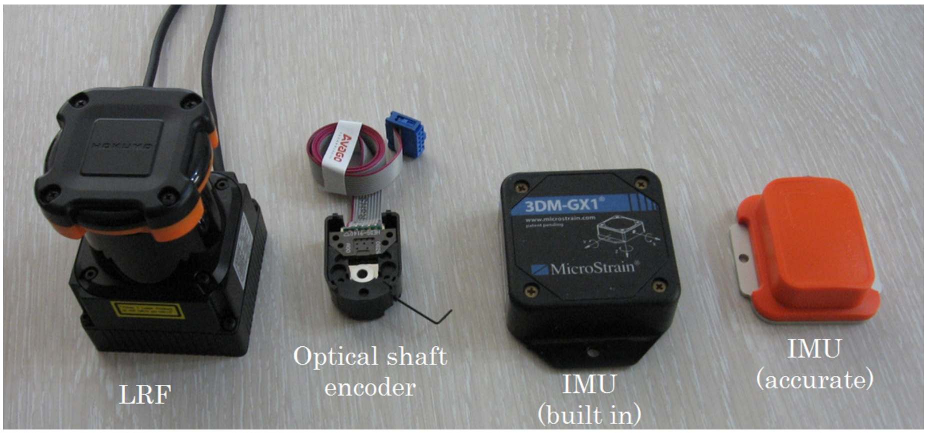

Fig. 3. Navigation sensors of our robots

7. Sensors for Victim Identification

Autonomous victim detection is mainly based on temperature sensor data. Four 8 pixel temperature sensors mounted on a precise servo are used to scan environment in 180 deg. field of view at 1 Hz for heat sources having 37±2 degrees Celsius. When such a heat source is detected, the control system informs operator and drives the robot autonomously into its direction and stops approximately 0.5 meter in front of the heat source if it is in full autonomous mode.
Although our robots are equipped with cameras, we don't use them for skin color based victim detection. Victim detection using skin color is not computationally efficient solution in RoboCup rescue arena due to the color of arena [13].

In addition to temperature sensors, we use one CO_2 sensor and a sensitive microphone on each robot to be aware of nearing to victim zones. Fig. 4 shows these sensors.

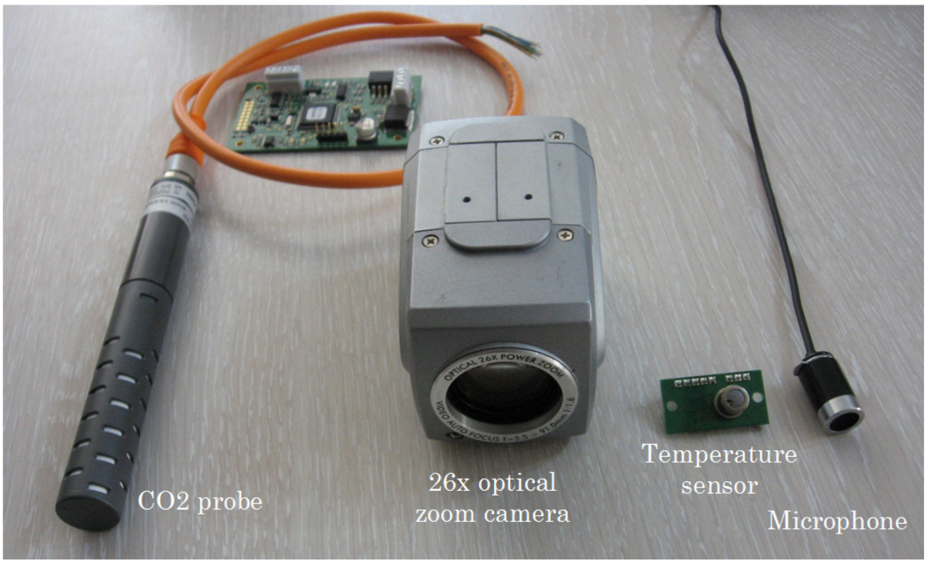

Fig. 4. victim detection sensors of our robots

8. Robot Locomotion

As mentioned before, we use a tank like tracked robotic platform which specially designed to operate in unstructured environments. It has an extraordinary Four-Tracked drivetrain layout which is called TTW.

