RoboCupRescue 2015 - Robot League Team <SEU-Jolly(China)>

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Abstract. This paper describes the SEU-Jolly rescue robot team, which are very interested in participating in RoboCup 2015. We have three robots: One of them is a tracked robot, which can autonomously navigate or be tele-operated in relatively flat environment. The other one is a tracked robot named SEU-Ⅳ with four flippers; It can move rough terrain with tele-operation. Both robots are able to automatically create global maps by fusion of multi-sensors' information that can be shared with each other. The third one is an UAV.We have made considerable improvements since the Robocup 2014 and we are still moving on.

Introduction

SEU rescue robot team was found in 2008 at Southeast University Robocup research group, which had participated in China Open 2009, China Open 2010, China Open 2013, RoboCup 2010 Singapore , RoboCup 2011 Istanbul and Robocup 2013 Netherland. Our team are originated from virtual robot competition SEU-RedSun team, which won the champion in RoboCup 2010 Singapore and RoboCup 2008 Suzhou, China and was awarded 2nd place in RoboCup 2009 Graz, Austria. We have got support from Nanjing Jolly Company since 2012. We will use SEU-Jolly as our team name.

Our first version of robot named SEU-Ⅰ was awarded 2nd place in China Open 2009; Our second version was named SEU-Ⅱ,which got 2nd place in China Open 2010 and participated in RoboCup 2010 Singapore and in RoboCup 2011 Istanbul. Our third version named SEU-Ⅲ participated in RoboCup 2013 Netherland.

Fig 1 shows our newest robots: the top one is our newest autonomous robot . it's also a tracked robot but without flippers. The middle one is our newest tele-operative robot named SEU-Ⅳ, which has obtained big improvement compared to SEU-Ⅲ.The buttom one is our UAV that is in developing.

For some reasons such as exit visa, Our team could not attend Robocup 2012 in Mexico .But we have successfully attended Robocup 2013 Netherland and Robocup 2014 in Brazil. We hope we can participate in the Robocup 2015 in HeFei.

Fig.1 rescue robots in our laboratory

1. Team Members and Their Contributions

- Yingqiu Xu Advisor
- Yingzi Tan Advisor
- Ruiming Qian Advisor
- YiJun Zhou Advisor
- Hao Ding Mechanical design
- Keyang Shen Mechanical design
- Zhonghui Zhao Controller development
- Pei Zhu Controller development
- Jing Wu Controller development
- Tianyi Zhu Software development
- Pengcheng Zhou Software development

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

We use only one notebook PC and one 70*40*10cm control box in which a network bridge and network switch are equipped for the operation, so our main devices are only two robot , one notebook PC and one control box. Therefore the operation is plug and play and the Set-up and Break-Down operation will be quick in a similar way.

3. Communications

The robots are configured with wireless network with 802.11a/5.8GHz. Both robots only use one wireless communication channel. We use high-power network bridge for communication (See Fig.2). Considering the reliability of wireless communication in practice, we reduce the dependence on wireless. The autonomous robot can run normally in drop-out zone because of fully on board data process control. The tele-operative robot can work in reduced functionality mode.

Fig.2 the high power network bridge

Table 1.Communication channels

Rescue Robot League		
SEU-Jolly (China)		
MODIFY TABLE TO NOTE ALL FREQENCIES THAT APPLY TO YOUR TEAM		
Frequency	**Channel/Band**	**Power (mW)**
5.8 GHz - 802.11a	1 channel/Selectable	500

4. Control Method and Human-Robot Interface

According to the different functionality, each robot use independently control method. On the autonomous robot, we use MCU + Notebook PC construction. Taking into account the scalability and flexibility for SEU-Ⅳ, we use PC/104+ construction to control the flexible mechanism. Meanwhile it is easy to update step by step, because each module is relatively independent. The common function control module, such as CO_2 , temperature, laser 2-degree servo module, can work on both robot platforms by no modification due to the use of CAN bus.(See Fig.3).

