

RoboCupRescue 2006 - Robot League Team R2K5 (Canada)

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The Walking Machine ÉTS team is a group of future engineers who have, over the past 13 years, made remarkable accomplishments in the field of mobile robotics. In the past, we've been described as a symbol of innovation during the SAE's annual competition: the Walking Machine Challenge. We now wish to push the envelope even further by building an autonomous robot with the potential for becoming a precious tool in the management of urban crises. This Team Description Paper will outline the main technical aspects of the R2K5 project, our team's entry in the Robocup Rescue competition. We will highlight the robotic platform's mechanical structure, its control software as well as the sensors and techniques employed for spatial positioning and the detection of victims.

Introduction

Modern robotics have made their mark in a wide range of fields. From the much publicized spatial exploration to the lesser seen yet essential industrial production, the applications for these machines are becoming more diverse. We believe in making mobile robotics a precious tool capable of negating the need for human presence in certain hazardous situations or simply to improve security in urban settings.

Robocup Rescue represents an ideal opportunity to make use of our diverse skills and our desire for technological evolution. The constraints imposed by this challenge combined with the nature of the mission insure that the technological developments brought forth by this project stay on course with real-world industrial needs. Furthermore, this challenge holds an interesting educational aspect, since every step of this multistage project, from the first concept drawing to the final presentation of the robotic system, has been executed following the strictest of documented guidelines to insure it's success.

A robotic platform created to meet the mission requirements for Robocup Rescue is fundamentally different from industrial systems or toy robots. A rescue robot is constantly confronted by new situations and unexpected obstacles. Due to the impracticality of pre-programmed linear sequences of actions, the robot must make it's own decisions based on a series of reflexes and sensory inputs.

We will be presenting a robot, named R2K5, which was designed specifically for Robocup Rescue. In it's initial phase of development, it will be controlled remotely by a human operator for most of the events. In the following phases, we will aim for nothing less than a fully autonomous R2K5 robot. Many obstacles will have to be overcome to reach our goal: absolute spatial positioning, the ability to independently compose its limitations when accessing different areas, recognize the more subtle signs of human presence and increasing the mapping accuracy.

In essence, R2K5's simple yet efficient design will single it out as a versatile high-mobility platform, capable of meeting this year's competition requirements while allowing for continued development in upcoming years.

1. Team Members and Their Contributions

- Simon Lessard Motor drive development (software)
- Philippe Hamelin Controller development
- Charles-Anthony Fortin Mechanical design and machining
- Simon Fr chet Motor drive development (hardware)

- Pascal Laforce Development of the main software framework
- Samuel Jacques Mechanical design and machining
- François Léveillé Development of the 48VDC ATX power supply
- Martin Rivard Mechanical design of the front fork
- David Florant Audio-video compression and streaming
- Elida Keo Drawing of electrical schematics
- Marc-Antoine Lemay Mechanical design of the planetary gearbox
- Julie Ferlate Development of the sonar mapping software
- Lovens Weche Development of the graphical user interface
- Acier Rive-Nord Sponsor
- Bombardier Aéronautique Sponsor
- Circuits Solaris Sponsor
- Dormer Sponsor
- Fabory Sponsor
- IRÉQ Sponsor
- Igus Sponsor
- Komatsu Sponsor
- Odessa Canada Sponsor
- Omron Sponsor
- Plastiques GyF Itée Sponsor
- SKF Sponsor
- Starrett Sponsor
- Thomas & Betts Sponsor

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

Physical setup (5 mins)

1. Install the notebook computer and the joystick on the table
2. Boot the notebook
3. Bring the robot in the arena
4. Power up the robot
5. Boot the two embedded computers on the robot

Software setup (5 mins)

1. Start the robot controller with a SSH connection
2. Start the graphical user interface on the notebook

The break-down only consists of removing the robot from the arena.

3. Communications

The robot is equipped with a wireless 802.11a router networking two embedded computers. The remote interface (notebook) uses a wireless 802.11a PCMCIA card.

Table 1. Frequency used for competition.

Rescue Robot League		
R2K5 (CANADA)		
Frequency	Channel/Band	Power (mW)
5.0 GHz - 802.11a	Configurable	-
50kHz Sonar Transducer	-	-

4. Control Method and Human-Robot Interface

The R2K5 robot is remote controlled. Using the onboard camera as a visual aid, the operator uses a joystick to remotely control the robot. Throughout the mission, the operator must:

- Observe the streaming video to learn the immediate environment.
- Control the robot with a joystick.
- Insert the victim positions on the map.
- Trigger sensor readings and associate them with a specific victim.
- Generate a report at the end of the mission.

