RoboCupRescue 2015 - Robot League Team
Red Knight RoboRescue Squad (USA)

Timothy E. Jump

Benilde-St. Margaret's School
Advanced Competitive Science Program
2501 Hwy 100 S.
St. Louis Park, MN USA 55416
www.bsmschool.org/acs

Abstract. Team RKRS is the enrichment component the Benilde-St. Margaret's high school engineering program (Advanced Competitive Science). The goal of the ACS program is to give students conceptual understanding in four engineering foundations (mechanical, electrical/electro-mechanical, design and control). Students that show extreme promise during their development of small scale rescue robots are invited to contribute to, and operate the team RKRS RoboCup-Major Rescue Robot. Ultimately, our participation at the RoboCupMajor level is an opportunity to demonstrate and integrate advanced engineering concepts and learning, both to and from the BSM-ACS students and to participate and expose students to a true research project preparing them to be competitive applicants for research positions as they enter their university studies. We also hope to produce functional products that can be implemented in higher level research projects and be commercially viable.

Introduction

Our focus is on developing an advanced mobility, intuitively controlled, significantly cost effective robot transport system. Our latest platform continues in the line of our robot platforms from the 2011to 2013 RoboCup entries, incorporating targeted improvements documented from robot performance at the RoboCup events. We continue our dedication to fixed climbing arms. Fixed arms increase control simplicity for the driver/operator compared to the complexity presented by arms that require driver managed control. We also continue our commitment to abdominal belts, giving our robot a significant force transmitting surface area and a minimum amount of static lower structure. This minimizes the potential for chassis hang on undulating surfaces. We have gone through several motor/gearbox designs with our fully custom solution first tested at the 2013 German Open. This new design offers significant improvement with no motor overheating so we have retained this power train. The radio upgrade we debuted in Mexico City continues to prove effective so we will retain this system for 2015. New for 2015 will be our portable, modular command center.

1. Team Members and Their Contributions

Engineering 3 Students/Seniors in the Benilde-St. Margaret's ACS Program participate across all of the following areas.

- Robot Locomotion (Mechanical and Electro-Mechanical)
- Robot Locomotion (Control)
- Navigation and Localization
- Victim Identification
- Map Generation
- Robotic Arm
- Operations

Students comprising the 2013 Benilde-St. Margaret's Rescue Major travel team:

TBD

Advisor: Timothy Jump

2. Operator Station Set-up and Break-Down (3 minutes)

With the addition of an independent power source, setting up the team RKRS operator station should be as simple as flipping a switch. The control console has an integrated WiFi router, antenna, control computer and monitor(s) as well as control devices (joystick, mouse, etc.) so it is an all-in-one control console solution.

Communication and application programs should start automatically upon boot saving time over computer boots where applications must be launched manually.

Operator station break-down is simply shutting down the control console.

3. Communications

The integrated multi-frequency radio (802.11 a/b/g/n) allows for expanded flexibility to meet the requirements of different locations. The radio maximizes performance on congested frequencies. We use the same components at both the robot and operator station.

MikroTik RouterBOARD RB/433AH
MikroTik R52Hn 802.11a/b/g/n 320mW mini PCI card (MMCX connectors)
MikroTik 2.4/5GHz 3dBi Omni Swivel Antenna (MMCX connector)

Rescue Robot League		
RKRS (USA)		
Frequency	**Channel/Band**	**TX Power (mW)**
5.0 GHz - 802.11a	Multiple Channel Options/Assigned channel can be set	316
2.4 GHz - 802.11b/g		
2.4 GHz – 802.11n		

Table 1. Communication protocols under testing and available for use.

4. Control Method and Human-Robot Interface

We control the team RKRS robot through both teleoperation and autonomous functions. Teleoperation is currently managed by our custom LabVIEW control interface MainController.vi but we are investigating a move to a ROS based control interface.

Fig. 1. LabVIEW control interface.

From our MainController.vi we simply input the robot IP address and connect. We can then drive motors, monitor sensors, monitor video and access video analysis protocols including horizon, edge, obstacle and motion (differencing) detection.

We switch the robot into autonomous mode via our LabVIEW MainController.vi by loading and executing picoC code.

We have a semi-functional interactive mode in our firmware that allows for simultaneous running of autonomous functions and teleoperative controls, but it still needs more work.

We also have the potential to run autonomously with Roborealm machine vision software running remotely on the control console computer but we have not yet implemented this functionality.

5. Map Generation

Following the 2012 RoboCup in Mexico City we began investigating the ROS based mapping of Team Hector-Darmstadt. In 2013 in Eindhoven we had mapping working on our laptops but could not get Hector SLAM to run on an embedded system (BeagleBone) on the robot due to inadequate processing power. We have now upgraded our robot hardware to a new Intel NUC i5 and all tests have been successful. We should have a fully functioning mapping system for 2015.

6. Sensors for Navigation and Localization

Teleoperative navigation is managed through visual data streamed through the OmniVision OV7725 camera and our LabVIEW vision interface. From the camera we can get edge, horizon and obstacle detection data as well as images.