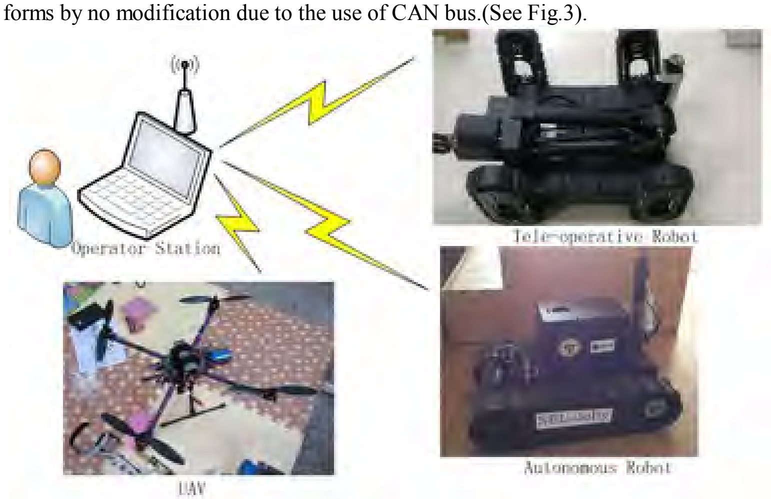

Fig.3 three robots control

4.1 Autonomous robot

Fig.4 describes the autonomous robot construction. The robot is equipped with notebook, the ColdFire MCU（the main controller on the robot for robot motion control）, sensor data acquirement (including laser scanner, electronic compass, CO_2 , temperature sensor, sonar and IR distance sensor).. The video and audio stream is obtained by PTZ IP camera, and directly transmitted to notebook through Ethernet.

The station is alternative as a remote monitor. The robot can be fully autonomous in the Yellow arena that is relatively flat.

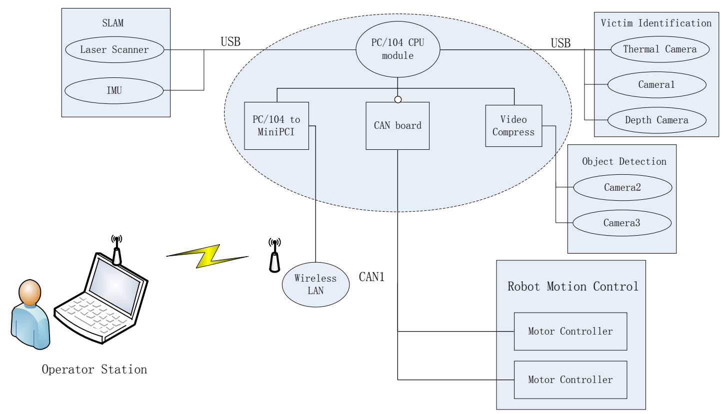

Fig.4 Diagram of the autonomous robot control hardware structure

4.2 Tele-operative robot

On SEU-Ⅱ, SEU-Ⅲ and SEU-Ⅳ, we use PC/104 and embedded PC as the main controller on the robot(Fig.5). As a common local bus standard, it is easy to implement each function independently. Meanwhile, for enough performance of CPU, the robot can run in drop-out zone with reduced function as we found the wireless communication is not always stable.

