# Emmy – Paraconsistent Autonomous Robot

# EMMY – PARACONSISTENT AUTONOMOUS ROBOT

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Abstract. This paper presents the development of the autonomous mobile robot Emmy based on the Annotated Paraconsistent Evidential Logic, Eτ. The Annotated Paraconsistent Logic deals with the imprecision and inconsistencies inherent to information through the Degrees of Favorable and Contrary Evidence, and through the Degrees of Certainty and Uncertainty. A Paraconsistent controller called Para-Control is used to deal with the logical signals in the context of Evidential Logic. This controller compares logical values and determines the domains of a state lattice corresponding to the output value. The Para-Control comprises both analogical and digital systems and maybe externally adjusted by applying positive and negative voltages. The autonomous mobile robot Emmy can move itself from a starting point to an end point, in a non-structured environment, both predetermined. A planning system gives the support to the robot's navigation system.
Keywords: Automation, Paraconsistent Logic, Robotics, Navigation System, Logical Controller.

## 1. INTRODUCTION

The Annotated Paraconsistent Systems have inspired applications in several fields. Particularly in Robotics, some autonomous mobile robots have been built to manipulate imprecise, inconsistent and paracomplete data. One of the robot series, called Emmy1), based on na Annotated particular system, namely, the Annotated Paraconsistent Evidential Logic Et, Abe (1992), began with the first prototype studied in Da Silva Filho (1999), Abe & Da Silva Filho (2003). Subsequently, some improvements have been accomplished in its second prototype, Emmy II Torres (2004), and this paper will be a sketch of the third prototype, Emmy III, discussing its navigation system.

## 2. ANNOTATED PARACONSISTENT EVIDENTIAL LOGIC, Et

The atomic formulas of $E\tau$ are of the $p(\mu, \lambda)$ type where $(\mu, \lambda) \in [0, 1]^2$, [0, 1] is the real unitary interval, and p denotes a propositional variable. Therefore, $p(\mu, \lambda)$ can be intuitively read: "It is assumed that p's Favorable Evidence is $\mu$ and Contrary Evidence is $\lambda$". Thus, p(1, 0) can be read as a true proposition, p(0, 1) as false, p(1, 1) as inconsistent, p(0, 0) as paracomplete, and p(0.5, 0.5) as an indefinite proposition.

The values of the degrees are introduced: Uncertainty Degree: $UD(\mu,\lambda)=\mu + \lambda - 1$; Certainty Degree: $CD(\mu,\lambda)=\mu - \lambda$ $(0 \leq \mu, \lambda \leq 1)$. An order relation is defined on $[0, 1]^2$: $(\mu_1, \lambda_1) \leq (\mu_2, \lambda_2) \Leftrightarrow \mu_1 \leq \mu_2$ and $\lambda_1 \leq \lambda_2$, constituting a lattice that will be symbolized by $\tau$. The Uncertainty and Certainty Degrees lead to the following 12 output states: extreme state and non-extreme states, shown in Table 1.

Table 1. Extreme and Non-extreme states.

| Extreme States | Symbol | Non-extreme states | Symbol |
|---|---|---|---|
| True | T | Quasi-true tending to Inconsistent | QT→I |
| False | F | Quasi-true tending to Paracomplete | QT→⊥ |
| Inconsistent | I | Quasi-false tending to Inconsistent | QF→I |
| Paracomplete | ⊥ | Quasi-false tending to Paracomplete | QF→⊥ |
| | | Quasi-inconsistent tending to True | QI→T |
| | | Quasi-inconsistent tending to False | QI→F |
| | | Quasi-paracomplete tending to True | Q⊥→T |
| | | Quasi-paracomplete tending to False | Q⊥→F |

All states are represented in the next Fig. 1.

