

RoboCupRescue 2010 - Robot League Team <Pasargad (Iran)>

Mohammad Ravandi¹, Soroush Sadeghnejad², Alireza Sheikhfafari³, Mehdi Nabi⁴, Farhad Bagher oskuie⁵, Reza Defaei⁶, Arash Nouri⁷, Ali Torabi⁸, Vahid Mehrabi⁹, Hadi Sadati¹⁰, Ali Abdollahi¹¹,

¹Mechanical Engineering Department of Amirkabir University of Technology
424 Hafez Ave. Tehran, Iran
Tel: +98-21-64543476

¹ravandi@aut.ac.ir, ²s.sadeghnejad@aut.ac.ir, ³sheikhjafari@gmail.com,
⁴mmnabi@gmail.com, ⁵f.bageroskuee@aut.ac.ir, ⁶mahyar_net@yahoo.com,
⁷arash1718@aut.ac.ir, ⁸alii.torabi@gmail.com, ⁹mehrabi_v@yahoo.com,
¹⁰sad.hadi@yahoo.com, ¹¹a.abdollahi1989@gmail.com

<http://www.asame.ir/pasargad>

Abstract. This paper represents current technical situation of Pasargad Rescue Robotic Team from Amirkabir University of Technology. As our previous experience from RoboCup2009 (Graz-Austria) and the regional competitions (Thailand Rescue Robotic Champions2009) and IranOpen2009, now we are developing more useful systems for this year competition. Pasargad team has been an active participant with one teleoperated robot, namely **ASAME2**, and one autonomous robot, **AutoASAME**, in RobocupRescue 2010. The autonomous robot designing and construction has been finished and now team has been trying to develop its features. In **ASAME2**, there has been an improvement in electrical design of both control and power circuitries. A new user interface that is more effective, will be used in 2010. In what follows we will present the electro-mechanical details and the algorithms that have been adopted in the above mentioned robots.

Introduction

The increasing need of employing robots in environments which are too harsh for humans, has led to vast researches in the field of robotics. In particular, rescue robots have attracted the attention of many researchers worldwide, due to their urgent applications. Due to geographical nature of Iran and the high possibility of earthquakes and other catastrophes, the Pasargad team commenced its research activities since 2005 under the supervision of Amirkabir's Scientific Association of Mechanical Engineering (ASAME). This team have designed and built two semi-autonomous robots, ASAME1 and ASAME2, and has finished designing an autonomous one, according to the rules and regulations of international RoboCup Rescue leagues. Even though actual field tests have not been conducted, we believe that these robots can become suitable for real disaster sites with few modifications.

ASAME1 is a remote operation robot that can operate in various unpredictable environments and can cope with rare conditions such as electrical shocks, high moisture, and electronic and communication disturbances.

It employs a four linkage mechanism, a cube-like mechanism with varying angles, and moves on a track with eight wheels. ASAME1 is equipped with victim identification and localization sensors and can produce the arena's map automatically with marking the victim location.