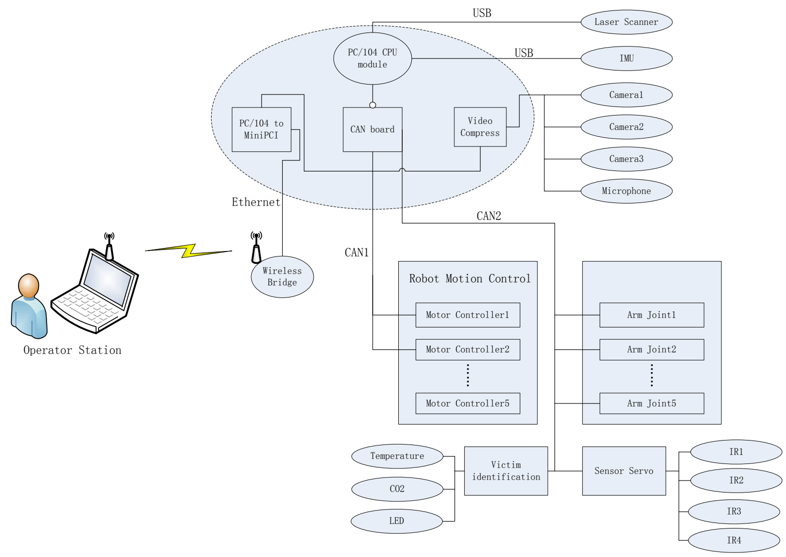

Fig. 5 Diagram of the tele-operative robot control hardware structure

Fig. 6 Embedded computer and camera on tele-operative robot

4.3 UAV

After Robocup 2013 Netherland, we designed our first UAV weighted 1.2kg with battery. The UAV is based on Tarot TL65B01 and equipped with APM2.6 flight controller. Our UAV have 10 min flying time.

Fig.7 shows the hardware structure of our UAV.

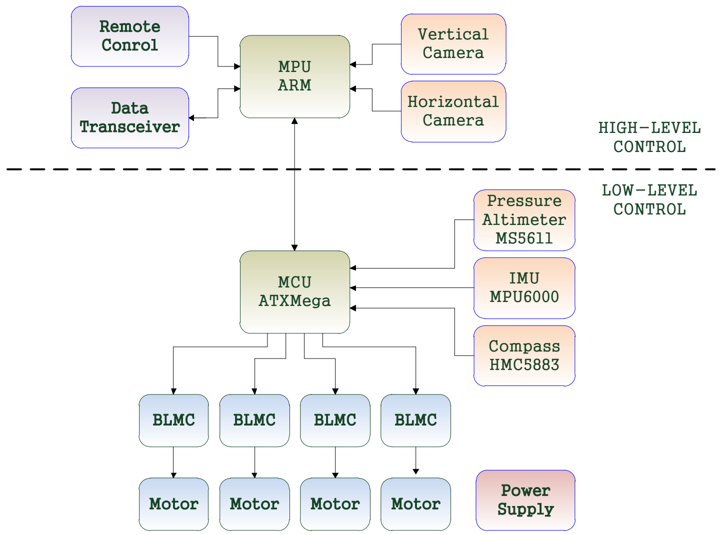

Fig. 7 Diagram of the UAV control hardware structure

Our robot uses two levels of control. The low-level controller is based on an AVR XMega MCU. It reads the data from the IMU chips and outputs signal to BLMC(Brushless motor controller) to control the stabilizing and attitude of the UAV. The high-level is an ARM base microprocessor that reads signal from the cameras and calculates the optical flow. The high-level gets the UAV's position from the calculated information and also receives control commands from the underground station. Then it sends commands to the low-level controller to achieve hovering and inching functions.

We are planning to use two wide-angle cameras on our UAV. The first one points to the ground to get the translational movements. The other one points forward. It is used when the UAV is required to hover before an object to take stable pictures.

4.3 Autonomous and Human-Robot Interface

There are some effective ways on localization, navigation, and multi-robot cooperation, which are tested in the simulation environment. We focus on complement this way on our real robot, and meanwhile find the differences between real world and the simulation environment in detail (the unconfirmed factor is more than the simulation environment). However, in the early phase, it is effective to use UARSim to develop the software framework and new method for testing, and it is not enough to test the method which used on the real robot. So in the new vision, we still use UARSim in the early phase to develop the software when the hardware of the robot is in update. In the framework of the software, there is a hardware-independent layer to reduce the effects of different hardware framework, which is shown on Fig.8. Fig.9 shows the GUI of robot control.

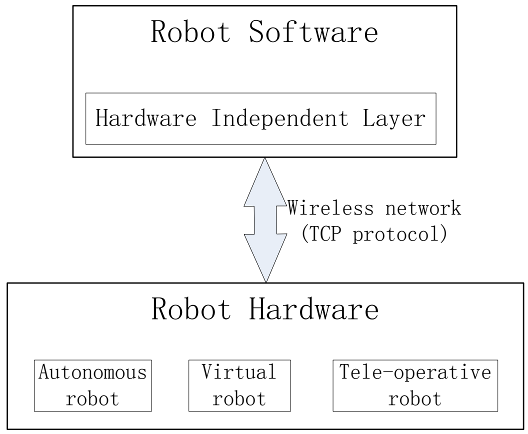

Fig. 8 The control method of software

Fig. 9 GUI of robot control

We use a control box instead of a PC to tele-control our our robot, which is very effective in operation. The control box have buttons，two screens ，one of which is a touch screen，joysticks and other interfaces.

