RoboCup Rescue 2017 Team Description Paper

CuerBot

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Info

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Abstract— This project is developed based into six wheels no holonomic with gravity center fixed mobile robot for rescue operations in Mexico, our principal goal is type-2 fuzzy logic algorithm to evaluate victim state and position; in this project use a software embedded to apply our control algorithms and manage data acquisition and actuator enveloped. Robotic design includes an innovative technique to evaluate route measurement with dual sensor style.

Index Terms—RoboCup Rescue, Team Description Paper, fuzzy logic, embedded controller, data acquisition systems.

Introduction

For this project we are working in a real situation of support for rescue teams of Nuevo Leon State, our topography is special for tracking vehicles and for this reason work with this type locomotion system. Taking as reference RoboCup rules [1], we consider CO_2, body temperature, sound and video processing; additional variables to consider are proximity Detection and level position. To link all these variables we use I^2C network under serial connections, every node in this network have either two elements: microcontroller and level conversion circuit. This microcontroller has a simple responsibility, manage a Universal Algorithm to Read/Write our Environment (UARWE), this algorithm includes protocol algorithm. All this nodes are controlled by an embedded card that uses C++ as platform to develop mapping and robot control. Some previous works was presented by [2, 4, 5, 6] For control algorithm we use two programs: one based in fuzzy logic type II with two options to evaluate, both are developed in embedded card with MATLAB and LabView software, this program consider CO_2, body temperature (IR sensor), Displacement and voice as inputs to evaluate, as output victim detection and, second Finite State Machine FSM algorithm is developed for single robot´s displacement. It´s very important take a consideration always manual control of robot movement is present and control algorithm helps to give a guide to operator to drive this robot.

For a communication we use two links to establish contact between the operator and the robot, the Wi-Fi type N net is used for communication between a PC with a Raspberry pi 3 with a regular configuration defined for TCP / IP protocol parameters. In this case, one computer (master) controls the robot and the Raspberry pi 3 controller is slave to the other, using software for remote control. The managed frequency is 2.4 GHz, and all the features are wrapped in Wi-Fi Consortium.

For video management we use three video cameras. The main camera is located in the support of the 3 dof mechanism see the figure 7, the second is in the robot arm of 6 dof, and we use a fixed auxiliary camera in the back of the robot, the cameras use the Wi-Fi link, these cameras generate a High-quality image processing with the control algorithm, located on the integrated platform system.

To give exact position of robot we consider two sensors to evaluate this date, gyroscope MEMS sensors that evaluate three axis position and acceleration and two encoders to make a measure of two axis positions, both variables are connected to microcontrollers commented lines up. Around robot structure we fit six proximity sensors to detect wall and free space, all processing is realized in control algorithm.

As mechanical references we use three mass elements to move this robot, one is main structure where caterpillar and mechanisms are linked to produce X, Y movement, another two structures are helping to climb and move down the main structure, every structure has a similar bonds with tracking system, maintaining or trying to, fit always our center of gravity.

For all this work we made some research over projects presented in lasted RoboCup competitions and as reference our participation local robotics contest; we try to evaluate our preliminary results and obviously our actual participation will be reflected in a potential product to introduce to national market free of providers of rescue robots.

Rescue Robot League		
CuerBot (MEXICO)		
MODIFY TABLE TO NOTE ALL FREQENCIES THAT APPLY TO YOUR TEAM		
Frequency	**Channel/Band**	**Power (mW)**
2.4 GHz - 802.11n	3	500
2.4 GHz - Other	FM	500

Table 1. Frequencies table used for this robot.

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

The operator system is packed in one middle CuerBot suitcase, and the robot is also packed in one large size CuerBot traveling box. Suitcase weight will not exceed 10 kg. And our robot is previously fully ensembles, to large travel it can be dismounting a re-ensemble again. Our Operator Station is formed either Computer (netbook) or smartphone, dedicated as interface of embedded card located in robot, all programs are located there; another accessory is one video web camera and receiver and the last element is a hand radio to receive environment sound from robot. A regular power supply is added to manage 110 V AC, but it is prepared for emergency energy plant or 12 V dc batteries. The setup is quickly is just plug and play and for break down in similar way.

2 Communications

The method of communication between the user and the robot will be by means of one laptop that has control over other embedded computer managed remotely, communicated a network Wi-Fi type N. Internal communication will be handled directly with I^2C network that will connect to microcontrollers with net bus [15], it will be in charge to receive and to carry out the orders that the mother-board requires. Another links are used for FM video transmitter with 2.4 GHz frequency, for the voice link used a camera with an integrated microphone for the broadcast and reception of sound is communicated via WIFI type N. All frequencies used shown in Table 1

3 Control Method and Human-Robot Interface

In the control method, already detected the variables of the victim by means of the sensors they are analyzed by means of fuzzy logic type I methodology. For the process of fuzzyfication the operators used are Min-Max method, this give us an implication of variables becomes taking

minimum from the exit variables, they are added considering its maximum values of each one of the same exits of the activated rules, and the method of desfuzzification is the centroid in the diffuse algorithm obtained a total of 9 evaluated rules and at the moment it is continued valuing the exact specification of the model for the detection of victims; as reference, comparing with old model reduce 30 % of computational process. For future hardware mapping decision, consider two steps for fuzzy control, first victim´s found subsystem and second voice analyze subsystem; for linguistic description variables Gaussian shapes are preferred, but in some cases trapezoidal graphs are used too. Some preliminary results, give us some differences about victim age; and it's expressed by different desfuzzification phase outputs with similar form but variable highly dependent of age. The last results give opportunity to use type-II fuzzy logic as methodology to found better refined desfuzzification victim variable [8]. All environments are developed in LabView to take access to interfaces and be compatible with OS. This part is been currently developed, but this manages motion control and victim detection indication in robot teach box, we are trying to connect a mechanical displacement accessory (joystick), using info packet over TCP/IP. Some references were in [3, 6].