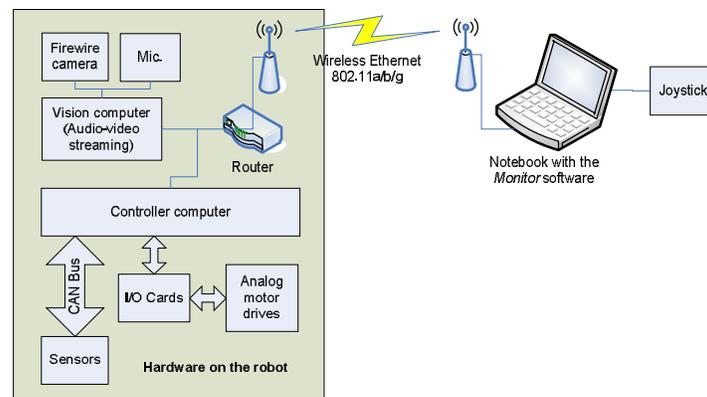


Fig. 1. System hardware setup.

Our system includes three (3) computers: a notebook computer, a vision computer and a control computer.

Notebook computer

The notebook computer is used to run the *monitor* software. This user interface is used to remotely control the robot. This application communicates with the robot's controller via a wireless TCP/IP connection. Therefore, this computer and its aforementioned software serve as the only command center for the R2K5 robot. This software is capable of the following:

- Configuration of the joystick
- Transmitting commands to the robot
- View the robot's position
- View the state of individual sensors
- Generate the 2D mapping (through a separate module)
- Generate mission reports

Vision computer

This high powered computer is primarily used for the following tasks:

- Video compression and streaming
- Audio compression and streaming
- Load balancing for the control computer

Control computer

This PC104 computer is responsible for the system's real-time control. Furthermore, it is tasked with the following:

- Direct and inverse kinematics
- Motor drive communication
- Sensors reading

5. Map generation/printing

The map is automatically generated using sonar data. The operator uses the *monitor* software to annotate the map with additional information (temperature, CO₂, movements, sounds, etc.). Finally, the *monitor* generates a HTML report of the mission.

We have 9 sonar in front of the robot to generate the map. Each sonar can cover up to 20 degrees.

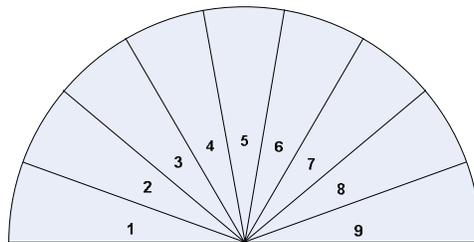


Fig. 2. Sonar pattern.



Fig. 3. 3D model of our custom sonar array.

6. Sensors for Navigation and Localization

The robot's direct kinematic are used to return its theoretical position (x, y, θ) using encoders. In reality, the odometric values begin to stray, especially when the robot enters a turn. Many solutions are being studied to rectify this problem:

- Laser stabilized odometry
- Accelerometers and inclinometers
- Electronic compass
- SLAM sonar algorithm

7. Sensors for Victim Identification

The robot has many sensors to help in victim identification:

Body Temperature	Servo actuated eight pixels thermal array
CO₂	CO ₂ sensor
Voice	Microphone (audio streaming)
Video	Firewire camera (video streaming)

We are also planning to use an IR Ethernet camera to measure body temperature.

8. Robot Locomotion

R2K5 is a high mobility wheeled rover based on the SHRIMP¹ design, originally from *École Polytechnique de Lausanne* (EPFL). The locomotion system is composed of six wheels, each powered by a 250 W brushless DC motor, linked to a two stages 36:1 planetary gearbox (Fig. 5). The front and rear wheels are used for direction. The onboard control computer determines the speed, power and slip of each wheel.



Fig. 4. R2K5: six wheeled, high mobility rover.

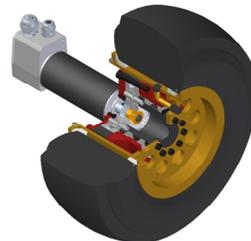


Fig. 5. Cutaway view of a typical wheel and its gearbox.

The rover as a total power of 1500W and a top theoretical speed of 18 kph. The brushless motors provide high torque at low speed, as to maintain optimal efficiency in any situations.