5. Map generation/printing

To achieve an accurate geo-referenced map, the robot should know its position synchronously and exactly during the exploration. While the position data got from the odometry senor or inertial navigation sensor is always with a large error, laser range scanners can deliver highly accurate measurements, and a position estimated based on scan matching is impressive for indoor environments.

we plan to use gmapping algorithm to create 2D occupancy grid map .the approach takes in raw range laser range data generated by range lasers like Hokuyo scanner and odometry collected by mobile robot .the robot is equipped with a horizontally-mounted ,fixed laser range-finder .each period when receiving the data ,we can get a roughly estimate of the location and orientation of the robot according to the odometry data .but the estimates have large error .so we need to correct the pose of robot by the following ways .firstly , we get pose fixed preliminarily by matching the fitting straight line with the globe map .Rao-Blackwellized particle filters have been introduced as effective means to solve the simultaneous localization and mapping problem. This approach uses a particle filter in which each particle carries an individual map of the environment.so we use the approach of improving grid-based SLAM with Rao-Blackwellized particle filters by adaptive proposals and selective resampling proposed by Giorgio Grisetti .As a result ,we can get the accurate pose of the robot and maps matching well .to mark victims ,the operator just needs to press the Enter key and the algorithm can get the signal and draw marks on the map .Generally the map of the environments is produced.

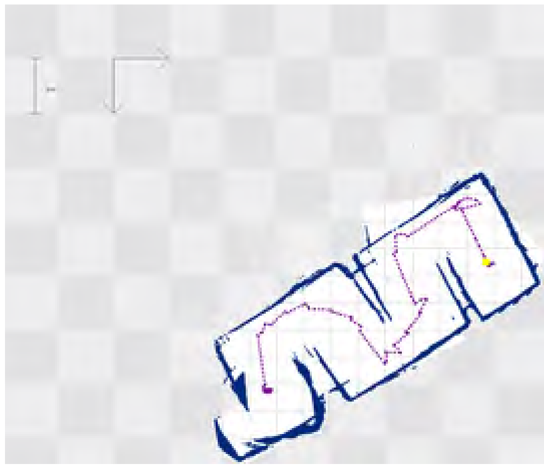

Fig. 10 the map in experiments

In the same time we are developing method of generating 3D map by Kinect 360 device assembled on out two-wheel robot. Fig 11 shows the 3D map example.

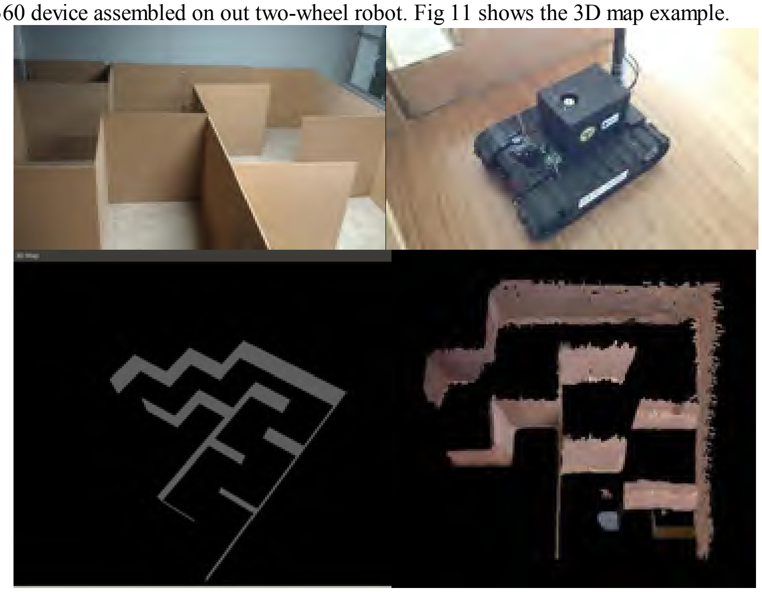

Fig. 11 The 3D map of simulated environment

6. Sensors for Navigation and Localization

In order to manipulate the robot in an unknown environment, we use several digital sensors to gather information of the environment. The robot is equipped with the following sensors for localization and navigation:

1) Scanning Laser Range Finder (URG-04LX) is used to provide a precise measurement [4].
2) Odometry, it use the rotate output to compute the head and distance. It is worth in the skipped environment, but it one option to help localization and navigation.
3) Kinect, it use two camera to get 3D information of the environment.