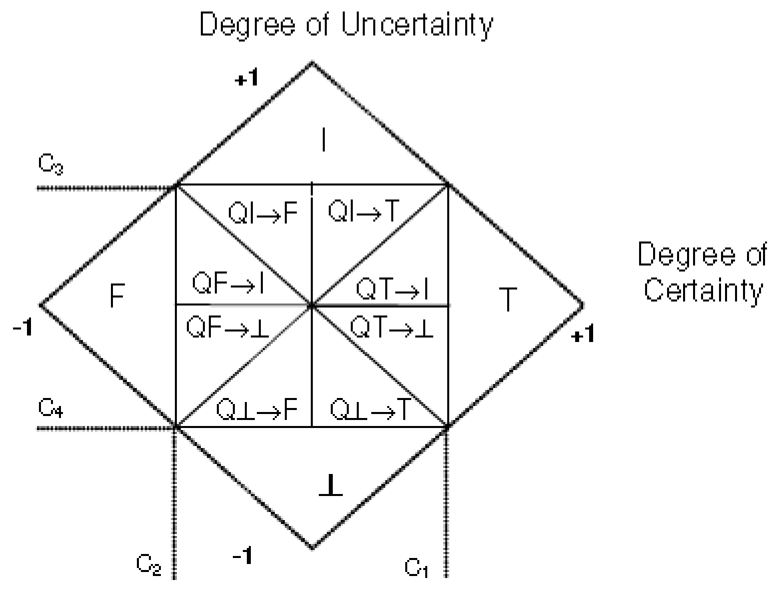


Figure 1: Logical states: extreme and non-extreme states.

Some additional control values are:

- Vmauc = maximum value of uncertainty control = C3
- Vmacc = maximum value of certainty control = C1
- Vmiuc = minimum value of uncertainty control = C4
- Vmicc = minimum value of certainty control = C2

## 3. PARA-CONTROL – LOGICAL CONTROLLER

The Para-Control is the electronic materialization of the Para-Analyzer Algorithm Da Silva Filho (1999), which is basically an electronic circuit to treat logical signals in a context of Et. Such circuit compares logical values and determines domains of a state lattice corresponding to the output value. Favorable Evidence and Contrary Evidence Degrees are represented by voltage. Certainty and Uncertainty Degrees are determined by the analysis of operational amplifiers. The Para-Control comprises both analogical and digital systems, and it can be adjusted externally by applying positive and negative voltages. The Para-Control was tested in real-life experiments with an autonomous mobile robot Emmy. Emmy's Favorable/Contrary Evidences coincide with the values of ultrasonic sensors. Distances are represented by continuous voltage values. 4. THE AUTONOMOUS MOBILE ROBOT EMMY The Para-Control controller was applied in this series of autonomous mobile robots. The autonomous mobile robot Emmy was presented in a few previous work (DA SILVA FILHO, 1999). Emmy consists of a round mobile aluminum platform of 30cm in diameter and 60cm high. While moving in a non-structured environment, Emmy gets information about the presence and/or absence of obstacles using the sonar system called Parasonic Abe & Da Silva Filho (2003). The Parasonic is able to detect obstacles in an autonomous mobile robot's pathway by transforming the distances to the obstacle into electrical signals of continuous voltage ranging from 0 to 5 volts. The Parasonic is basically composed of two POLAROID 6500 type ultrasonic sensors controlled by an 8051 microcontroller, shown in Fig 2. The 8051 is programmed to carry out synchronization between the measurements of the two sensors and the transformation of the distance into electrical voltage. Emmy II is an improvement of the first robot Emmy and it is described as follows.