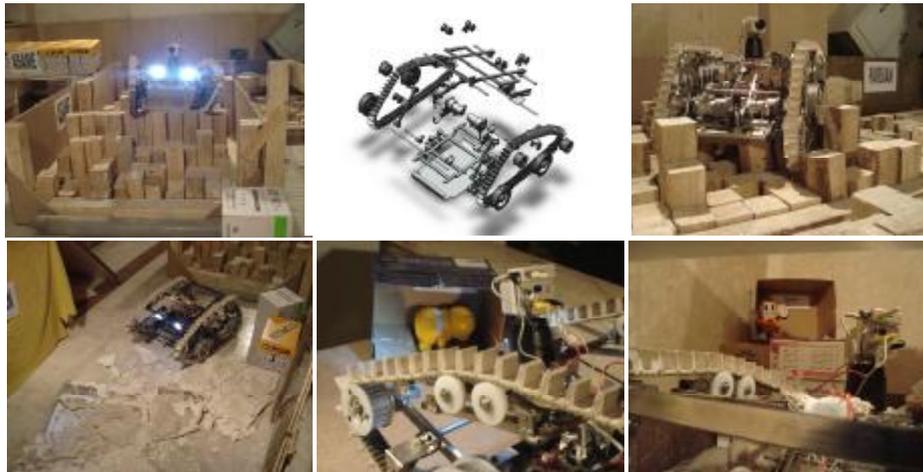


Fig.1. ASAME 1

ASAME2 is particularly capable of moving across various difficult environmental obstacles. It has four linear self-locking links that can rotate relative to the main body independently of each other. A manipulator has been designed on top of this robot that facilitates the movement of camera and the group of sensors. (Fig 4) This mechanism has three degrees of freedom and can cover 600mm above the robots surface.

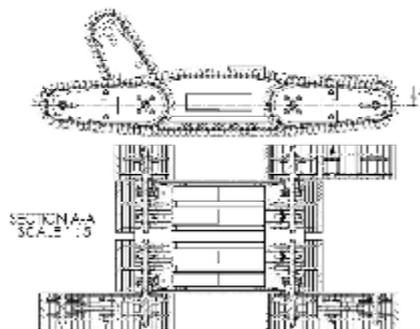


Fig 2 Pasargad Rescue Robot ASAME2



Fig 3 ASAME2 in Thailand Rescue Robotic Champions 2009

ASAME2 is equipped with various sensors for identification of victim's status, e.g. thermal and CO₂ sensors, cameras, and sensors for movement and sound detection. A localization system by an electronic compass, encoders and an acceleration sensor has been composed.



Fig 4 ASAME2 in RoboCup 2009 Graz-Austria

The AutoASAME is a fully autonomous robot. It has laser scanner and image processing to explore environment, determine the path, and detect victims. The autonomous localization and 2D mapping is mainly based on LASER scanner data. Its victim identification is mainly based on temperature sensors data. Team has used TPA81 sensors for victim identification and recognizing the heat sources. In addition to temperature sensors, team has used one CO₂ sensor and a sensitive microphone on the robot to be aware of nearing to victim zones. Also AutoASAME is equipped with cameras to detect the victims.



Fig 5 Pasargad Autonomous Robot (AutoASAME)

1. Team Members and Their Contributions

- | | |
|-------------------------------|---|
| • Mohammad Ravandi | Mechanical Design, Team leader |
| • Soroush Sadeghnejad Limouei | Mechanical design, Test arena designer |
| • Alireza Sheikhjafari | Electronics design, Map Generation & SLAM |
| • Farhad Bagher oskuie | Electronics design, Programming |
| • Reza Defaei | Communication establishment |
| • Arash Nouri Sagharlou | Communication establishment, GUI |
| • Mohammad Mehdi Nabi | Programming and software development |
| • Ali Torabi Parizi | Mechanical design |
| • Vahid Mehrabi | Mechanical design |
| • Hadi Sadati | Mechanical design |
| • Ali Abdollahi | Mechanical design |
| • Dr.M.R Razfar | Technical Adviser |

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

Regarding the limited amount of time for preparation of robots and the team's experiences in former international leagues, the operator system and the robots have been prepared distinctly. The operator system is ready in a toolbox. It includes an operator's laptop, an extra monitor, headphone, access point and a communication antenna that have been collected in a single unit for quick installation and also other equipments like pedal and throttle. The robot is ready to receive the operator commands as soon as it receives the signal from the on/off key. All these tasks for set up will be ready in just 3 minute.



Fig 6 Pasargad Operator Station Toolbox

3. Communications

A wireless communication has been established using W-LAN802-11a communication network at 5GHz frequency. The information is gathered in the central processing unit of the robot via a hub-switch. The processed information is sent to the operator using Access Point. In case the communication fails, the robot will intelligently switch to autonomous mode until the reestablishment of communication.