The sensors are shown in Fig.12.

Fig. 12 Scanning Laser Range Finder & IMU & Kinect

7. Sensors for Victim Identification

At the RoboCup Rescue, the main target is find victims in an unknown environment. The victims are simulated by a puppet with a heating panel in the background to get a thermal structure. In order to detect heat source and determine whether it is a victim, we use several sensors to gather visual information of the environment. The robot is equipped with the following sensors for Victim Identification:

1) Thermal Camera (Optris PI 160) is used to detect heat source in the search arena.

2) Depth Camera(Asus Xtion) is used to obtain depth information for avoiding obstacles and estimating the position of victims.
3) RGB Camera is used to determine whether there is a victim in the heat source.

The sensors are shown in Fig.13.

Fig. 13 Thermal Camera & Depth Camera for Victim Identification

8. Robot Locomotion

The robot is the same as shown in the Fig 14. The drive system of the robot use conveyer belt which can be used on different types of terrain. This robot includes several parts: two movement modules for the left and right and two pairs of flipper (front and back). Each pair of flipper can rotated 360 degree and work independently of each other. Through compare and research, we find that this structure is better for the disaster situation. In order to step up the bottom of the body, the body and movement module are entirely separated except several linkers. Therefore, three DC motors are hided in the body of movement module, one for the movement of belt and the others for the rotation of flippers. Most of the structure is made of Aluminum and the belt is made of synthetic rubber. This year we plan to re-design the belt to adapt to complex terrains.

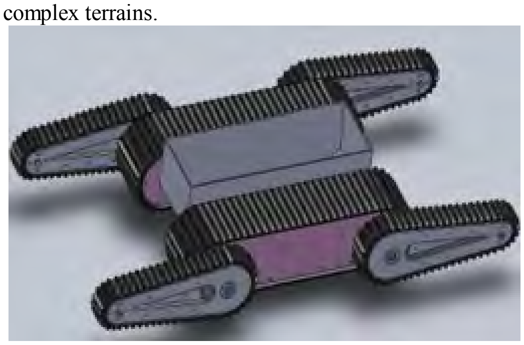

Fig. 14 Tele-operative robot

9. Other Mechanisms

Modular design approach is used for the robot. In that way, the robot can be divided into several modules: left and right main track modules, two pair of flipper, body control section and mechanical hand. Every module can be easily removed and assembled. When a certain part comes across with a problem, we can quickly get to replace the module in a short time, so the robot can play a greater rescue role.

We have redesigned a new mechanical arm that can deliver up to 5kg payload. The new designed mechanical arm has three fingers，two of which can adjust relative position to deliver payload of different shapes. The Fig 15 shows the design.

Fig. 15 Mechanical arm and hand

We also have redesigned our control box. We use embed computer as control center with two display screen，one of which is a touch screen. The control box has various buttons and joysticks that can be used to control the motion of our robot.

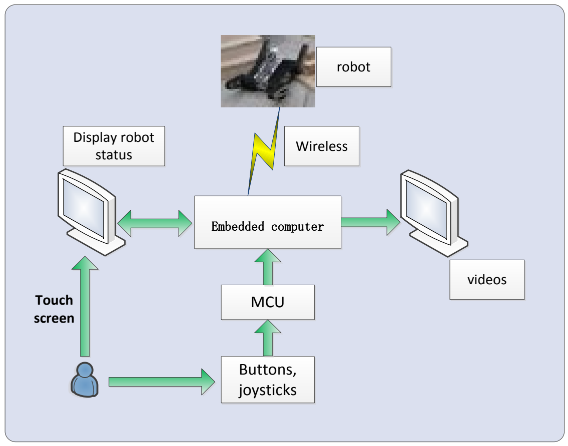

Fig. 16 Hardware structure of control box

10. Team Training for Operation (Human Factors)

The operator should be familiar with the structure and the function of the GUI and be able to immediately understand the data of all sensors showed in the GUI. As the operator, he also needs to drive the robot remotely according to the video stream of the camera and the distance of the obstacles scanned by laser. So we set up a similar simulated environment(see Figure 17)in lab which has ramps, stairs,flat flooring, wall, stepfield terrains and so on. The operator spends a lot of time to familiar with driving. To totally understand the structure of the robot, the operator separates the robot into deferent modules and then re-assembles the robot.