Type-2 fuzzy logic systems

Interval type-2 (IT2) fuzzy logic systems (FLS) constitute an ~ emerging technology. A type-2 fuzzy set [1], denoted by A, is characterized by a type-2 membership function μ a (x, u), Where x $\in$ X and u $\in$ J x $\subseteq$ $[0, 1]$ and all variables Enveloped into human detection are evaluated under this consideration

$$\tilde{A} = \left\{ \left((x, u), \mu_{\tilde{A}}(x, u) \right) \mid \forall x \in X, \forall u \in J_x \subseteq [0,1] \right\} \text{ and } 0 \leq \mu_{\tilde{A}}(x, u) \leq 1.$$

This means that at specific value of x, say x', there is no longer a single value as for the type-1 membership function (u') [8]; instead, the type-2 membership function takes on a set of values named the primary membership of x', $u \in J_x \subseteq [0,1]$. It is possible to assign an amplitude distribution to all of those points. This amplitude is named a secondary grade of general type-2 fuzzy set. When the values of secondary grade are the same and equal to 1, there is the case of an interval type-2 membership function. In human detection, the inputs of the IT2 FLS model are the victim's body temperature, CO2 These rules represent a fuzzy relations between the input space $X_1 \times X_2 \times X_3$ and the output space Y, and are complete, consistent and continuous.

Composition, and the voice frequency.

The primary membership function ~l ~l A1 , A2 and ~l A3 of the architecture of the IT2 FLS is established in that way those each consequent is a Gaussian function with uncertain means, see parameters are continuously optimized. The number of rule - figure 4.1. Since the center-of-sets type-reducer replaces each antecedents are fixed to three; one for the body temperature consequent set (divided into three IT2 fuzzy sets), one for the CO2 C ~ by its centroid, then yll and ylr are the Gl consumptions (divided into five IT2 fuzzy sets), and one for consequent parameters. The voice frequency (divided into five IT2 fuzzy sets), resulting (3 * 5 * 5 = 75) twenty five rules. Gaussian primary membership functions of uncertain means are chosen for the antecedents and consequents. The resulting interval type-2 TSK FLS uses type-1 singleton fuzzification, join under maximum t-conform, meet under product t-norm and product implication. The training mechanism used is the back-propagation (BP) method. The IT2 CTC model has three four inputs x1 ∈X1, x2 ∈X2, and x3 ∈X3 and one output y ∈Y, and a rule base of size M = 75 of the form:

R~l : IF x1 is 1 and x2 is A~l , and x3 is A~l, THEN y is G~l here l= 1, 2,…75.

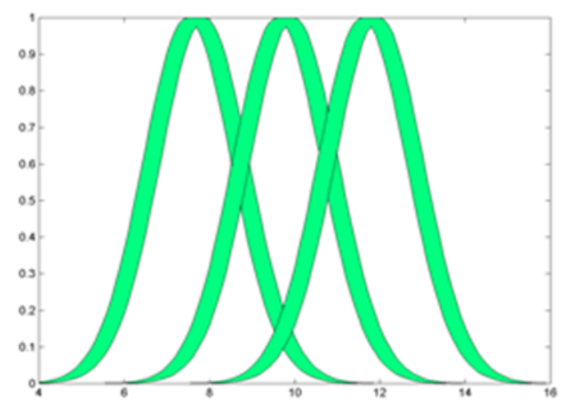

Fig 3.1 Temperature type-2 membership functions, it's a simple example of temperature evaluation.

Initially, only the input-output data training pairs (x(1):y(1)), (x(2):y(2)),…, (x(N):y(N)) are available and the initial values for the centroid parameters yll and ylr may be determined according to the linguistic rules from human experts, as is the case of this application.

As support of fuzzy design we are using X fuzzy software to support all initial models of linguistic variables used to detect victims. Additional tools was used to develop all fuzzy algorithms as Matlab and OMEdit, to validate all structures of behaviors of victim detection. We depict the follow figures with explanation of fuzzy strategy to develop a detection of every variable such as temperature, distance detection, position and vision, all figures from 3.2 to 3.8 explain over their variable modeling process.

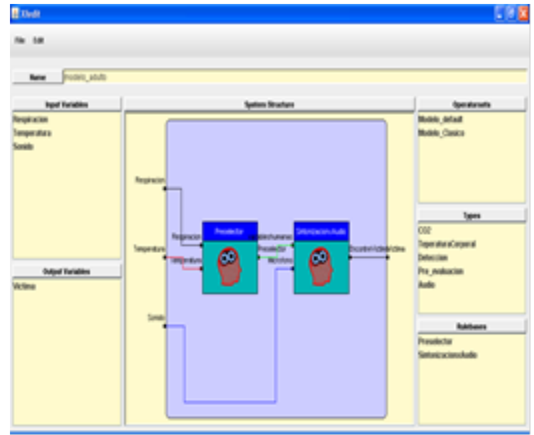

Fig 3.2 Structure of I/O of fuzzy controller, for this case Pre-selector controller evaluate human variables available CO_2 and temperature; fitting controller evaluate audio voice, this step is changing with old age. This first evaluation steps was developed in fuzzy type I style, as reference as start point to variable evaluations [22].