Rescue Robot League		
Pasargad (IRAN)		
Frequency	Channel/Band	Power (mW)
5.0 GHz - 802.11a	1-14ch	10 (mW)

4. Control Method and Human-Robot Interface

The two robots are controllable in both automatic (non autonomous) and manual modes. In the automatic mode, the robots gather and transfer information using an intelligent program and in case any problems occurred in the automatic control system, the type of the error is reported to the operator. In the manual mode, the operator can send signals to each of the robots, using throttle and pedal, keyboard, and manipulator, and observe the gathered information of the robot through the monitors and gages. The operator can observe the picture of on second monitor, and also can exchange the different facilities of software between two monitors arbitrary. Other information that is available to the operator at any instant include the amount of carbon dioxide, temperature, charge of batteries, the orientation of robot rela-

tive to north pole, the angle between the robot links and main body, the amount of sound signals of the environment, and the instantaneous graphical shape of the robot. The program also enables the operator to perform some predetermined tasks such as climbing up and down stairs, ramps and also step fields.



Fig 7 User interface of the operator station (Switch on ASAME 2).

5. Map generation, Navigation and Localization

For orientation and mapping a simple algorithm is used. This algorithm takes and combines its inputs from encoders, accelerometers, compasses with laser range finder. To generate the map, **laser scanner (Laser range scanner Hokuyo UGB-04LX-F01)** as a sensor, is being used. the angle of sight of this sensor is 240 degrees with accuracy of 0.36 degrees with a speed of 100 scans per second and the length of sight is from 0.02 to 6 meters with accuracy of 1mm.

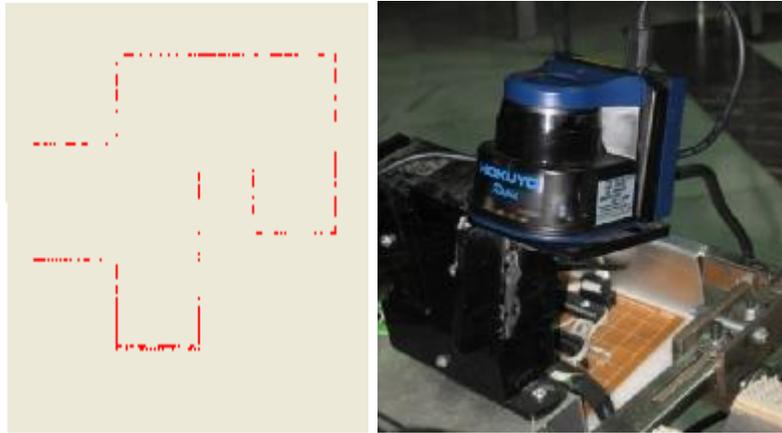


Fig 8 laser scanner (Hokuyo UBG-04LX-F01)

Three parameters will be identified in this map:

- Environment map
- Robot exploring path
- Victim location

Using the motor encoder, the displacement of the robot will be identified. The output of the encoders needs to be modified by using the accelerometer due to these reasons:

- Heavy shock
- Slipping of the robot in ramp field.
- Another error of the encoders output.
-

The procedure of this method is as follows; the output of accelerometer will be integrated two times in each period of time. With this action the displacement will be known. This displacement will be compared with encoders output and at the end the encoders output will be modified. Laser scanner will be placed on a three degree of freedom (3-DOF) pan tilt. This pan tilt will hold the laser scanner in horizontal state throw north direction. In fact, it is used to minimize the probability of errors. X and Y motion will minimize the error that may occur due to trapping an exploring in ramp arenas and the Z motion will decrease the time of calculation due to robot rotation.