Fig. 3. RCM Blackfin Controller with OmniVision OV7725 camera.

We are also investigating autonomous navigation through the inclusion of a perimeter detection system that will set off warnings at the control console if an unseen obstacle penetrates our *Clearance Zone*. The *Clearance Zone* represents the area around the robot that must be clear in order for the robot to make clean turns and navigate through doorways, paths, etc. We are experimenting with Sharp digital and analog IR sensors and short range Maxbotix ultrasonic sensors as detection devices.

Once we have the perimeter detection system working we will begin to integrate code to get the robot to move through the arena based solely on the data received through the perimeter detection sensors. Elements of difficulty will include interpreting skewed data from when the robot is on uneven terrain.

Fig. 4. Sharp digital IR (left), Sharp analog IR (center), Maxbotix Ultrasonic (right).

7. Sensors for Victim Identification

Victim identification incorporates five primary data groups (motion, thermal, CO2, form, sound). We get motion and form direct from the OV7725 color CMOS camera and the SRV-1 camera/control board.

Thermal comes from our custom designed thermal sensor that uses a Perkin Elmer A2TPMI334-L5.5 OAA060 single pixel thermopile sensing element.

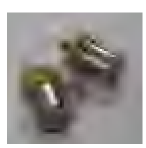

Fig. 5. RKRS custom thermal sensors with Perkin Elmer thermopile elements.

CO2 detection comes from our custom designed CO2 sensor using a Heimann CO_2 Gas Sensor element.

Fig. 6. RKRS custom CO2 sensor with Heimann gas detection element.

Auditory is also under development. We have used an Audio-Technica ATR35s Lavalier Microphone with some success, but we are pursuing a much smaller device for easier inclusion in our arm head used to insert into smaller access cracks.

8. Robot Locomotion

Our fixed climbing arm continues to be well received. We feel we have equal mobility to a managed climbing arm system but with a significant reduction in user complexity. Our fixed arm system only requires basic differential drive control awareness so the user only needs to know forward, reverse, spin left, spin right, turn left, turn right maneuvers.

Going to fixed climbing arms also significantly reduces the cost of the robot base. With fixed arms there is no longer any need for arm motors, speed controllers, position encoders, etc. Fewer high-torque demands such as comes with climbing arms also means extended operation time of the robot as there are now fewer demands on the battery system.

We have retained abdominal drive with our new mobility base. Abdominal drive makes almost every bit of the lower surface of the robot a force delivery mechanism, minimizing opportunity to get stuck on a ledge or rubble that can hold robot wheels/treads off the ground.

Belts for our drive continue to be an issue. Rubber belts presented multiple problems, not least of which was fabrication with accurate timing elements (teeth, slots) so we transitioned away from rubber belts and to a ‘chain-belt’ system from Intralox (Intralox manufactures plastic conveyor chain). We eliminated our timing issues with the 'chain-belt' but now we are encountering gumming up of the joints when driving in sand. There is also failure with these 'chain-belts' associated with driving in gravel and getting stones lodged between the belt and the drive sprockets. We are developing a new belt system using cables and cleats. With the cable belts there will be no joints for sand to gum up and a very open architecture to allow larger debris to fall through and not conflict with the drive interface between the sprockets and cable belt.

Fig. 7. RKRS Mobility base.

9. Other Mechanisms

We currently retain our arm and sensor head fitted with a set of the victim ID sensors and a high power LED spot light to illuminate dark areas. We have a new arm design that includes a multi-axis manipulator for grasping objects and an extension component to improve reach, but we have yet to begin fabrication of the new arm.

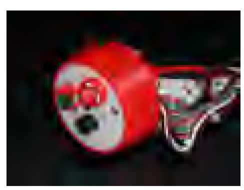

Fig. 8. Robotic Arm (sensor head detail).

10. Team Training for Operation (Human Factors)

We constructed a RoboCupRescue test arena in our lab. Students take what time they need on the course to test design concepts and evaluate ease of use and control accuracy of our robots and data systems.

11. Possibility for Practical Application to Real Disaster Site

It seems that many of the developers of rescue and other robot systems have price points that make them impractical for mass market distribution. Our primary goal is to generate a cost effective, highly functional mobility base that gives greater access to rescue robots to all institutions.

We are also targeting ease of use. Many existing mobility platforms are difficult to control without hours of practice. Our hope is for our system to be so intuitive that only minutes of training is needed to accomplish successful operator control.