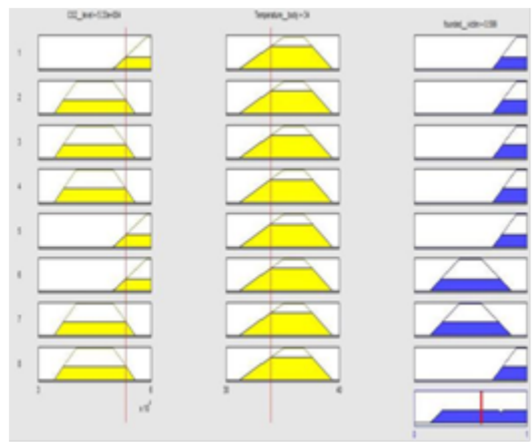

Fig 3.3 Graphic evaluation of preliminary fuzzy graphs of pre-selector controller.

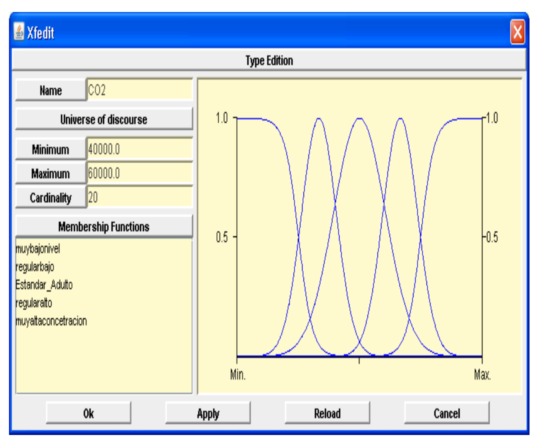

Fig 3.4 Fuzzy graphs typical used for fuzzy controller, Gaussian form are considered in all variables.

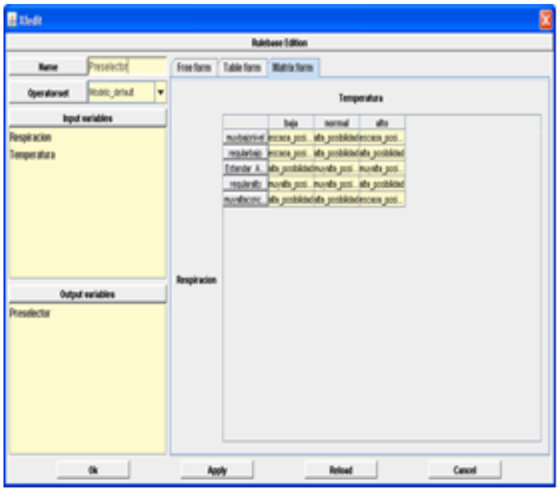

Fig 3.5 Fuzzy Algorithm Matrix, this figure represent linguistic experience of rescue operator expressed in general way, in other words, with natural language.

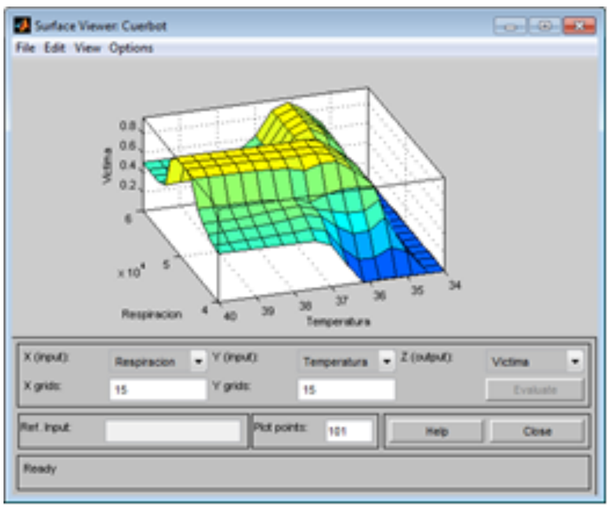

Fig 3.6 Fuzzy System Type I, it will be integrated with another two systems, all was evaluated into Matlab© and Xfuzzy.

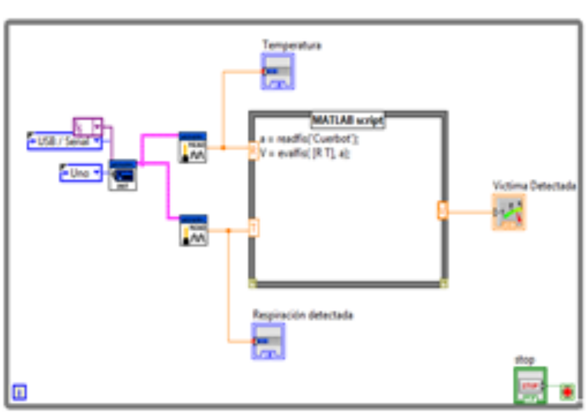

Fig 3.7 Fuzzy System Type I with hardware interface with Arduino microcontroller, integrating control and victim indicator.