6. Electrical design

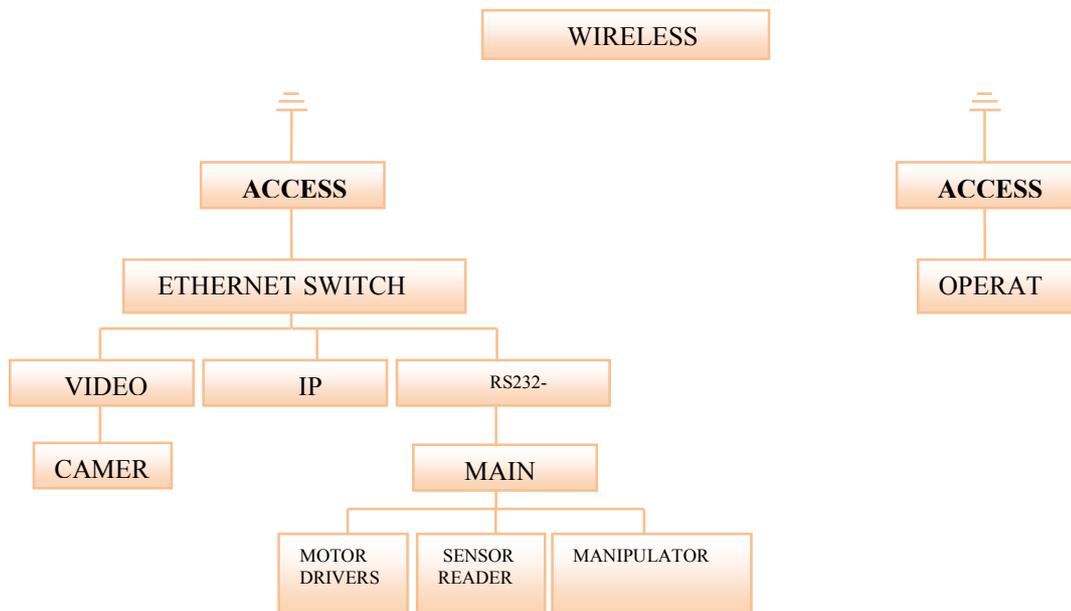
- **Main Board**

Main Board corresponds to communicate data between all electronic board, sending or receiving data, commands. All modular boards such as motor drivers and sensors have their own unique addresses. When each of these modular connects to internal Bus, main board will recognize them via protocol described in section below. Main board manages the alloca-

tion of internal Bus and calls each modular board between specific time intervals. If that board has been connected to the internal Bus, main board will send corresponding commands and then will receive status information or sensor data. Block diagram of main board is shown below. It is consist of an AVR microcontroller of Atmega series (Atmega 128) that operates on 16 MHz clock frequency. This microcontroller has two Usart ports. One of these Usart ports is used to communicate with RS232-Ethernet convertor and the other one is used as an internal Bus for modular boards.

Whenever a packet of data received from Rs232-Ethernet convertor, microcontroller checks its validity due to packet header, trailer and size that has been defined in communication protocol. If the packet passes the validity tests, its data will be used, otherwise the packet will be ignored.

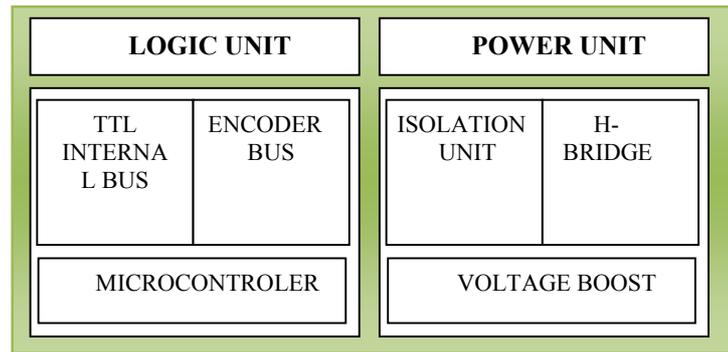
Other duty of main board is to prevent the actions that may cause critical damages to the robot. Such situation, may occur when operator commands two arms that are in the same side of the robot, to move toward each other. All the time main board acquires arm position via motor drivers and whenever requirement arises, it can terminate the operator commands to preventing the arms contact. Although in wireless communication failure, main board will be command all modular boards to go safe mode. For example in such situation main board will command motor drivers to turn off motors after 5 seconds. Also main board measures the battery charge level and manage charging process.