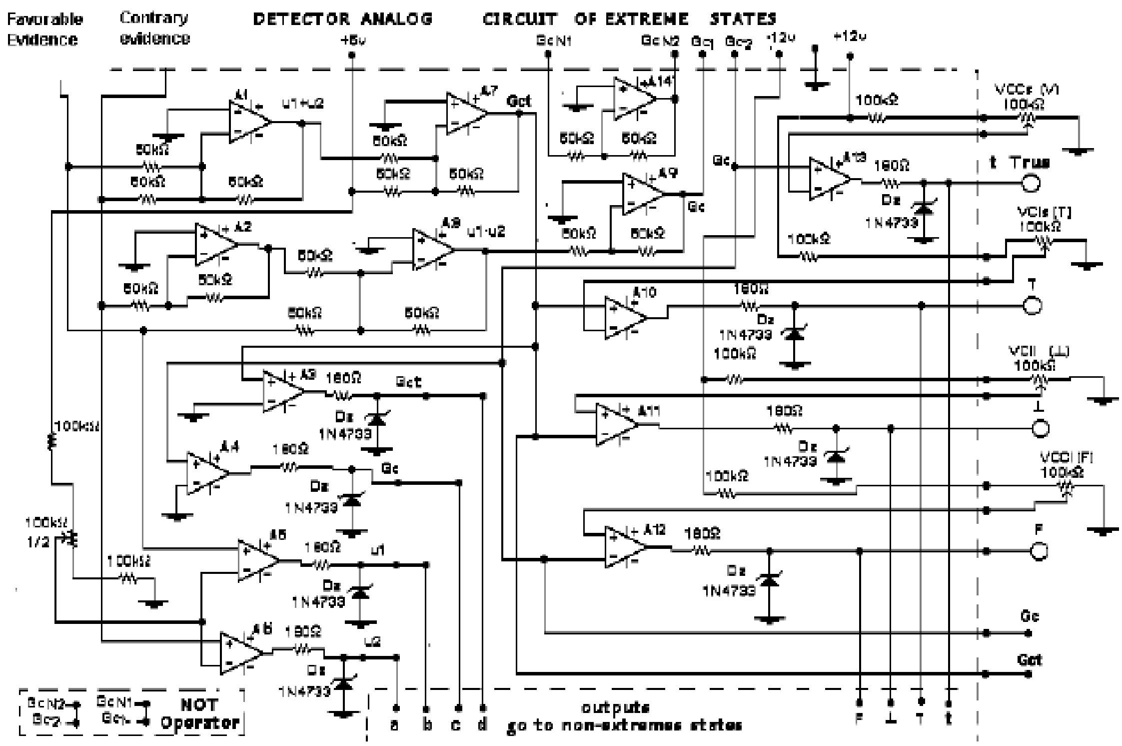


Figure 2: Para-Control circuit.

## 5. ROBOT EMMY II

The round shaped platform used to assemble Emmy II is approximately 23 cm high and 25 cm in diameter. The main components of Emmy II are a microcontroller of 8051 family, two ultrasonic sensors, and two DC motors. Figure 3 shows Emmy II´s mechanical structure. The signals from the sensors are used to determine the Favorable Evidence Degree μ and the Contrary Evidence Degree l regarding the proposition "The robot's front pathway is free". Then, the Para-Control, recorded in the internal memory of the microcontroller, uses Evidence Degrees in order to determine the robot's movements. Also, the microcontroller is responsible for supplying power to the DC motors. Figure 4 shows the decision state lattice that Emmy II uses to determine what movements to perform. Table 2 shows the actions related to each possible logic state. Each of the robot's movement lasts approximately 0.4 seconds.

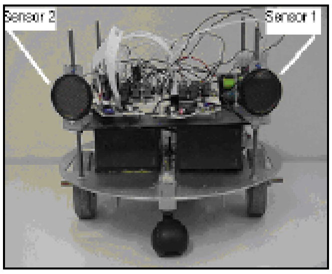


Figure 3. Emmy II.

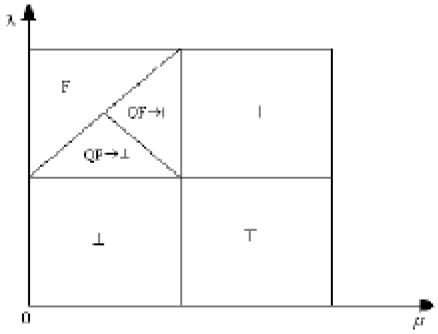


Figure 4. Emmy II's logical output lattice.

Table 2. Logical states and action.

| Symbol | State | Action |
|---|---|---|
| T | True | Robot goes ahead |
| F | False | Robot goes back |
| ⊥ | Paracomplete | Robot turns right |
| I | Inconsistent | Robot turns left |
| QF→⊥ | Quasi-false tending to paracomplete | Robot turns right |
| QF→I | Quasi-false tending to inconsistent | Robot turns left |

The source circuitry aim is to supply 5, 12 and 16.8 Volts DC to Emmy II's other circuitries. Figure 5 shows this circuitry.