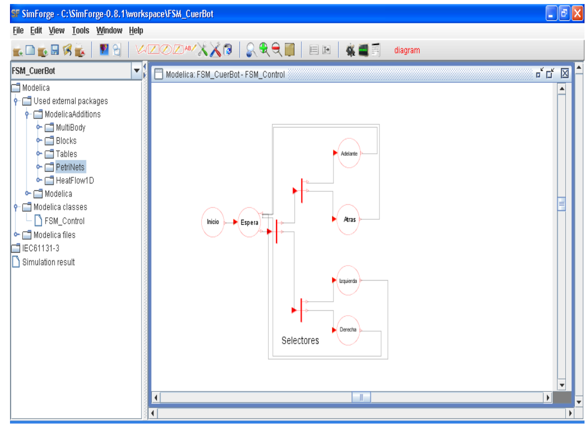

Fig 3.8 FSM algorithm tested by SimForge tool for manual control of robot displacement, this figure depicts Petri Net equivalent for general structure [23, 24].

In this moment, we are defining our expected results based into knowledge base of Operator experience in rescue operations and 6 possibilities are been evaluated in this moment according human age [9-13].

To integrate our Fuzzy Logic philosophy in easy mode, follow a simple strategy to develop out initial effort; with LabView based into Matlab© interface: With Matlab, create simple examples of fuzzy type I developments, calling them with LabView, we create a simple mathematical platform with all these controllers integrating one fuzzy logic type 2 system. As initial work only two variables are considerate, as sequential job audio treatment will be added into project.

For basic movement of robot an Finite State Machine FSM algorithm is currently designed for manual control, the simple way to represent this control is following joystick over user indicated displacement, i.e., moving left indicates to motor their current flow and as speed regulation based into two PWM duty cycles previously fixed (k= 0.45 and 0.8). As experience, an improved technique over speed motor control is developing to prevent recurrent damage over DC drivers.

Both control algorithms are initially implemented in embedded card that but some deficiencies are detected in past, to improve it, some powerful computer are better; for this reason an atom processor changes all software potential. In this version a netbook are used with graphic language with quick access to every sensor and actuator [12, 13]. This computer is supported with auxiliary Arduino microcontrollers.

4 Map generation/ printing

For mapping generation we are designing a program to detect obstacles and give telemetry info about position of robot and victim detection. We are integrating in embedded card a control protocol program that obtains info of encoders, gyroscope and accelerometers; all of them are processed for this program. An develop XY map tool is currently developed to show and print robot position, in this moment only simple detection of trajectory is created, for victim detection fuzzy algorithm helps to main program to establish the possibility of victim presence. For measurement proposes, we are using metric units. This program is making developed in LabView.

5 Sensors for navigation and localization

For this purpose we use old sensor scheme used in previous prototype, remembering it consider two element to make it, two absolute encoders located into robot structure and they give us 360 degrades for X-Y Axis motion, their mechanical mounting will be specified in the next sections.

In this case electrical parameters are compatible with TTL level managed by microcontrollers used in this robot, all information is driving with control PC program into embedded card. The resolution of this sensor is 4 revolutions by one track band revolution considering 0.000694 lineal meters reflected in X-Axis and for Y-Axis consider angular displacement 1440 pulses by revolution.

Another innovator element included is a gyroscope based in MEMS technology to give us either two parameters: level and acceleration measurement, digital output in serial format is used to communicate with your corresponding microcontroller. This smart sensor has a resolution of 0.004o by axis and considers 3D level detection and, in similar manner is treated acceleration measurement.

Both displacement sensors used are evaluated to prevent false measurement by wheels sliding and home fixing, additional algorithms are developed to translate acceleration and binary to ASCII conversion. Both sensors are depicted into figures 5.1 and 5.2, respectively.

Fig 5.1: Absolute encoder used to mechanical movement detection.

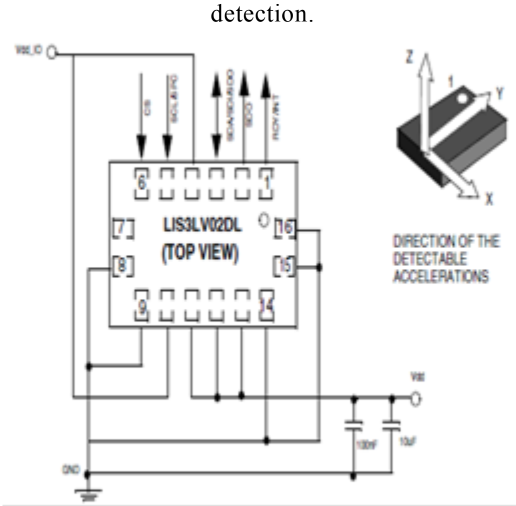

Fig 5.2: Sensor based in MEMS 3D level and acceleration [14].

As proximity wall and space detection we use four optical sensors symmetrically hosted in robot structure to give to control program information about tracking and obstacles detected for these sensors, they are directly coupled to microcontroller because they have fixed distance detection and obviously use discrete signals.