The front-left and rear-left tracks (or the front-right and rear-right tracks) have a common powertrain which their velocity is controlled by an accurate motor controller. Thus, both tracks at each side move in the same velocity and provide skid steering capability. In addition to tracks, the robot can move forward or backward by rotating its triangular modules. These modules are position controlled and they can also be used to acquire maximum traction force of tracks by precisely adjusting the orientation of tracks to contact surface. The following table lists mechanical characteristics (Fig.3) of our robots.

Table 2. Mechanical characteristics of our robots

Feature	QTY
Weight	32 Kg
Nominal power	540 w
Max continuous velocity	1.4 m/s
Max discrete velocity	1.3 m/s

Max velocity	2.7 m/s
Max passed gradient	0.9 (42 deg)
Max payload (at max gradient)	42 Kg

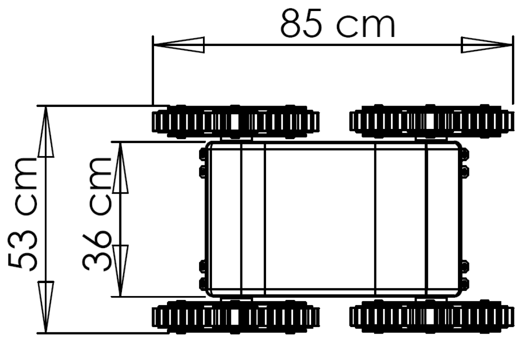

Fig. 3. Dimensions of our robots

9. Other Mechanisms

Our robotic platforms use a power management system which supervisory controls all activities inside the robot (e.g. switching devices on/off, voltage - current monitoring and limiting). The power management system is the first and only system that a user can directly turn it on/off. When it turned on, it follows a step by step procedure to turn on and test all necessary devices to be wirelessly connected to the OCU (e.g. Ethernet switch and Access Point). If anything goes wrong it begins blinking an LED and alarming.
After first step of booting up, the power management system directly connects to the OCU and waits for operator's commands. At this time operator is able to boot up onboard Industrial computer. Using this system, operator is able to remotely turn on/off or restart any onboard devices even Industrial computer.

10. Team Training for Operation (Human Factors)

Although we do our best to make our HRI more and more user friendly, but it still needs about one day of familiarization to drive the robots properly. After becoming acquainted with robot controlling, it will be quite similar to game playing.
Also it should be taken into account that not using our HMD is strongly recommended to people suffering from hurt disorders, high blood pressure or eye diseases and who are under 15 years age.

11. Possibility for Practical Application to Real Disaster Site

We don't have any practical experience with real disaster sites yet. Actually we are taking our first steps towards this high goal of rescuing human life.

12. System Cost

The following table lists approximate cost of our system.

Table 3. Price list

Part Name	Company	Type	QTY	Unit Price
Robot platform	Takbot	ALPHA	2	35,000 USD
LRF	Hokuyo	UTM	2	5,590 USD
IMU	Xsens	MTi	2	2,550 USD
CO2 sensor	Vaisala	GMM	2	925 USD
Temperature sensor	Devantech	TPA81	7	112 USD
Camera	Telecom	---	2	32 USD
Microphone	---	---	2	8 USD
Industrial computer	Advantech	UNO-2182	1	2,250 USD
Access Point	PLANNET	WDAP-2000PE	1	190 USD
Gamepad	Xbox	Xbox 360	1	48 USD
HMD	Cybermind	See through Visette45ST SXGA + Head Tracker	1	15,200 USD
Other Electronics	---	---	---	700 USD

Total Price 107,382 USD

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