The Kunka Aña Mobile Robot

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***Abstract*— The development and implementation of a mobile robot is presented. The robot uses Fuzzy Logic to navigate in varying environments and his implementation has been carried out using inexpensive components and tools. The achieved performance encourages that this work will serve as a basis platform for the research of other paradigms in Control and Artificial Intelligence.**

Keywords— **Mobile robots; reactive control; fuzzy logic; odometry; M•CORE; Case Based Reasoning.**

I. Introduction

Mobile robotics is still emerging and new applications are being developed in diverse areas including the agro, industry, home, disaster mobile manipulators, and space exploration among others. Robot mobility is inherently related to the knowledge of the entity has of the environment; in this sense, two main approaches are used for the robot navigation. The first one contemplates the acquisition of detailed knowledge of the navigation environment, based in this information a navigational plan is elaborated and executed. On the other hand, in the second approach, the mobile robot has little information and his navigation is based only in the reaction to data acquired in real time from the environment in order to achieve his goal. This second approach is the development base for the mobile robot presented in this article.

The navigational control of mobile robots uses intensive demand computing algorithms, and some algorithms cannot be used in a real time control approach [1]. Dealing with the real world and his uncertainties, like moving surrounding bodies, needs the use of basic intelligent control strategies for the mobile robot navigation [2]. Relative position of the robot to a known mark and the detection of the surrounding bodies are essential for navigation toward his goal position. Currently the navigational control is supported by techniques based on artificial intelligence [3] [4] [5].

This article presents the implementation and results of the mobile robot denominated "*Kunka Aña*" (KA), which in Aymará language [6] means "*the one that walks proudly*" and use the Fuzzy Logic [7] as its basic control strategy [8][9][10]. The remainder of this paper is structured as follow. Section II gives the fundamental background of the mobile robot. Section III presents the *Kunka Aña* system organization and implementation. Section IV shows some experimental results. Section V concludes this paper and establishes the future work.

II. Background

The deductive calculus known as "Dead Reckoning" has been derived from the marine navigation term "deduced reckoning"[1]. This calculus establishes the mathematical procedure for computing the present sailing ship location, taking into account a known starting position and also the course and speed of the body. As the sailing ships, a great majority of the mobile robotic systems works today with deductive calculation for the knowledge of its position.

A. Odometry

A widely used technique for deductive calculus is the odometry. A typical odometry system consists of a data acquisition system added to the mobile robot's wheels, and a group of equations for the calculus of its position.

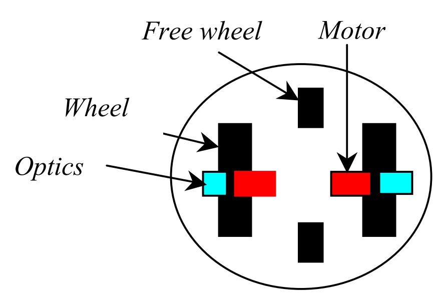

Figure 1. Inferior view of a mobile robot platform

Optical encoders give us a pulse of the moved angle by each one of the motorized wheels, acquiring indirectly in this way the robot displacement. The distance moved by the robot in calculated by means of:

$$c_m = \pi D_n / n C_e \qquad (1)$$

where C_m is the conversion factor that translates the pulses from the encoder to lineal displacement; D_n is the nominal diameter of the wheel in millimeters, C_e is the resolution of the codifier and n is the reduction factor between the motor and gear of the wheel axle. From (1), the traveled distance is calculated by taking into account the relative movement of the left and right wheels, ΔU_{Li} and ΔU_{Ri} respectively, then:

$$\Delta U_{L/R,i} = c_m N_{L/R,i} \qquad (2)$$

where N represents the increment pulse with a I sample rate [1]. The incremental lineal displacement ΔU_i of the robot's center is given by:

$$\Delta U_i = (\Delta U_R - \Delta U_L)/2 \qquad (3)$$

and the orientation is computed with:

$$\Delta \theta_i = (\Delta U_R - \Delta U_L)/b \qquad (4)$$

where b is the diameter of the mobile base and ideally is the distance between the two points of contact of the wheels with the floor.

The new relative orientation of the robot θ_i can be calculated from:

$$\theta_i = \theta_{i-1} + \Delta \theta_i \qquad (5)$$

and the new relative position of the robot's center is given by:

$$x_i = x_{i-1} + \Delta U_i \cos\theta_i \qquad (6)$$

$$y_i = y_{i-1} + \Delta U_i \sin\theta_i \qquad (7)$$

where x_i and y_i are the relative coordinates, accumulate the center C of the robot at instant i [1].