6 Sensors for Victim Identification

Essentially four victim detection is evaluated to use as references to detect initial human conditions, all of them are directly connect to embedded control system; mixed output signals are used to connect to embedded controller. Our sensors for human identification are:

- **CO2 sensorial gas:** It contributes to the perception and identification of the gas emitted by man, is not necessary its calibration, can detect from 0 to 100,000 ppm; it is necessary to be located closer to robot without human physical contact, around 20 centimeters; see figure 6.2 and table 3 for essential characteristics.
- **Absolute encoders:** Located one in each gear of the flank of the robot, it will show to the number of returns or revolutions to us that each gives to the band that crosses a certain position, their values will not lost your exact position. On the other hand, internal counter is implemented to register all complete rotations of every encoder.
- **IR thermal:** This sensor is essential to make measurements of health conditions over body; our typical range over 34 to 40 degrees is covered over this sensor of 0 to 50 degrees centigrade, with acceptable resolution. Additional DAQ circuit was designed to connect with embedded system, as default voltage output is 0 to 5volts, easy to convert to digital form, see the table 2.
- **Cameras:** We use cameras with optical accessory to cover 360 degrees of vision. Four megapixels is current resolution, this number cover our necessities for image caption; this camera is connected using Wi-Fi technology with high resolution to be processed with software vision algorithms based into LabView tools.

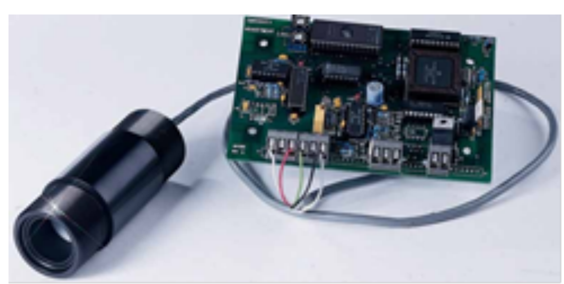

Fig.6.1 IR Sensor model OS65 used for body temperature measurement

Characteristic	Range
Sensing range	0..300
Type	OD 100 GA 300
Voltage Supply	18…32 DC
Current consumption	<40 mA
Current output	4…20 mA
Angle of vision	<10º
Reproduction	$\pm$1 ºC
Temperature coefficient	$\pm$0.1 of the measuring value
Response time	<100 ms
Measuring accuracy	$\pm$3 of the measuring value
Ambient temperature	-10…+60 ºC
Load resistance RL	<500 Ω
MV-class	A
Protection [EN 60529]	IP 67
Material	AISI 316 Ti
Connection	M12 connector

Table 2. IR temperature specifications.

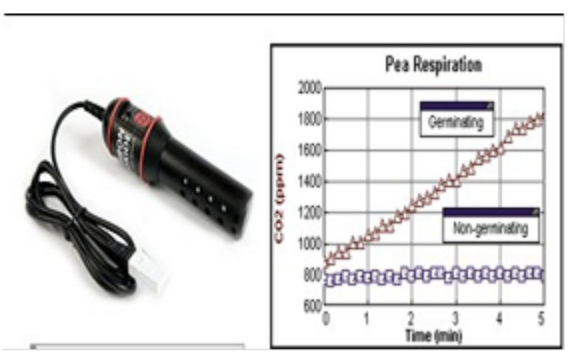

Fig 6.2: CO2 sensor and response.

Characteristic	Range
Output signal range:	Standard level
Input potential:	0-4 volts
Gas sampling mode:	5 volts ($\pm$ 0.25 V)
Normal operating temperature range:	25ºC ($\pm$ 5ºC)
Operating humanity range:	5-95% (non-condensing)
Storage temperature range:	-40 to 65ºC

Table 3. CO_2 sensor characteristic.

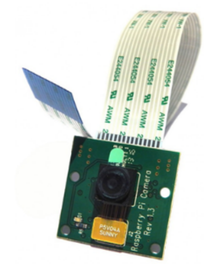

Fig 6.3 Cameras with high resolution

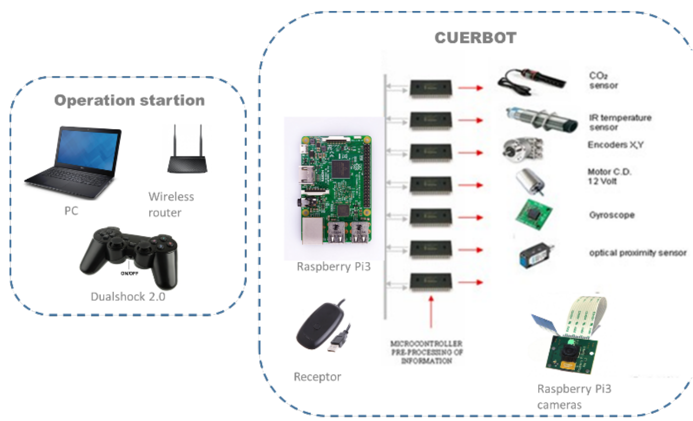

Fig 6.4 Full system integration of robot's controller, we depicted all sensors & actuators enveloped to complete functionally.

