RoboCup Rescue Robot League Competition
Awardee Paper
Padova, Italy, July 2003

TEAM: **CEDRA**
COUNTRY: **IRAN**
AWARD: **2nd Place**

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Abstract—**This article present s an overview of the mechanical design features and characteristics of a Rescue Robotic unit for operation in unstructured environments. Upon fabrication, this unit has been tested in clean laboratory environment as well as ill-conditioned arenas similar to earthquake zones. The obtained results has been satisfactory in all aspects and improvements are currently underway to enhance capabilities of the rescue robotic unit for various applications.**

***Index Terms*—Rescue Operations, Shrimp Rover, Tele-operation, Unstructured Environments.**

1 TEAM INTRODUCTION

The purpose of this project was to design and manufacture an intelligent rescue robot unit. In rescue-like operations a person may encounter difficulties in properly seeking and assisting the victim, especially in unstructured environment. Therefore using a robot for searching the injured as well as describing the best path to reach the victim decreases the risk of a rescue operation. In addition, it will increase the accuracy, safety, and the speed of a rescue operation.

One of the challenging issues in the design of the rescue robots is their ability to handle unstructured and unstable physical conditions of the working environment. Therefore, a flexible robotics system that can sustain difficult conditions with a dependable control system is essential for the rescue team. On the other hand being able to recognize the injured by checking the skin color, skin tissue, and living signals such as temperature, voice and body movement are important.

Shrimp rescue robot rover is one of the several laboratory robots made at the Center of Excellence in Design, Robotics and Automation (CEDRA). As a general rule, rover robots are more adaptable and stable than walking robots. They are less complicated and more efficient in unstructured environments. The only deficiency in shrimp rovers is that they can't generally climb too much.

The Shrimp rover robot has somewhat similarities in motion to the sea creature "shrimp". Setting a four rod elbow, front fork, side wheels that work by parallel bogie system and robot flexible chassis make it possible for shrimp to climb stairs with the height of 20 cm, and also to pass through areas with unstructured obstacles. On the other hand setting wheels with controllable speeds, and a turning system that adjusts the angle of front and back wheels makes it possible for the robot to maneuver with high accuracy in confined areas. The shrimp rover robot can also be used in military like mine detecting, combat, search, and surveillance operations.

This Robot is guided and controlled by the rescue team from the rescue station. The guidance system checks the environment and robot conditions using microphones and cameras which are fixed on the robotic structure. The rescue robot can be navigated via an interface program.

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CEDRA rescue team started its activities on February 2003 at the Center of Excellence in Design, Robotics and Automation. Members of our team are M.Sc. and B.Sc. students with specialties in mechanical, computer and electrical engineering.

In this project, at first, an Alpha prototype was fabricated. Then by examining the first model and optimizing our designs, the second model "Beta prototype" was designed, and at last the final robot "Modified shrimp rover" was designed and fabricated (see Figures 1-2).

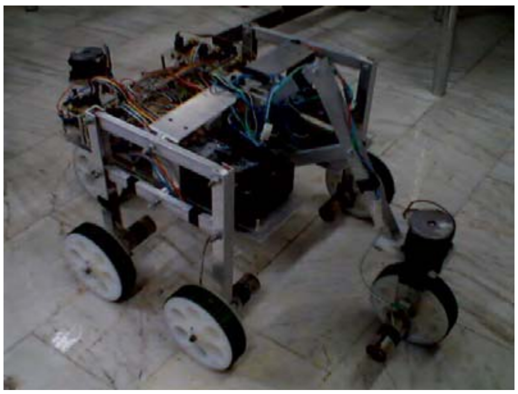


Fig.1. Alpha prototype of the Shrimp Rover

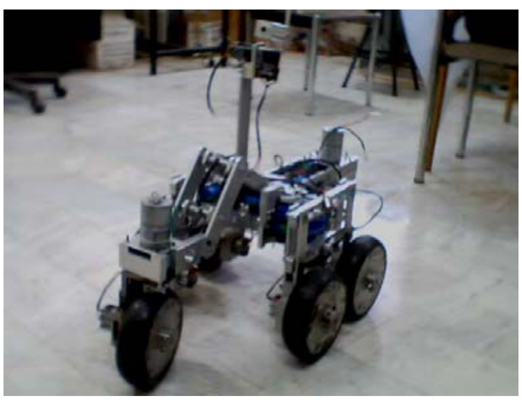


Fig.2. The Modified Shrimp Rover

2 ROBOT LOCOMOTION

Shrimp Rover has six wheels that operate separately; back and front wheels and four side wheels that are mounted in parallel bogies system, and the front wheel is placed on a front-fork mechanism. Special design, flexible elbows, a spring fitted in the front elbow that work as a pushing force, makes it possible for robot to adjust rough areas and obstacles such that all six wheels touch the ground simultaneously.