- **Motor Drivers**

The robot has six Maxon DC motors, with 500 step Encoder and 24 V driving voltage and maximum power of 150 watts. Starting current of motors is 75 A, due to this we have to limit the output current of motor driver boards to 25 A via sensing the motor currents. Also we

need to control speed of motor. To do so, we apply a PWM signal to a powerful H-bridge. Encoder data can be served as speed feedback for locomotion motors and position data for four arms motors.



- **Internal Bus communication Protocol**

Every modular board, such as CO2 sensor, thermal sensor and motor drivers connect to a Bus, called Internal Bus. This internal Bus is controlled by main board microprocessor. Actually main board serves as master and other modular board acts as Slave. Every modular board has unique address master sequentially puts valid addresses on the internal Bus and waits for response. All modular boards receive this address but only one board will response to that, by sending back own address to master. If master receives response in specific time interval, It will start to send commands, then master will wait for receiving responding data of modular board.

Bus is 9600 bits/s, that is suitable for our noisy environment in the robot. Also this board rate supports our real time requirements.

Also this protocol allows each board to plug/unplug process independently and freely that facilitate repairmen process. Block diagram of these drivers is shown above . Logic ports operate from 5 volts of internal Bus and have ability to sense motor current, encoder pulse counter, storing latest position of motor. Logic parts connect to internal Bus via microcontroller USART and receives commands from main board and then sends sensed current data and encoder position to it.

Power parts have isolated 24 V power supply to driving motors and special voltage boost unit to signal H-Bridge MOSFET Gates. Maximum allowable driving power supply is 200 volts and maximum driving current is limited to 25 A therefore maximum power of driving boards is 600 Watts.

- **Communication Protocol**

Communication protocol between robot and computer interface is as mentioned. Main board puts its gathered data in a packet and sends it via USART port to Rs232-Ethernet convertor.

Rs232-Ethernet put this packet in standard Ethernet packets and send to Ethernet Hub-Switch and then to access point to transfer to the base. Our crude packet consists of a header and trailer and has its defined size and some CRC bits to checking validity. If a packet fails

to pass validity check, will be neglected. Such protocol are used to send data from computer interface to robot.

7. Sensors for Victim Identification

- **Compass**

In this robot three different compasses with 3 different assumed north directions are used, each north differs by 45 degrees relative to the others. This has been done to improve accuracy and reduce erroneous results.

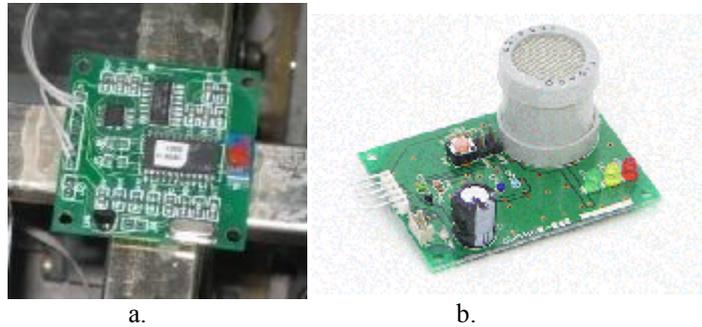


Fig 9 a. Compass sensor .b. CO2 sensor -CDM4160-MOO

- **Ultrasonic**

In the left and right sides of the robot, in which the operators sight is limited ultrasonic devices are used to find blocks or objects.

- **Thermal sensor**

Three TPA81 sensors which are none contact sensors are used.

- **CO2 sensor**

The CO2 sensor used is CDM4160-MOO that has the ability to measure CO2 levels up to 8000 ppm. (Fig.9-b). The microcomputer takes data and renews it once per second. The processor calculates CO2 concentrations based on the difference between current sensor output and a baseline value.

- **Microphone**

The cameras installed all have microphones and these microphones are used to gather sound.