B. Data Acquisition and Final Control System

Currently technology enables the use of a single microcontroller for the implementation of complex embedded systems like the necessary one for the mobile robot navigational control. The following figure schematizes the regular functionalities inside a single die like the M•CORE [11] [12] embedded in the mobile platform.

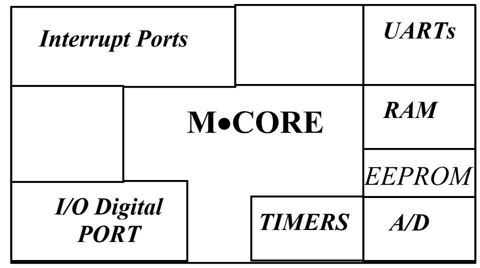

Figure 2 Microcontroller architecture.

III. KUNKA AÑA ORGANIZATION AND IMPLEMENTATION

The architecture of the Kunka Aña system consists of two main components depicted in figure 4: 1) Personal Computer (PC) which holds the fuzzy logic control and the real time depicting system. 2) Mobile robot platform with a data acquisition and control system implemented with a microprocessor.

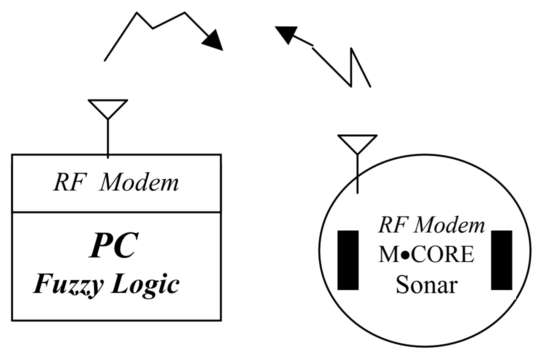

Figure 4. KA architecture System

The acquired data is packed in a frame by the microprocessor and is sent to the personal computer through a wireless communication system. The received data feeds the fuzzy logic inference machine, which returns control actions to the mobile robot for its navigation.

The ISTEC[1] laboratory was used to prove the robot movements; in this displacement environment, the initial position of KA robot is known as depicted in the captured image of the developed system (figure 5), the circle represents the mobile robot and the label "META" inside the box corresponds to the final position into the laboratory. This developed tool actualizes in real time the position of the robot.

[1] R&D laboratory at Universidad Privada Boliviana (UPB) [13]

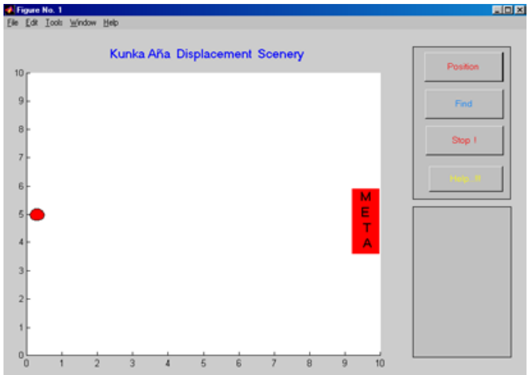

Figure 5 KA displacement scenery

KA Odometry System. The implemented odometry system uses an optic encoder with 48 measurement strips, attached to the wheels' axes as can be seen in the following figure:

Figure 6. Encoder in Wheels

Reflective sensor [14] was used to measure the angular position of the wheels. This simple system fulfills the sensing requirements for this *Kunka Aña* mobile robot implementation.

M•CORE - The controller. The M•CORE, a 32 bit RISC processor from MOTOROLA is used for data-acquisition, data communication and control as depicted in figure 7.

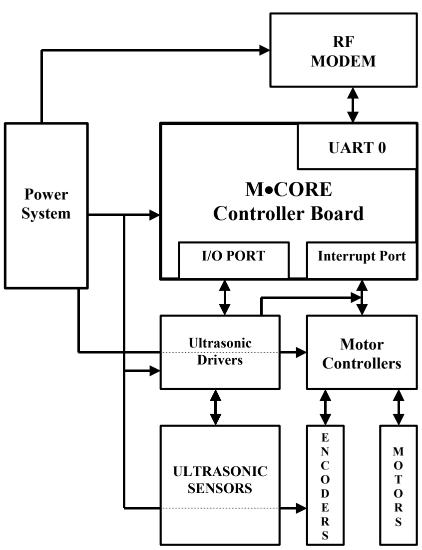

Figure 7. Embedded controller

The detection systems of surrounding bodies was carried out with the use of a Polaroid sonar [15], which measures the distance of near bodies through the determination of the time of flight [1] of the sonar wave. The microprocessor generates signals waking up the sonar, which emits a sonic wave, initializing at the same instant a timer. The reflected wave generates an interrupt signal into the processor, the service interrupt reads the actual value of the initialized timer and calculates the distance of the reflecting body. Three interrupts were used for measuring the distance of the surrounding bodies to the robot, and other two for the internal counters updating, which accumulates the number of detected pulses by the enclosed sensors in the wheels. Another important functionalities developed by microprocessor includes the data frame construction for the wireless communication with the PC, the transmission of the acquired data, the reception of the processed data and the generation of the PWM signal generation for the control the robot's motors,