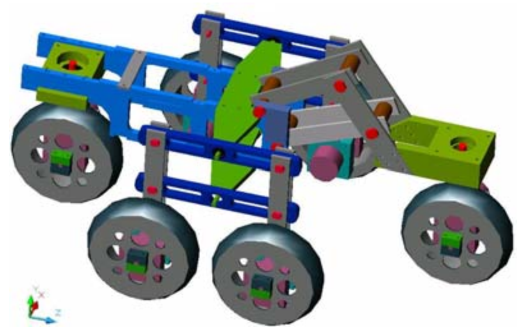


Fig.3. CAD model of the modified Shrimp Rover

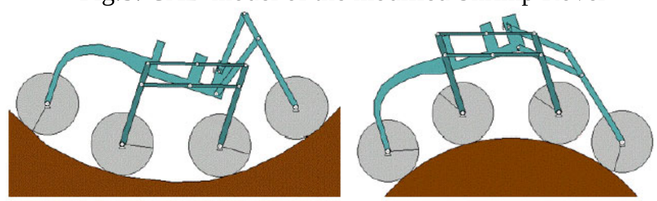


Fig.4. Robot flexibility in Convex/Concave environment.

2.1 Front Fork

The robot's front fork has three roles and duties (see Figure 5):

1-The spring makes it possible for wheels to touch the ground all the time.

2-When the robot encounters an obstacle, the horizontal force acting on the front wheel creates a torque around the instantaneous rotating center of front wheel. The four bar mechanism design in the front wheel shows that the instant center is set under the horizontal line, and therefore causes the wheel to move up accordingly.

3-When the front wheel is going up, spring is compressed and energy will be stored in the front wheel. Although, other wheels are not in a good condition during climbing and they don't touch the ground completely, but this stored energy helps them move up easier.

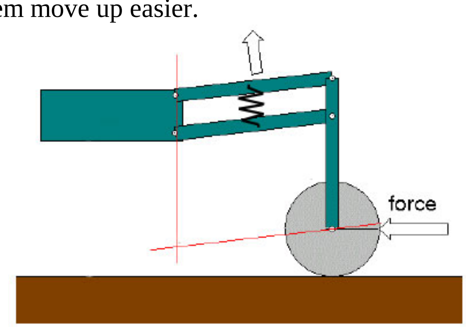


Fig.5. Front wheel

2.2 Bogies

Parallel bogies are being used in this design, because they pass the obstacles easier than classical bogies, although both have similarities in kinematics and in kinetics.

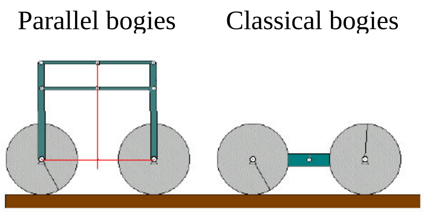


Fig. 6 Bogies

2.3 Robot seesaw system

Wheels are coupled so that the force distribution is the best as possible. Spring and dimensions of the robot are designed in a way that when it is standing on a planar surface, forces acted on all six wheels are the same.

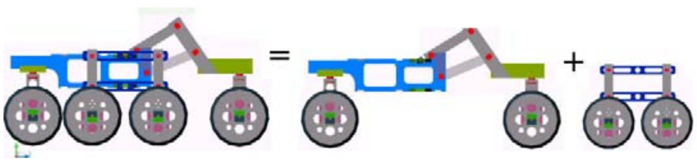


Fig. 7. Seesaw in robot

2.4 Steering

In this robot, six wheels have separate drivers, the front and back wheels have angle adjusting and controlling system. So the steering, causes speed difference in side wheels and adjust the angle of front and back wheels. This steering strategy increase the accuracy of robot maneuvers, and the robot can also turn in its place with minimum slip.