- **Camera**

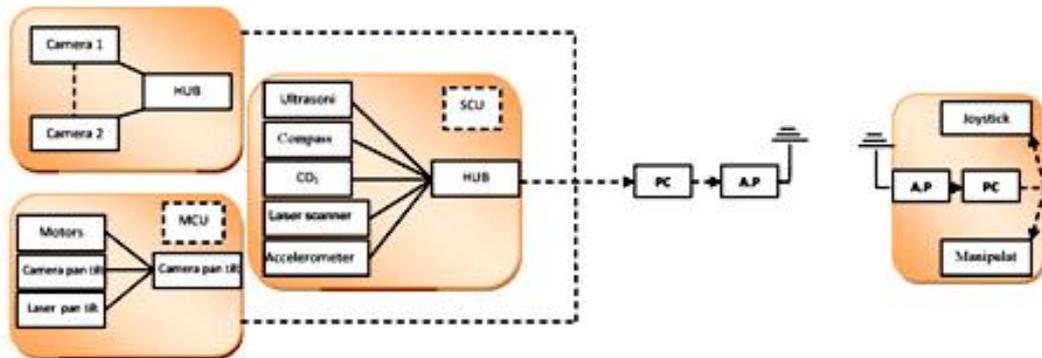
Three cameras will be used in our robots:

Main camera: Panasonic BB-HCM580 IP surveillance camera with pan tilt 21x optical zoom, low light capability and motion detection. This camera will be assembled on the AutoASAME. By using this camera; the robot can identify the victim main situation.

Camera 2: It is used to show a wide scene in front of the robot for its perfect locomotion.

Camera 3: It is used on the manipulator for detecting the victims.

Block diagram



8. Robot Locomotion

The Pasargad team will compete with a teleoperated robot with tracks and a autonomous robot in this competition. As robot with tracks perform better than robots with wheels in difficult and variable paths in competitions, the choice of using tracks seems to be the best choice. Robots that have tracks or chains for movement can easily traverse obstacles that would stop robots with wheels

Track robots have this capability of motion but at the price of the difficulty of design and building, cost and lower efficiency. So tracks are a good option here but they are not always the best choice.

8-1 ASAME1 Designed Mechanism For the track mechanism of this robot, each wheel has a gear like profile of the standard type XL on its outer surface which engages the same profile in the inner surface of the tracks. On the outer surface of the tracks cuboids of average height of 35mm are places 30mm apart to produce the capability of engagement with different obstacles. Each of the pair of propulsion wheels has two motors of the type Buhler-1.61.050.446 on either side (Fig.10). These motors are 12 volts with direct current, and each has a gear box with a ratio of 1:96. The speed limit of the motors is 2400 rpms and maximum torque output of 46.3 mN.m. The choice of motor was based on the calculations relating to the dynamics of the robot as well as a comparison of motors provided by different manufacturers. The robot has the capability of lowering its tracks to increase the surface of contact of the robot with different obstacles. This is achieved by a Buhler motor of the type 1.61.050.448 with a gear box designed by the team with a ratio of 1:3.



Fig 10 - Buhler DC motors (ASAME1 & AutoASAME) **Fig 11** - Maxon DC motor (ASAME 2)

8-2 ASAME2 Designed Mechanism ASAME2 is a robot with the capability of traversing the most difficult of obstacles. This robot has four linear arms which have the ability to rotate freely relative to the main body of the robot, even though they have been designed to be self locking. The robot has six worm gear boxes each with its own motor, so that two motors move the robot itself and the other four rotate the arms. Other advantage is its fully wrapped shape with tracks. It causes the robot cross step field easily. The motors were purchased from MAXON Motor Co. of the model 148867.

For this robot, manipulator has been designed to move the camera and other sensors. This manipulator has three degrees of freedom.