Fuzzy Controller. The fuzzy controller was implemented with the Matlab toolbox [16] and comprises of the main program in charge of the communication and pack and unpacks data in the personal computer system. When data is received, the main program feeds the fuzzy machine with four variables of entrance and this controller produces two outcomes for the control of the movements of the robot. Figure 8 depicts the general fuzzy control organization.

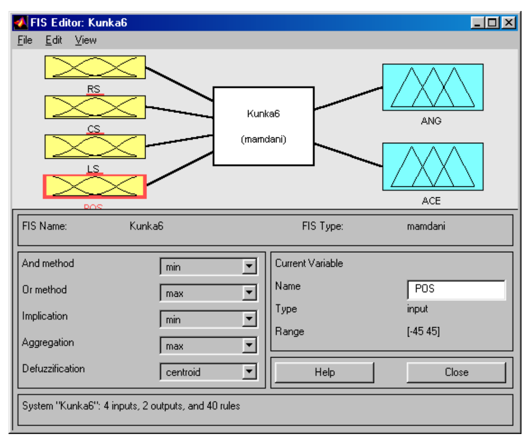

Figure 8. Fuzzy Logic Machine

The linguistic variables of entrance were easily coded, thanks to the graphic editor that Matlab [16] possesses. The following figure presents the fuzzy sets used for the fuzzification process of the linguistic variable Right

Sensor (RS). [2]

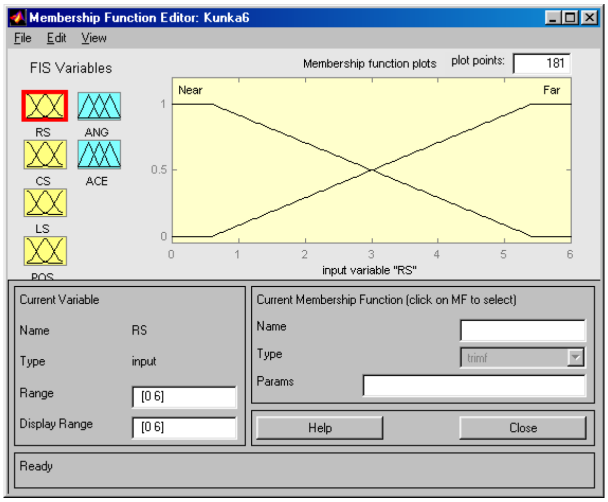

Figure 9. Right Sensor Fuzzy Sets

The five diffuse sets were used for modeling the Position, given in this way a greater flexibility in the decision-making

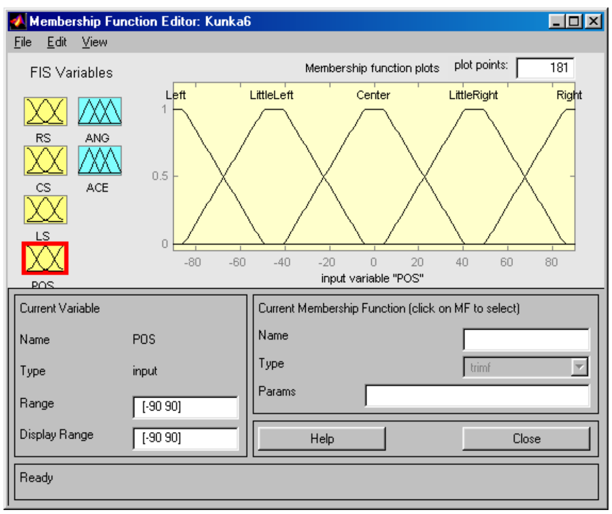

Figure 10. Position Fuzzy Sets

The outcome of the fuzzification process it is evaluated into a group of Fuzzy Logic Control Rules. Different sets of heuristic rules were tested for the controller tuning. Table I presents the set of rules used in the fuzzy scheme; and the following rule meaning, exemplifies the usual interpretation used for these heuristics rules

IF the result of the measure of the Right Senor (RS) is Far and the Central Sensor (CS) reports a Far body and the Left Sensor (LS) as well, and the odometry determines that the position goal (POS) is in the Left direction; **THEN** the mobile robot should go to the Left (ANG) and with an Acceleration (ACE). This rule can be also be described by the following representation.