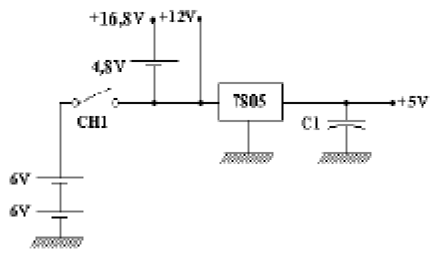


Figure 5 – Emmy II source circuitry scheme.

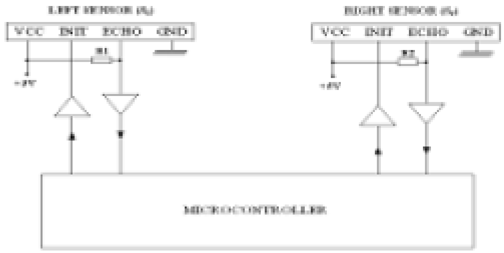


Figure 6 – Emmy II sensor circuitry scheme.

The "Polaroid 6500 series Sonar Ranging Module", Datasheet of Polaroid (1996) was used in Emmy II. This device has three inputs (Vcc, Gnd and Init) and one output (Echo). When INIT is raised by the microcontroller, the sonar ranging module transmits 16 pulses at 49.4 kilohertz. After receiving the echo pulses, which cause the ECHO output high, the sonar ranging module sends ECHO signal to the microcontroller. Then, with the time interval between INIT sending and ECHO receiving, the microcontroller may determine the distance between the robot and the obstacle. Figure 6 shows Emmy II sensor circuitry scheme. The microcontroller 89C52 from 8051 family is responsible for controlling Emmy II. Two DC motors supplied by 12 Volts DC are responsible for the robot's movements. The Para- Control, through the microcontroller, determines which DC motor must be supplied and which direction it must spin around. Basically, power field effect transistors – MOSFETs compose the power interface circuitry. Figure 7 shows the main microcontroller connections.

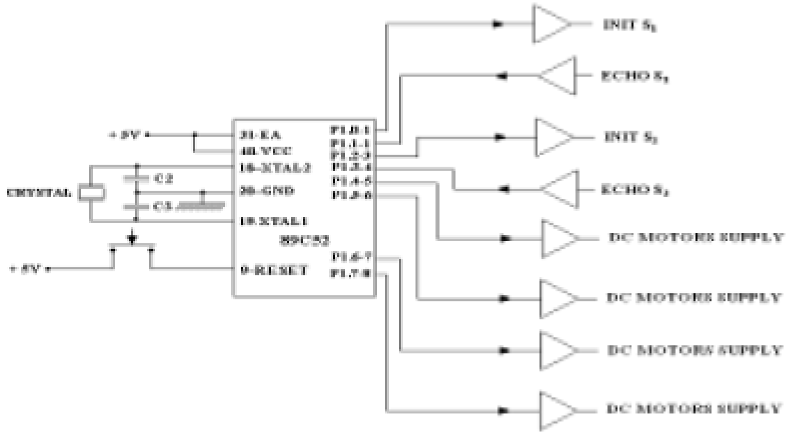


Figure 7 – Emmy II main microcontroller connections

Figure 8 shows Emmy II power interface circuitry.

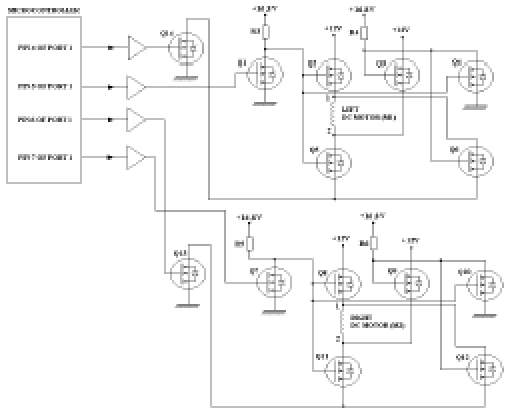

Figure 8 – Emmy II power interface circuitry.