12. System Costs

Part(s)	Quantity	Total Cost	Internet Site
Operator Station	1	$3000.00	
1 Intel NUC i5/Windows Computer		$800.00	http://www.logicsupply.com/computers/custom/industrial-computers/core-ml320/
1 Intel NUC i5/Ubuntu - ROS Computer		$800.00	http://www.logicsupply.com/computers/custom/industrial-computers/core-ml320/
2 Monitors		$200.00	http://www.bestbuy.com/site/insignia-19-class-18-1-2-diag--led-720p-hdtv-black/2799043.p?id=1219077483779&skuId=2799043
External Controls (i.e. mouse, key-board)		$150.00	
MikroTik radio (see below)		$250.00	
Power Supply		$250.00	http://www.meanwell.com/search/HRP-300/HRP-300-spec.pdf
Battery Backup		$150.00	http://duracomm.com/siteresources/apps/catalog/Downloads/LPBC-25_5_2013.pdf
Mounting Stand		$400.00	

Communications			
MikroTik Router-BOARD RB/433AH	2	$126	http://www.balticnetworks.com/mikrotik-routerboard-433ah.html
MikroTik R52Hn 802.11a/b/g/n 320mW mini PCI card (MMCX connectors)	2	$80	http://www.balticnetworks.com/r52hn-802-11a-b-g-n-320mw-minipci-card-with-mmcx-connectors.html
MikroTik 2.4/5GHz 3dBi Omni Swivel Antenna (MMCX connector)	2	$38	http://www.balticnetworks.com/mikrotik-2-4-5ghz-3dbi-omni-swivel-antenna-mmcx-connector.html
Mapping			
Hokuyo URG Laser Scanner	1	$2375.00	http://www.acroname.com/robotics/parts/R283-HOKUYO-LASER1.html
CHR-UM6 IMU	1	$199.00	http://www.chrobotics.com/shop/orientation-sensor-um6
Navigation			
XL-MaxSonar-EZMB 1340 Ultrasonic Range Finder	5	$150.00	http://maxbotix.com/uploads/MB1240-MB1340_Datasheet.pdf
Sharp GP2D12 IR	TBD	($12.50ea)	http://www.acroname.com/products/R146-GP2D120.html
Pololu MinIMU-9 v3	1	$19.95	https://www.pololu.com/product/2468

Victim Identification			
RCM Blackfin w/Omni Vision OV7725 Color CMOS Image Sensor	1	$350.00	
Heimann CO_2 Gas Sensor	1	$35.00	http://www.boselec.com/prod-ucts/documents/HeimannThermopiles6-7-11.pdf
PerkinElmer A2TPMI334-L5.5 OAA060 Single Pixel Thermal Sensor	1	$25.00	http://www.datasheetlib.com/datasheet/583048/a2tpmi334-oaa060-625_excelitas-technologies.html
Robot Locomotion Mechanical			
CIM Motors	2	$56.00	http://www.andymark.com/CIM-motor-FIRST-p/am-0255.htm
Machine work on custom gearbox	2	$1600.00	
AndyMark Omni wheels am-0383 (4 inch)	2	$38.00	http://www.andymark.com/ProductDetails.asp?ProductCode=am%2D0383
Intralox Chain-Belting	Var.	$300.00	http://intralox.com/Ilox_BeltIden.aspx?id=1998
Fabrication Supplies			
Axles	Var.	$30.00	
Acetyl Plates	Var.	$150.00	

3D Printed Parts	Var.	$450.00	
Fasteners	Var.	$100.00	
Misc. Supplies	Var.	$50.00	
Robot Locomotion			
Control			
RCM Blackfin w/Omni Vision OV7725 Color CMOS Image Sensor	1	$350.00	
Talon SR Motor Controller	2	$130.00	http://www.andymark.com/Talon-p/am-talon-discontinued.htm
Other Mechanisms			
Electrical			
ACS Buss Board	2	$35.00	
LiFePO4 Batteries	2	$337.50	
Assorted Electrical Connectors/Wiring	Var.	$50.00	
Robotic Arm			
HSR-5980SG Servo Motors	3	$327.00	http://www.robotmarketplace.com/products/0-HRCM5980.html
Illuminator			
Star Bright LED LXHL-LW6C	1	$26.99	http://www.luxeonstar.com/luxeon-v-portable-star-led-white-lambertian-120-lm-700ma-p-250.php
Fraen Medium Beam Low Profile Lens	1	$2.45	http://www.luxeonstar.com/item.php?id=749&link_str=121::123&partno=FLP-HMB3-LL01-0

ACS Illuminator Control

LuxDrive Buck-Puck 700mA Dimmable DC LED Driver 3021DE700	1	$17.99	http://www.luxeonstar.com/buckpuck-700ma-dc-led-driver-pcb-mount-p-31.php
Analog Devices AD5241 Digital Potentiometer	1	$3.00	http://www.analog.com/static/imported-files/data_sheets/AD5241_5242.pdf

Totals

Operator Station	**$3000**
Communications	**$244**
Mapping	**$2574**
Navigation	**$400**
Victim Identification	**$410**
Robot Locomotion (Mechanical)	**$2000**
Robot Locomotion (Control)	**$500**
Other Mechanisms (Electrical)	**$500**
Other Mechanisms (Arm)	**$400**
Other Mechanisms (Illuminator)	**$50**
Combined System Cost	**$10,000**