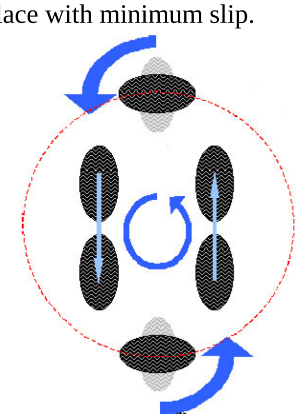


Fig.9. Turning of robot

3 MECHANICAL ANALYSIS

To model our shrimp rover robot, analysis are done for each components, and calculations are divided into two categories namely kinematics and dynamics analysis.

3.1 Kinematics analysis

One of the important properties of robot is the path of each component and the performance of robot is so sensitive to this parameter.

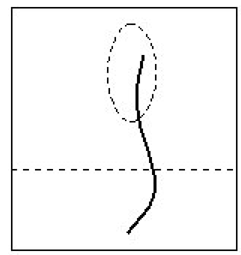
3.1.1 Front fork's path

Shrimp Rover's behavior very much depends on the front elbows, where a non-proper elbow size causes misbehavior of the robot. Front elbow designing standards, are listed below:

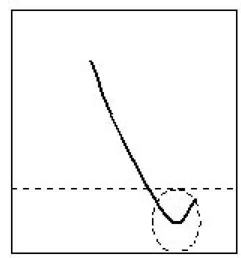
- *Front wheel proper climbing while striking an obstacle*
- *Front wheel proper range for rising and descending*
- *Non-existence of death point in the mechanism while striking an obstacle*

Some samples of misbehavior in the central locus is shown in Fig 10:

Non-proper climbing although the wheels go up nicely while striking obstacles



Too little descending of the wheel and existing of death point.



Too little descending and non-proper rising, another critical problem is that the wheel goes down while striking obstacle.

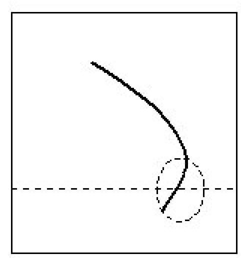


Fig.10. Some misbehavior in the path of front fork

According to what explained and considering parameters mentioned above, a suitable function was defined using optimization methods, where the mechanism illustrated in Fig.11 has the best result.

3.1.2 The Center of Gravity's path

The robot is designed to be able to climb stairs with 20 cm in height. While passing through obstacles, front and side wheel's mechanism cause the center of gravity to move gently. Robot behavior while passing stairs is shown in Fig.12. In this picture, path of C.G on stairs is very close to the behavior of a slope with the average stair slope. To soften the movement, two parameters of size and location of bogies play an important role. Path of C.G while climbing stairs is shown in Fig.13 for different values of bogies size.

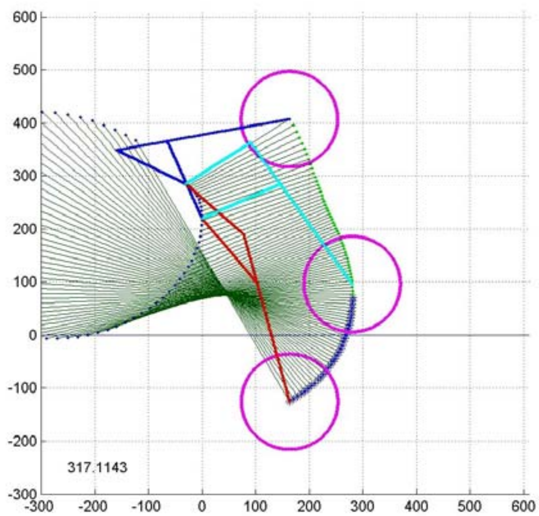


Fig.11. Front fork mechanism used in Shrimp Rover (all dimensions are in mm)