When the microcontroller 89C52 I/O port 1 pin 0 is raised, the sonar ranging module 1 transmits sonar pulses. The sonar ranging module 1 ECHO is connected to microcontroller 89C52 I/O port 1 pin 1. So, when this pin is raised, it means that sonar echo pulses have just returned. Hence, it is possible to determine the distance between sonar ranging module 1 and the obstacle in front of it. The robot is able to measure distances between 0 cm and 126 cm. Therefore, a distance of 0 cm means that the Favorable Evidence Degree (μ) in the proposition "The robot's front pathway is free" is 0. And a distance of 126 cm means that the Favorable Evidence Degree (μ) in the proposition is 1. In the same way as described for the Favorable Evidence Degrees determination, the Contrary Evidence Degrees (l) in the proposition "The robot´s front pathway free" is determined. But now, a distance of 0 cm between the sonar ranging module 2 and the obstacle in front of it means that the Contrary Evidence Degrees (l) in the proposition is 1. And a distance of 126 cm between the sonar ranging module 2 and the obstacle in front of it means that the Contrary Evidence Degrees (l)in the proposition is 0.

## 6. AUTONOMOUS MOBILE ROBOT EMMY III

The goal of the autonomous mobile robot Emmy III is to be able to move from a starting point to an end point, both predetermined, in a non-structured environment. First, the robot must be able to move from a point to another in an environment without any obstacle. This environment is divided into cells Elfes (1989) and a planning system gives the sequence of cells the robot must follow to reach the end cell. This idea was applied in Desirato (2006) and Maran (2006). The second step evolves from the first step; the robot must be able to avoid cells that are supposed to have some obstacle in. A sensor system will detect the cells that must be avoided. This sensor system will use Annotated Paraconsistent Logic to deal with information captured by the sensors. Emmy III structure is:

### 6.1 Sensing system

The robot's environment is composed of a set of cells. On the other hand, the sensing system has to determine the environment with enough precision; however the information captured by the sensors always has an inherent imprecision, which leads to an uncertainty regarding the position the robot is actually in. In order to manipulate this kind of information, the sensing system is based on the Annotated Paraconsistent Evidential Logic Et, which captures the information generated by the sensors using Favorable and Contrary Evidences Degrees as seen in the logical controller Para-Control.

### 6.2 Planning system

The objective is to build a planning system able to determine a path linking an initial point to na end point in a non-structured environment with some obstacles. For this, the environment is divided into cells and the planning system gives the sequence of cells that the robot starting from the initial point reaches successfully the end cell. The first step is to build a planning system for na environment without any obstacle, that is, an environment with all cells free. In the second step the sensing system informs the planning system what cells have objects in.

### 6.3 Physical construction

Emmy III's mechanical part must perform the schedule determined by the planning system. It must know the cell it is in; therefore, a monitoring position is part of this construction. In the process, for each cell that the robot reaches, the possible error of position should be considered. Items 7 and 8 describe two of Emmy III prototypes where a robot is able to follow a path determined by a planning system in an environment without any obstacle.

## 7. FIRST PROTOTYPE OF THE AUTONOMOUS MOBILE ROBOT EMMY III

The first prototype is composed of a planning system and a mechanical construction. The planning system considers an environment divided into cells. This first version considers all cells free. Then it asks for the initial point and the aimed point./target. After that, a sequence of movements is given/shown on a screen. Also a sequence of pulses is sent to the step motors that are responsible for moving the robot's physical platform. So, the robot moves from the initial point to the target point. The physical construction of Emmy III's first prototype is basically composed of a round platform of approximately 286 mm in diameter and two step motors. Figure 9 shows Emmy III first prototype. The planning system is recorded in a laptop. And the communication between the laptop and the physical construction is done through the parallel port. A potency driver is responsible for getting the pulses from the laptop and sending them to the step motors.

Figure 9 – The first prototype of Emmy III robot.