9. Other Mechanisms

The robotic platform is composed of four (4) main structural parts: the articulated fork (Fig. 6), the two independent laterals bogies (Fig. 7) and the body (Fig. 8). This innovative mechanical architecture has the capability to passively change its con-

¹ <http://asl.epfl.ch/research/systems/Shrimp/shrimp.php>

figuration. R2K5's mechanical structure guides it and adapts to a variety of ground features, giving it higher mobility when compared to other rover designs.



Fig. 6. Articulated fork.



Fig. 7. Lateral bogie.



Fig. 8. Main body.

To climb over obstacles, the front articulated fork follows the ground's profile. The rover can climb over objects measuring 80% of its own height. Following the front fork, the lateral bogies also passively follow the ground and, through the wheel's own propulsion, climb over objects, thus negating any need for electronic control. The rear wheel is directly attached to the main frame and is designed with the power to push the robot over a flat surface, if the other wheels cannot provide lateral motion.

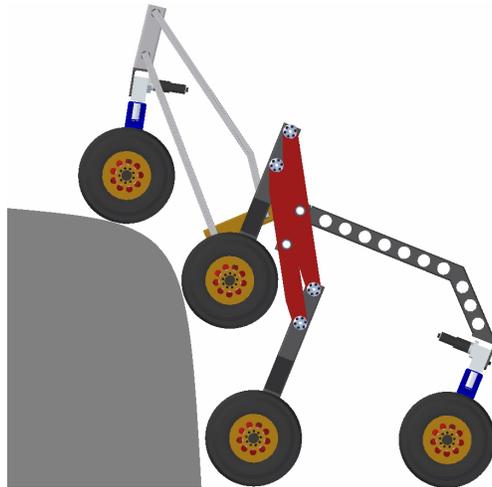


Fig. 9. Rover climbing over an obstacle.

10. Team Training for Operation (Human Factors)

To competently control the robot, an operator must have the following skills:

- Take the appropriate steps to run the software setup, as detailed in the "Station Set-up" section.
- Understand the *monitor* control software's main modules.

- Undertake a training session on the robot simulator and the actual machine.

11. Possibility for Practical Application to Real Disaster Site

Our robot could be used in a real disaster site with some modifications:

- Improve robot autonomy;
- Protect electronic components;
- Improve camera field of view;
- Reduce power consumption.

12. System Cost

Please note that prices are in Canadian dollars.

Description	Price (CDN)
Controller Computer	\$ 1,300.00
Kontron Viper 830 Computer	\$ 850.00
1 Go CompactFlash Ultra Memory	\$ 200.00
Advantech PCM3680 PC104 CAN Bus Communication Adapter	\$ 250.00
Vision Computer	\$ 900.00
Industrial EmbATX Motherboard Commell Systems LV-670M	
Pentium 4-M 2.2GHz Processor	
1 Go DDR Memory	
48VDC ATX Power Supply	\$ 200.00
Unibrain Fire-I IEEE1394 Camera	\$ 175.00
Saft 8500mAh NiMH Batteries (80 x D Cells)	\$ 1,000.00
802.11a/b/g Wireless Router	\$ 150.00
Six Maxon EC45 250W Brushless DC Motors (Propulsion)	\$ 6,000.00
Two Maxon Custom 11W DC Motors (Direction)	\$ 1,500.00
Eight Elmo Ocarina 5/100 Analog Drive	\$ 3,000.00
Two Sensoray S526 Motion Control Board	\$ 1,200.00
Terminal blocks, connectors, cables and buttons	\$ 1,000.00
Fastners	\$ 90.00
Structural Components	\$ 1,068.00
Aluminum 2" x 2" x 1/8" Tk.x 20' Tubing	\$ 60.00
Aluminum 4" x 4" x 1/4" Tk.x 20' Angle	\$ 120.00
Aluminum 4" Dia.x 6' C20 Tubing	\$ 138.00
Aluminum 4" Dia. x 3' Bar	\$ 310.00
Aluminum 4' x 4' x 1/4" Plate	\$ 230.00
Aluminum 20 x 20 x 20' extruded profile	\$ 80.00
Steel 2 1/2" Dia. x 3' Bar	\$ 95.00
Steel 5/8" Dia. x 10' Bar	\$ 10.00
Steel 2" Dia x 2' Bar	\$ 25.00
Transmission Components	\$ 1,678.00
Gears (Propulsion)	\$ 1,368.00
Gears (Direction)	\$ 310.00
Tooling	\$ 559.00
Machining Time	170 hours
Total (CDN\$) :	\$ 19,820.00