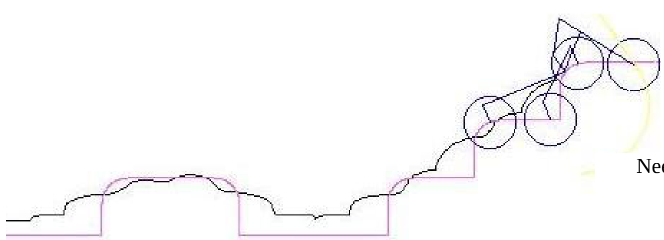


Fig.12. The path of C.G on the experimental stairs

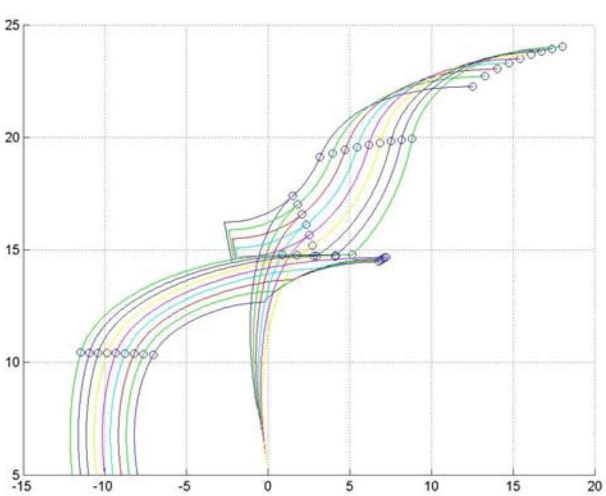
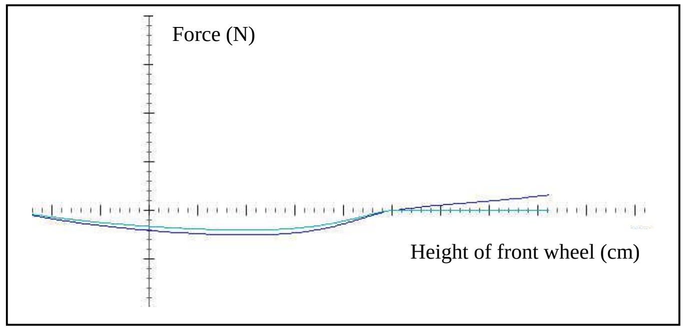


Fig.13. The path of center of gravity for various bogies size (all dimensions are in cm)

3.2 Dynamics analysis

3.2.1 The forces that act on the front wheel

While passing the stair's slope, horizontal force for pulling up the front wheel is less than other five wheels. On the other hand, when fork reaches the top it exerts vertical force to other parts of robot to help the whole body to move up. Front fork size, location of spring, and their strength are all horizontal forces that act on the front wheel when rising the



stair's slope. Calculation is done for a 5 N.m torque motor.

Fig.14. Horizontal and vertical components of front wheel force during climbing

3.2.2 Necessary front wheel torque for climbing

Considering the front wheel height, spring stiffness, front mechanism size and pre-compression of spring, the torque needed for pulling the robot up the stairs is determined. This torque must be less than the motor's maximum torque.

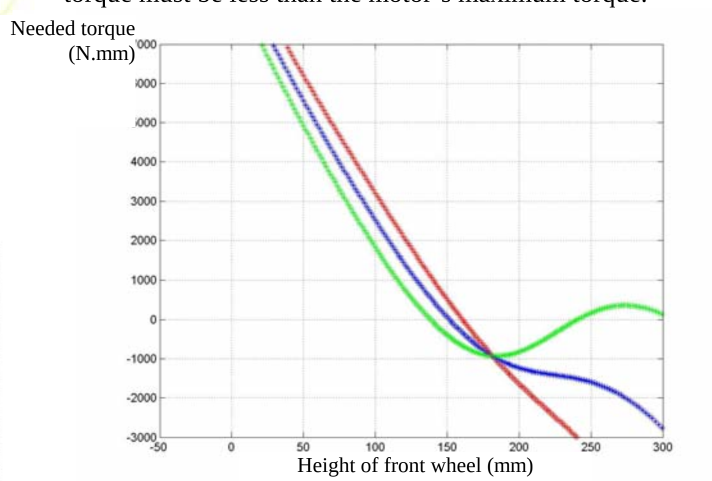


Fig.15. Torque needed for climbing for three different springs

3.2.3 General Power of Robot

Unlike previous parts, we now consider the robot as a whole and determine the slip condition, rolling of the wheels, possibility of non-contact wheels, motor torques, contact forces, and mass center acceleration.

Examining other alternates, we notice that contact forces should not increase and robot speed must be passive. For example when the mass center returns back while going forward, acceleration becomes negative and too much strength is exerted to the wheels. This method defines good parameters in robot designing.