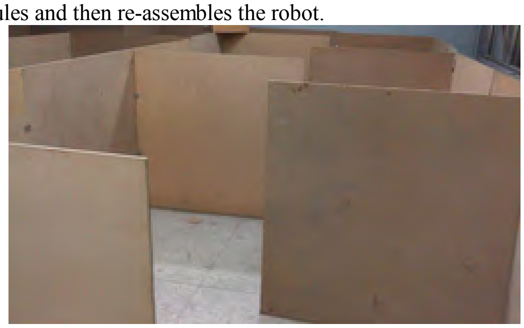

Fig. 17 Simulated Environment

11. Possibility for Practical Application to Real Disaster Site

We yet have no practical experience with real disaster sites. However, we consider the practical application when designing the robot, such as compact mechanism, modular design, less operator station setup time. The using of life-detecting sensor and modern mobility make the robot having the possibility for detecting victims in rear disaster site. The audio communication module can help us establish communications with victims.

12. System Cost

Table 2.autonomous robot cost

Part Name	Quantity	Unit Price(RMB)
Optris PI 160	1	35000
Asus Xtion Pro Live	1	1000
Maxon motor (RE36) + Gearhead + Encoder	3	5160
Maxon motor (RE40) + Gearhead + Encoder	2	6400
Other mechanical parts and manufacture		20,000
Scanning Laser Range Finder(URG-04LX)	1	19,000
HMR3300	1	3,000
Wireless router (DIR-628)	1	1,000
Laptop	2	15,000
PCB		2,000
Other electrical parts		2,000
Battery	2	1,000
Total		110,560

Table 3. tele-operative robot cost

Part Name	Quantity	Unit Price(RMB)
Maxon motor (RE36) + Gearhead + Encoder	3	5,160
Maxon motor (RE40) + Gearhead + Encoder	2	6,400
Maxon motor(RE-max21) + Gearhead + Encoder	1	10,575
Maxon motor (RE26) + Gearhead + Encoder	1	5,828
Maxon motor (RE35) + Gearhead + Encoder	3	5,414
Other mechanical parts and manufacture		80,000
PC104-plus computer	1	15,000
Scanning Laser Range Finder(URG-04LX)	1	19,000
MTi AHRS (MTi-28 A53 G35)	1	18,000
Laptop	1	15,000
Camera	3	5,000
Video card	1	1,500
Laser servo controller	2	2,000
PCB		3,000
Other electrical parts		5,000
Battery	2	4,000
Total		245,925

Table 4. UAV cost

Part Name	Quantity	Unit Price(RMB)
Frame	1	685
Motor	4	205
BLMC	4	108
Controller & Sensors	1	1000
Camera	2	100
Battery	1	360
Remote Controller	1	640
Battery recharger	1	150
Spare parts	-	250
Total	**-**	**4537**

13. Lessons Learned

We never stop improving and perfecting our robot. We will continue to improve the SEU-Ⅲ robot, and with the same time our SEU-Ⅵ is in perfecting progress. On SEU-Ⅵ, we have carried out many changes in the mechanical structure. It will be lighter, more flexible and more powerful. As the wireless communication maybe unstable in disaster environment, in the SEU-Ⅵ robot, we use high-power network bridge for communication to ensure stability.

Autonomous robot also has application in extreme environment. So a new robot that can be used in extremely cold environment in our lab is on the way.

We are also designing mechanical hand that can be added to the SEU-Ⅵ robot. With the mechanical hand, our robot can deliver fluids, nourishment, medicines to found victims.

We will do our best to prepare this year's competition.

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