7 Robot Locomotion

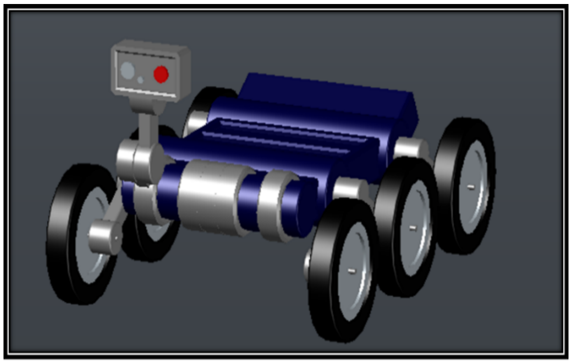

Fig 7 3D model of the base structure and the mobile camera

Our robot consists of a rigid body and two arms that support all the moving parts on the displacement structure, this model is based on a model of six wheels represented in figure 7.1

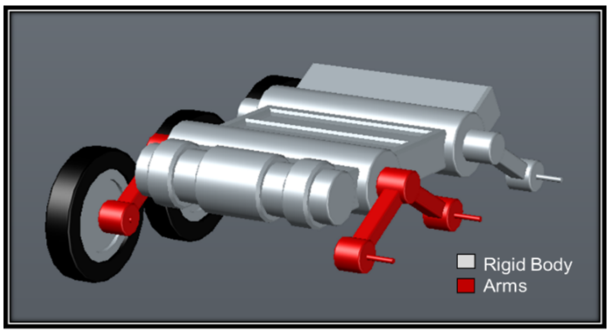

Fig 7.1 Representation of structure parts

For this model, we adapted some mechanisms to our needs, eliminating the mechanism of four bars of the previous model, achieving a simpler and functional design, our control programs and hardware is designed, to evaluate different strategies and necessities for rescue operations. In the Figure 7, show the body Robot, Total size of robot's world is 29x19x16 inches (Without considering the robotic camera).

This robot has a structure body and tows mechanism with wheels, could be mobiles based in two arms with an angle to carry out various tasks in irregular areas, see the figure 7.2

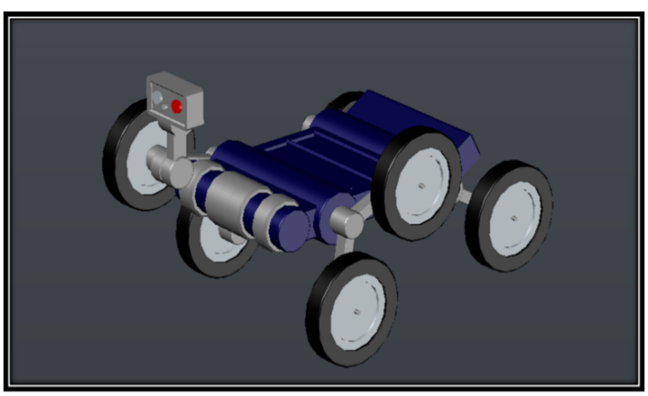

Fig 7.2 Mechanic movement of structural mobile robot

The arms were specially designed with a 120 degree angle to take advantage of the reaction force in wheels, raising the arms and allowing him to climb, see the figure 7.4

The main idea was taken of the six wheels strategy, this model is ideal for hard ways, only modify the internal structure of robot, with our sensors and actuators

Transmission

The robot can move through a transmission with 8 gears and four chains as shown in Figure 7.3, all have a ratio of 1: 1. Thus, when the engine turns one, all the gears give it.

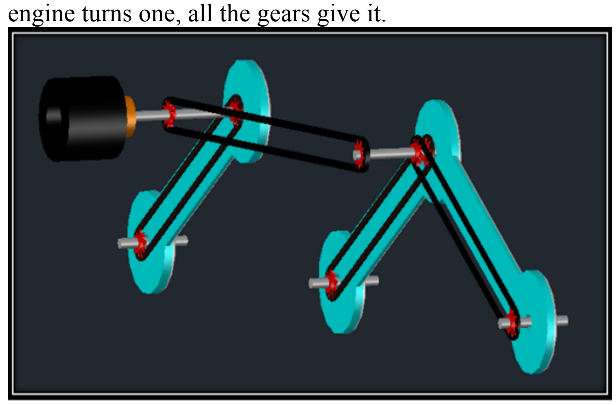

Fig 7.3 transmission system

Robot chains system used to move one side of symmetrical movement of all wheels by central wheel moved by electrical motor and measured by encoder.

The new model avoids exposing important parts of the transmission, protecting it from external elements that can open it, see the figure 7.4

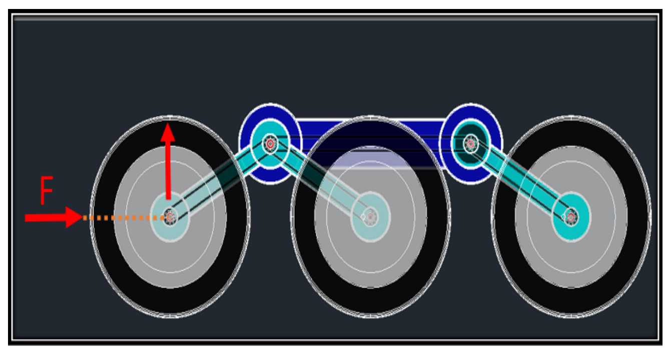

Fig 7.4 Operation of the arm and transmission mechanism

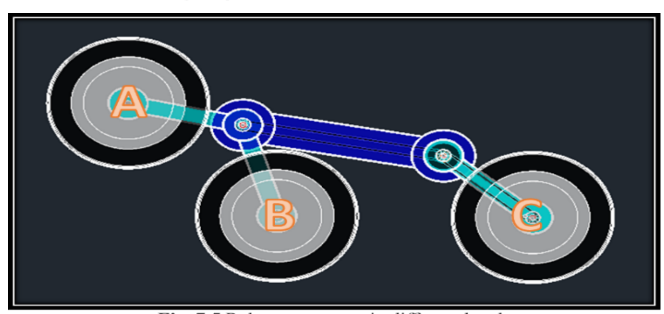

Fig. 7.5 Robot movement in different levels.