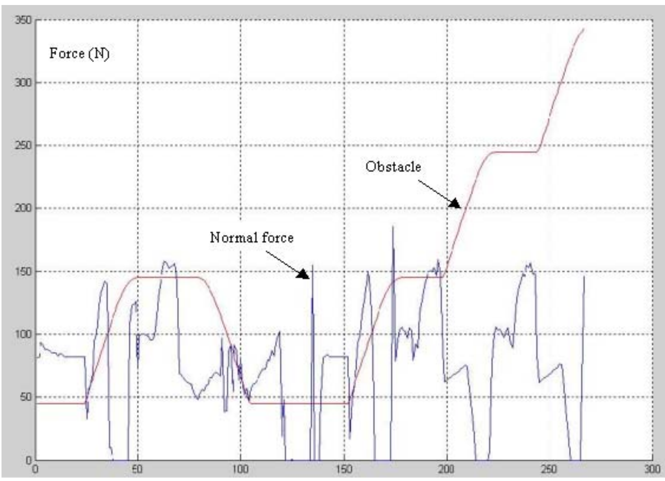


Fig. 16. Back wheel force diagram during obstacle crossing

3.2.4 Energy Based Analysis

From the energy viewpoint, the motors must be powerful enough to provide the necessary energy for upward motion (climbing stairs) and a change in the spring's length. The disordered situation of robot wheels during motion prevents motors to inject their energy all the time. Therefore, when the robot moves in horizontal path, the energy is stored in the spring, and when it moves upward, this energy is released.

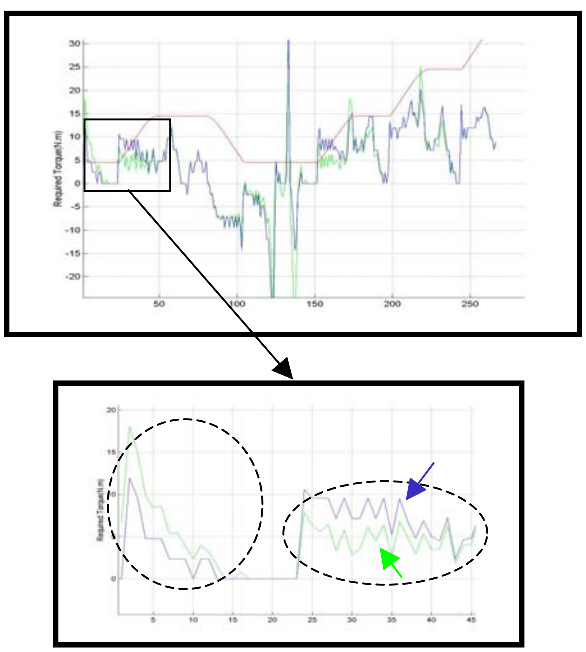


Fig. 17 Needed torque to provide energy in two cases: with and without the spring

3.3 Simulation with Software

Upon designing different components of the robot, using Working Model®, the performance and ability of the robot in different conditions were tested.

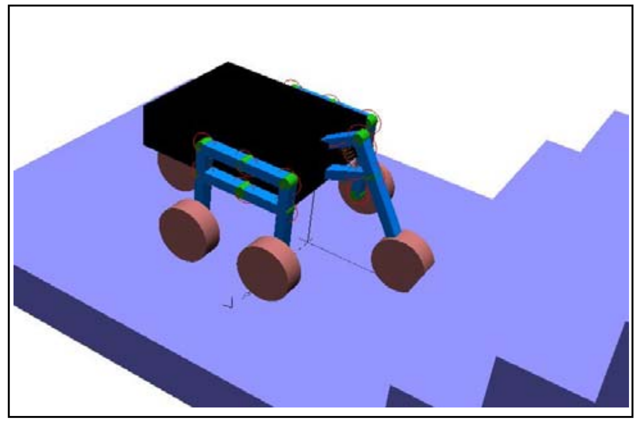


Fig. 18. The modeled robot in the Working Model environment

4 SENSORS, NAVIGATION, AND CONTROLS

Navigation, victim identification and preparing a map of the environment are the tasks performed by the operator using the video received, from the cameras mounted on the robot. The cameras are wireless Proline, operating in 2.4 Ghz. One has two degrees of freedom; yaw and pitch, ad the other one is fixed and is used to move the robot in tight and confined areas.

Control scheme and operator interface is through tele-operation. The operator uses a joystick to control the robot motion. Four buttons on the joystick are used to control the camera motion and another two to switch back and forth between different robots. Three screens were used, two televisions to display the video from cameras and a laptop to monitor the communication and status of the robots (Fig. 19).