## 8. SECOND PROTOTYPE OF THE AUTONOMOUS MOBILE ROBOT EMMY III

Similar to the first prototype, Emmy III second prototype is basically composed of a planning system and a mechanical structure. The planning system is recorded in a personal computer and the communication between the personal computer and the mechanical construction is done through a USB port. The planning system considers the environment around the robot divided into cells. So, it is necessary to inform the planning system which cell the robot is in, and the target cell. The answer from the planning system is a sequence of cells that the robot must follow to go from the origin cell to the target cell. The output of the planning system is shown in Fig 10.

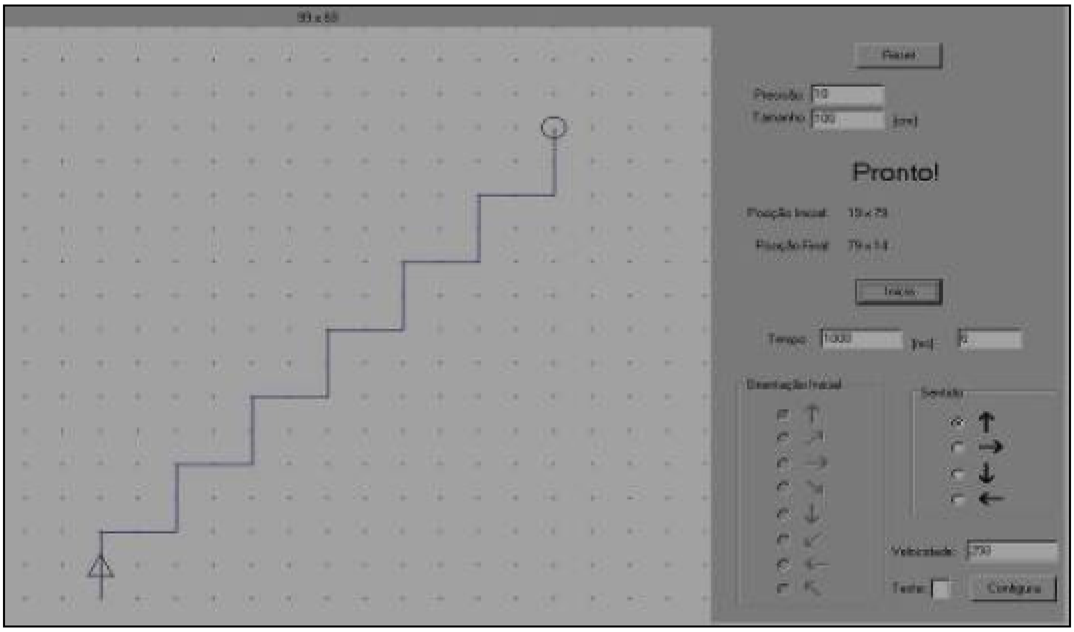


Figure 10 – The output of the planning system - Emmy III.

Figure 11 – The mechanical structure of the Emmy III second prototype.

The planning system considers all cells free. The mechanical construction is basically composed of a steel structure, two DC motors and three wheels. Each motor has a wheel fixed on its axis besides a free wheel. Figure 11 shows the mechanical structure. There is an electronic circuitry on the steel structure. The electronic circuitry main device is the microcontroller PIC18F4550 which is responsible for receiving the schedule from the planning system and activating the DC motors. Also, there is a potency driver between the microcontroller and the DC motors.

## 9. CONCLUSIONS

This paper described the development of the autonomous mobile robot Emmy series. The goal is to make Emmy move from a starting point to an end point in a non-structured environment. Two prototypes of this robot have already been built. They are composed of a planning system and a mechanical structure. They are able to move from a starting point to an end in an environment without any obstacle. Both of them displayed satisfactory performance. The next prototype will have the same characteristics as the ones described but adding a sensing system. So, this new robot is going to be able to move from a starting point to an end point in a non-structured environment with several obstacles. The sensing system is going to be based on the Paraconsistent Annotated Evidential Logic Eτ. Acknowledgements The authors would like to thank CNPq, CAPES, and FAPEMIG - Brazilian research funding agencies, for the research scholarships, which supported this work.

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