We can see the movement of the wheels, the wheel C is fixed while the wheel A and B can UP and Down respectively.
The robot counts on 2 motors DC (12V) used to send traction in the bands of the Tires. When we want Turn Right, the motor A run Forward and the motor B run backward but if we want turn left, the motor B run Forward and the motor A run backward. Forward movement motors will transmit his torque wings rims by means of a system of gears, see the figure 7.6

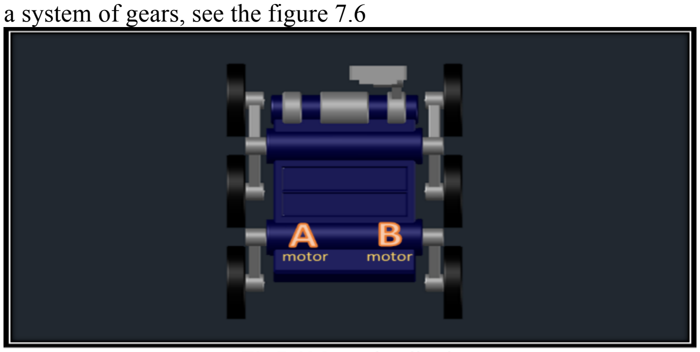

Fig 7.6 Motors localization

Sprockets and chains

The sprockets do not depend on friction to transmit power, which allows a minimum tension. In addition, by not sliding between the sprocket and the chain, there is synchronization between the axes. Among the technological aspects are the use of chains and sprockets instead of belts and pulleys for transmissions that offer more reliability. See Figure 7.7 for the sprockets and chains used

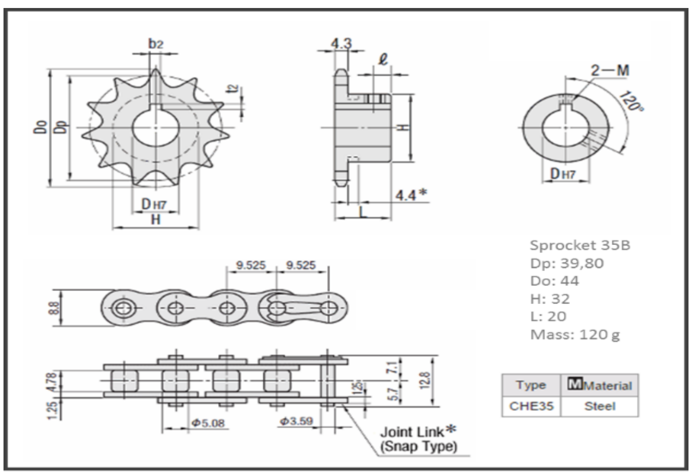

Fig 7.7 Sprockets and chains specification

Main body of Robot

The material changes are too much benefit the project in its design and speed of assembly, Profile No 5 was the material used in past version. The new material provides strength and stability to the robot land, now we will ensure that in the places where our robot acts (in any natural disaster zones), will remain stable and solid in any situation.

Rescue Robot Model and Views

We will show a series of front and side views of the robot assembly, and to appreciate better the changes in design (comparing with the past model). The figure below shows our Robot in the moving parts of the wheels, have internal mechanisms, protecting them from blows or shocks in the field.