Analog communication was used for the cameras, and the robot control was performed through a wireless LAN. The laptop in the control room was connected to the SENAO access point. The biscuit computer inside the robot used a wireless Micronet LAN card with a frequency of 2.4 Ghz.

5 CONCLUSIONS

The CEDRA Rescue Robotics System with its novel mechanical design "Shrimp Rover" has been briefly described. The shrimp mechanism was shown to provide great flexibility in the robotics system to move over obstacles, and successfully pass through unstructured environments. The robotics system has been tested in many areas within the laboratory and open fields and its performance were observed to be excellent.

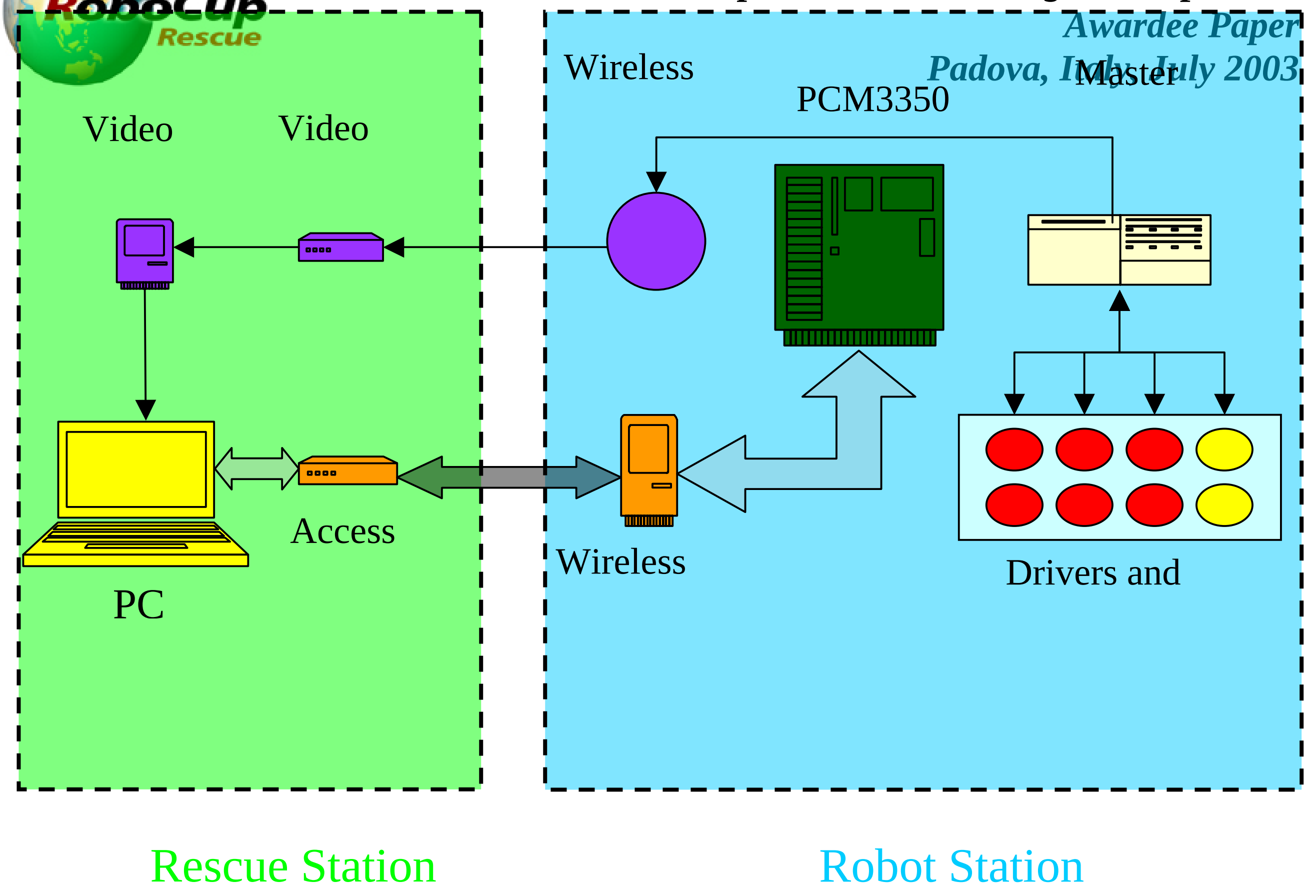


Fig. 19. The communications and control units

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