IF (RS == Far ∧ CS == Far ∧ LS == Far ∧ POS == L)
THEN (ANG ← L ∧ ACE ←A)

Table I

Fuzzy Logic Control Rules

IF				Then	
RS	**CS**	**LS**	**POS**	**ANG**	**ACE**
Far	Far	Far	L	L	A
Far	Far	Far	LL	LL	A
Far	Far	Far	C	C	A
Far	Far	Far	LR	LR	A
Far	Far	Far	R	R	A
Far	Far	Near	L	PD	C
Far	Far	Near	LL	C	C
Far	Far	Near	C	C	C
Far	Far	Near	LR	LR	A
Far	Far	Near	R	R	A
Near	Far	Far	L	L	A
Near	Far	Far	LL	LL	A
Near	Far	Far	C	C	C
Near	Far	Far	LR	C	C
Near	Far	Far	R	LL	C
Far	Near	Far	L	L	A
Far	Near	Far	LL	LL	A
Far	Near	Far	C	LR	C
Far	Near	Far	LR	LR	A
Far	Near	Far	R	R	A
Near	Near	Near	L	L	B
Near	Near	Near	LL	LL	B
Near	Near	Near	C	C	B
Near	Near	Near	LR	LR	B
Near	Near	Near	R	R	B
Near	Near	Far	L	L	A
Near	Near	Far	LL	LL	A
Near	Near	Far	C	LL	A
Near	Near	Far	LR	LL	C
Near	Near	Far	R	LL	C
Far	Near	Near	L	LR	C
Far	Near	Near	LL	LR	C
Far	Near	Near	C	LR	A
Far	Near	Near	LR	LR	A
Far	Near	Near	R	R	A
Near	Far	Near	L	C	C
Near	Far	Near	LL	C	C
Near	Far	Near	C	C	C
Near	Far	Near	LR	C	C
Near	Far	Near	R	C	C

The rule evaluation outcomes feed the output variables, obtaining in this way the final control variables of the entire system, which are ready to be encapsulated and transmitted to the mobile platform in order to correct the path and acceleration on the Kunka Aña. The fuzzy sets of the variable Angle (ANG) for the computing of the final control signal are presented in figure 11.

[2] The central and left sensor has similar codes, for these reason they are not presented

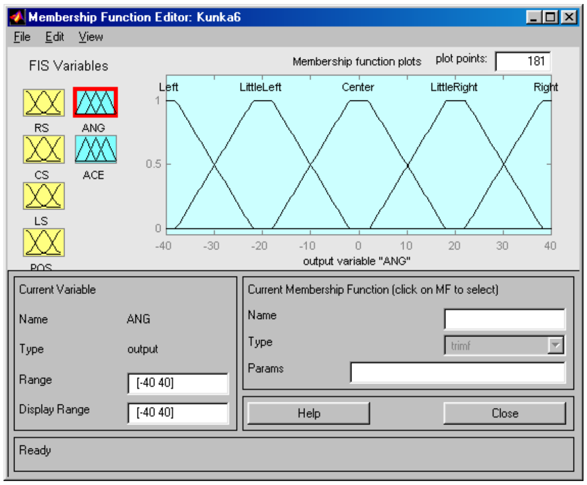

Figure 11 Angle Fuzzy Sets

Again, the increased number of fuzzy sets gives the necessary flexibility for the achieving of a more accurate result.

Finally the Acceleration Variable (figure 12) is modeled with three fuzzy sets and the outcome provided is essential for the control of the mobile robot enabling to diminish the velocity when surrounding bodies are present or accelerate when no bodies are near.

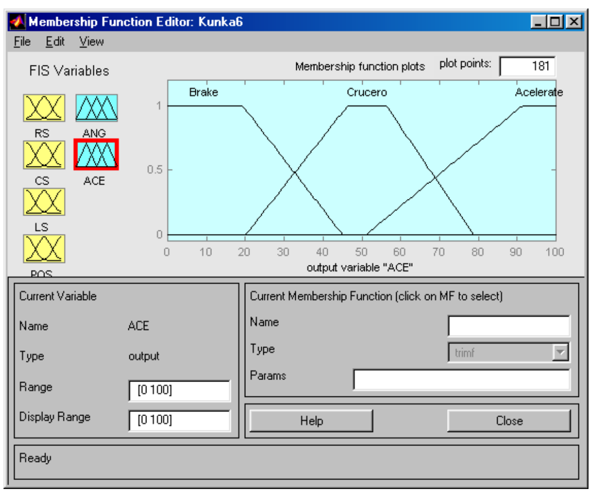

Figure 12 Acceleration Fuzzy Sets

IV. Experimental Results

The following figure presents the robot's performance in its navigation scenario. Can be seen three different experiments; the robot was tested from three starting points, one of them was in front of the goal (META), the second starting point was at the right of the goal and the third point was on the left of the goal.