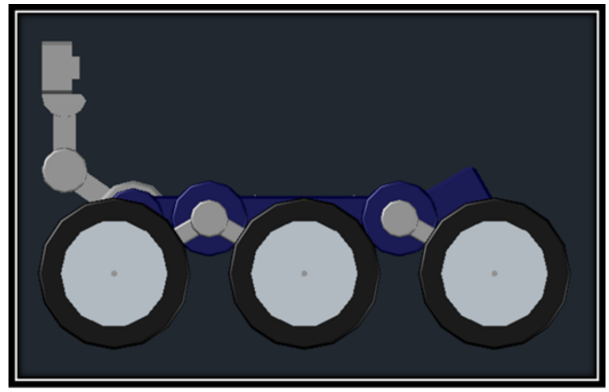

Fig 7.7 Side view of the robot

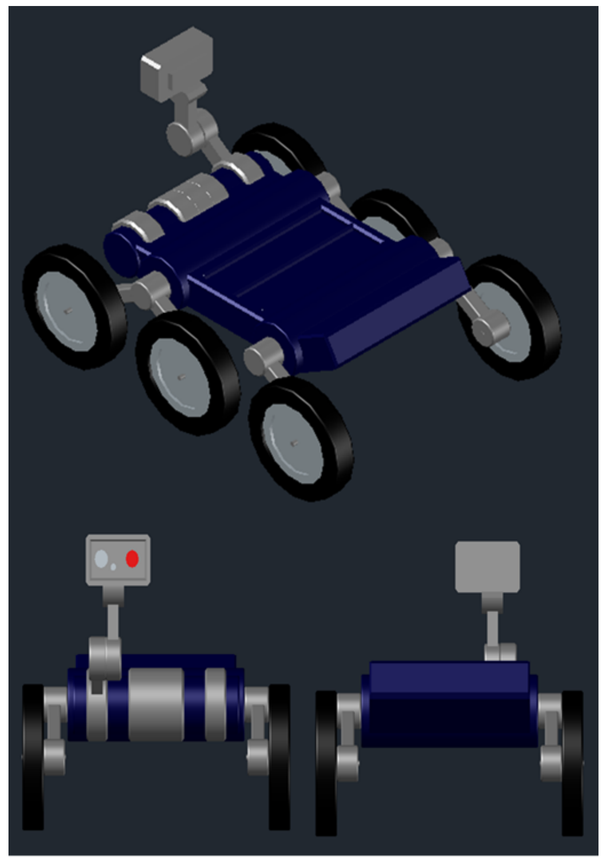

Fig 7.8 front side and backside view of the robot

8 Other Mechanisms

The robot counts with pan /tilt integrated camera, mounted over 6 DOF robot integrated into robot structure. This additional robot is take visual auxiliary support to find victims and take some light pieces to facilitate robot displacement and visual contact. This robot is previously designed by commercial manufacturer MECATRON-1, but is prepared to be mounted into CuerBot structure.

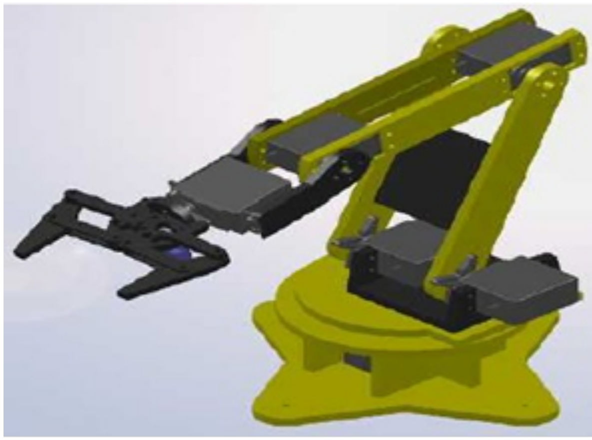

Fig. 8.1 Illustration of Robot used in CuerBot structure.

The robot also has a robot camera as shown in figure 7, this has 3 degrees of freedom that allow us to change the perspective of the vision from different points of view.

9 Team Training for Operation (Human Factors)

In order to operate the system of the Cuerbot in the movement aspect, it is necessary to know where one is its point of balance and its different movements, as well as its length, speed and the distance of turn in the direction.

In addition to its different functions as they are, the form to elevate the dynamic camera, and as is its length of elevation; the form to interpret the values of the different sensors, like: infrared, sensorial sensor of CO2, sensor of temperature, in addition to the proximity sensors that are located in the flanks, to the front and in the back part of the CuerBot. Essential robot drive teaching is developed either State Rescue Team or our Team.

10 Possibility for practical application to Real Disaster Site

We are currently working with FONLIN program and supported by Red Temática Robótica y Mecatrónica CONACYT with special sponsoring of Robotics Mexican Federation FMR that consider new projects with new technology and developing, the main goal is to give us tools to put this robot into market, and another thing is that we are working together with Emergency State Services to share training and provides of one robot for community service. Remember our objective is to try to solve a local problem in disaster events

11 System Cost

System cost total	
Concept (model)	**Cost per piece**
Absolute Encoder	$180 USD
Microcontroller	$3 USD
Gyroscope	$600 USD
Pan and Tilt Camera	$150 USD
Wireless camera	$80 USD
Netbook	$350 USD
IR Temperature Sensor	$1250 USD
CO_2 Sensor	$317 USD
CD Motors for displacement	$25 USD c/u
Batteries	$54 USD c/u
Chains	$20 USD
Metal structure to form body	$250 USD
Industrial PVC for mechanical support	$95 USD
Sprockets	$60 USD
Bearings	$15 USD
Lamps	$15 USD
IC circuits (average)	$10 USD
Raspberry PI3	$20 USD
Access point	$95 USD
Proximity Sensors	$60 USD
USB Memory 8Gb	$2 USD
Accessories	$1257 USD
Robot 6 DOF	$1,200 USD
TOTAL COST APROX	*$6,357 USD*

Table No. 4 Cost for robot development, accessories aren't considerate.

12 Lessons Learned

This is an incredible experience to develop a lightweight and transportable rescue robot, because for a real application you need a robot with these characteristics, in the last RoboCup 2016 we learned that we must consider all the phenomena involved for the correct operation of the robot, We learned that devices must be designed to adapt to any risk situation because sometimes we do not know what we are facing. Another important thing is our improved structure, mobile mechanisms and the application of artificial intelligence based on integrated technologies, all experiences are good goals for new knowledge for this research group and give us the opportunity to support our undergraduate programs and related mastery (human resources and specific projects related to companies). On the other hand, other experiences were received on our internal support and reengineering was applied. The most important value are our undergraduate and graduate students, this project gives them the opportunity to develop knowledge in specific areas of robotics; this project has generated 7 degrees and master's degree. We will add more information about our experiences when we are participating in this Robocop 2017.

And we will continue to be better, because the competition with other teams from different countries helped us to grow in our knowledge and expand our world.

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