8-3 AotuASAME Designed Mechanism For the track mechanism of this robot, each wheel has a gear like profile of the standard type XL on its outer surface which engages the same profile in the inner surface of the tracks. On the outer surface of the tracks cuboids of average height of 30mm are placed 25mm apart to produce the capability of engagement with different obstacles and moving smoothly over ramps. Each of the pair of propulsion wheels has two motors of the type Buhler-1.61.050.446 on either side (Fig.10). This robot is capable of traversing new obstacles that is introduced in new rules of RRRL2010.

9. Team Training for Operation (Human Factors)

Team training for operation needs to be familiar with the robot control system. Our very easy and user friendly interface, let any new operator to be a well trained operator. Having a professional operator also needs to have practice in a real arena of competition and try that situation. So we have prepared a small arena which includes some step fields, Staircase, some ramps and also pallets. So it can be a good practice for any team to gain some experience before participating in any competition.



Fig 12 Pasargad Team Training Sample Arena

10. Possibility for Practical Application to Real Disaster Site

Even though the robot has not been tested in realistic environments, the team believes that based on tested performed in simulations of real environments and competitions the robot can perform adequately in these environments.

Still, realistic situations were taken into account during the entirety of the design process. The mechanical equipments and capabilities of ASAME2 stand it in good stead to traverse environments with small stones, surfaces with different slopes, areas with discrete stairs, and unstable uneven surfaces. It can also be assembled and disassembled very easily and this can also be done by an untrained person and thereby also transported to the area easily and quickly. Also the body of both robots can take the stains of a real situation.

11. System Cost

Item	Qty	Price/Pcs	Price
DC motor	6 (Maxon)	570 \$	4045
	5 (Buhler)	125 \$	
Laser scanner	1		2560
Laptop	3	500 \$	1500
IP camera	2	850 \$	1700
Webcam	5	20 \$	100
Thermal sensor (TPA81)	2	400\$	800
CO ₂ sensors	2	150 \$	300
Other sensor		1000 \$	1000
Manufacture		4000 \$	4000
Staple		1100 \$	1100
Total			17,105 \$

12. References

1. Jorge Angeles,” Fundamentals of Robotic Mechanical Systems: Theory, Methods, and Algorithms, Second Edition”, Springer-Verlag New York, Inc., 2003
2. Roland SIEGWART, Illah R. NOURBAKHSH, “Introduction to Autonomous Mobile Robots”, Massachusetts Institute of Technology, 2004
3. Johannes Pellenz. Mapping and map scoring at the robocuprescue competition. In Quantitative Performance Evaluation of Navigation Solutions for Mobile Robots (RSS 08, Workshop CD), 2008.
4. M. Waleed Kadous, Raymond KaMan Sheh, Claude Sammut: “Effective User Interface Design for Rescue Robotics”, 2005
5. E. Mihankhah.: TDP of Resquake Robotic Team, K.N.Toosi University of Technology (IRAN). RoboCup Rescue Robot League (2009).
6. J. Suthakorn*, S.S.H. Shah , S. Jantarajit , W. Onprasert and W. Saensupo,S. Saeung, S. Nakdhamabhorn,V. Sa-Ing, and S. Reaungamornrat “On the Design and Development of A Rough Terrain Robot for Rescue Missions”. Proceedings of the 2008 IEEE International Conference on Robotics and Biomimetics Bangkok, Thailand, February 21 - 26, 2009
7. Maxon Motor. DC Motor. [Online].
8. V. Nguyen, A. Martinelli, N. Tomatis, R. Siegwart. A Comparison of Line Extraction Algorithms using 2D Laser Rangefinder for Indoor Mobile Robotics. In Proc. of the IEEE/RSJ, IROS, 2005.
9. www.figarosensor.com
10. <http://www.hokuyoaut.jp/02sensor/07scanner/urg.html>
11. <http://panasonic.co.jp/pcc/products/en/netwkcaml/>

Videos:

Pasargad team training test videos and also the team performance in the Workshop of Thailand Rescue Robotic Champion 2009 can be found in the address link below: (With great respect to Team CASulty from Australia, specially Prof.Claude Sammut, for taking the video)

<http://www.ASAME.ir/Pasargad>