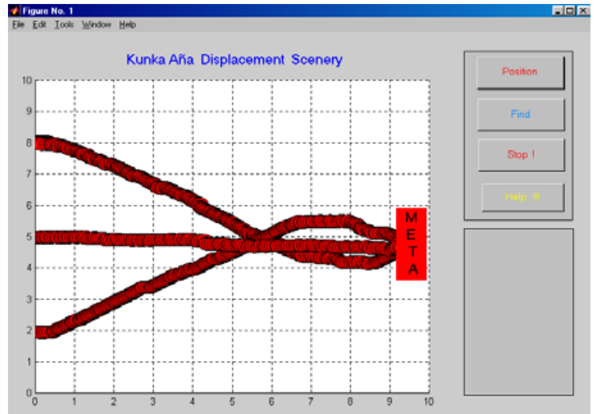

Figure 13. Kunka Aña Navigation

The previous figure depicts the convergence of the KA robot towards his goal, starting from different initial locations. Furthermore, the robot was also tested in presence of obstacles, one of these experiments is presented in figure 14 in which the robot evades the obstacle and returns to his path, reaching finally his goal.

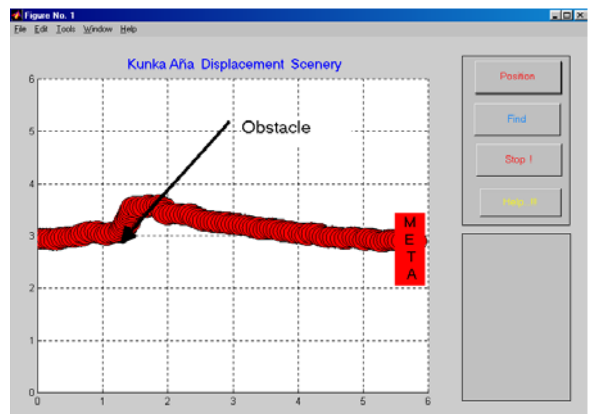

Figure 14. KA path in presence of an obstacle.

V. Conclusions and Future Work

The development of the Kunka Aña mobile robot introduced us into the mobile-robot world, and from the achieved results, it is clear that the fuzzy logic proves to be a viable control alternative of mobile robots in unfamiliar scenarios.

The future works includes the increment of the number of sonars, achieving in this way an improvement about the knowledge of the surrounding environment. Also an additional floor should be added to the three-floor distribution depicted in figure 15 (MODEM occupies the Third floor) , in order to separate the microprocessor and the noisy sonar system. Additionally, an improvement of the odometry system can be made with the inclusion of more measure strips diminishing in this way the error introduced in the measurement of the mobile robot movement.

Figure 15 Kunka Aña's Mobile Platform

Future seems promissory at the ISTEC-UPB laboratory; the study of hybrid systems relating Fuzzy Logic, Genetic Algorithms and the Neural Networks, as those presented in [3] [17] will be a fertile field into our research activities. Also the use of more sophisticated structures [18], relating Case Base Reasoning and Fuzzy Logic in a two level organization of reasoning like the one depicted in the figure 16 will be studied.

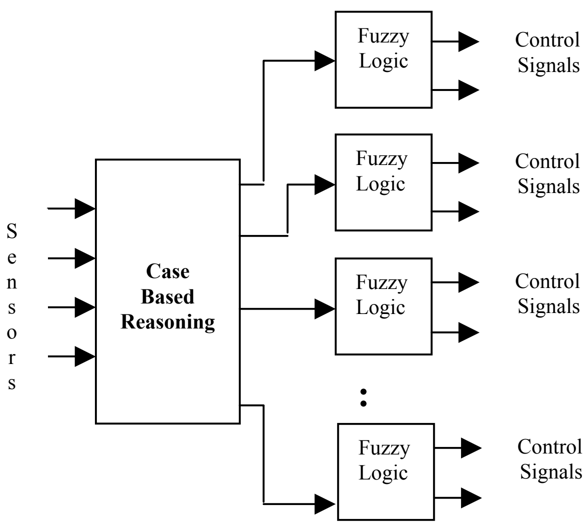

Figure 16 Hybrid control

VI. ACKNOWLEDGEMENTS

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