Intelligent System of Paraconsistent Logic to Control Autonomous Moving Robots

Conference Paper · December 2006

DOI: 10.1109/IECON.2006.347609 · Source: IEEE Xplore

4 authors:

Claudio Rodrigo Torres
Universidade Metodista de São Paulo

Germano Lambert-Torres
PS Solutions, Itajuba, Brazil

Luiz Eduardo Borges da Silva
Universidade Federal de Itajubá (UNIFEI)

Jair Minoro Abe
Universidade Paulista

Intelligent System of Paraconsistent Logic to Control Autonomous Moving Robots

Cláudio Rodrigo Torres
Germano Lambert-Torres
Luiz Eduardo Borges da Silva
Federal University of Itajuba
Av. BPS 1303
Itajuba – 37500-000 - MG
BRAZIL
{germano, leborges}@unifei.edu.br

Jair Minoro Abe
Institute of Science and Technology
University Paulista
BRAZIL
jairabe@uol.com.br

***Abstract* –This paper shows a controller based on the evidential annotated paraconsistent logic E – Paracontrol. The Paracontrol is a variation of the logic analyzer. This work also shows an autonomous mobile robot, which is named Emmy II, in order to demonstrate the Paracontrol's new properties. As an innovation, the Paracontrol presents besides the characteristics of the previous controller (manipulation of uncertainties, contradiction and paracompleteness information), the speed control in the various robot's actions**

I. INTRODUCTION

The current paper presents some adding characteristics to the controller. It can be classified as sophistication and an improvement related to the movement of the robot Emmy. The proposed control system, which maintained the name Paracontrol [1], uses six (6) logic states and presents new commands that did not exist in Emmy.

Speed control in several actions: for example, when an obstacle is detected ahead, the new Paracontrol allows the gradual breaking of the robot, allowing a "gentler" halt. Moreover, when the robot faces contradictory data as aforementioned, the robot turns around more "gently".

The new controller permits backward movements. In certain situations, the robot can move backward or turn with a fixed wheel and another one turning backward, permitting the robot to perform gentler movements than Emmy's.

The combination of both characteristics above, more the other ones presented in the original prototype, makes the new prototype a robot with more sophisticated movements than the previous one. Therefore, a step further is taken to meet the expectations of an autonomous moving robot. Such genre of robot built using the new Paracontrol is denominated Emmy II.

II. HIGHLIGHTS IN LOGIC

The classic logic rose, as evidenced, by 384-322 B.C. with Aristotle and presents the following basic principles, among others:

- Identity principle: every object is identical to itself.
- Contradiction principle: (some authors denominate it non-contradiction principle): from two contradictory propositions (i.e., one is the denial of the other) one of them must be false.
- Excluded middle (or third party) principle: from two contradictory propositions, one of them must be true.

In 1910, the Russian logician Nicolai A. Vasil'év (1880 – 1940) and the Polish logician Jan Lukasiewicz (1878 – 1956) independently published papers dealing with logics that admitted contradictions in the Aristotle level, though.

In 1948, the Polish logician Stanislaw Jaskowski (1906 – 1965) formalized with base on the discursive logic, a paraconsistent propositional calculus denominated discursive propositional calculus. Independently, in 1954, the Brazilian logician Newton C.A. da Costa (1929 -) developed many paraconsistent systems, containing all the usual logic levels: propositional calculus, predicate calculus, predicate calculus with equality, description calculus and higher-order calculus (under the form of the set theory).

With the breed of alternative logic systems to the classic logic, nowadays, we can conceive the Logic as a science comprising many logic systems (classic, paraconsistent, fuzzy etc). Therefore, not strictly, Logic can be divided into two classes: deductive and inductive.

The deductive logic studies the interferences logically needed (or valid), in a way that, if the premises are true, the conclusion necessarily is also true. This logic category, by its turn, can be divided into two wide groups: the classic deductive logic and the non-classic deductive logic.

The nuclear part of the classic deductive logic is about the study of the first-order predicate calculus and some of its important sub-systems, such as the classic propositional calculus and the classic implicative calculus.

The non-classic deductive logic can be divided into two types of studies:

The one that complements the scope of the classic logic. It is included in this category various modal systems, such as: knowledge logic, deontic logic, temporal logic and others; the one that substitutes the classic logic in some of its points or in the majority of its domain. This last branch is called rival or heterodox logic. It is included in this category: the various multi-valued logic, fuzzy logic, paraconsistent logic, noted logics etc.

As in this paper, the paraconsistent logic presents an important role, we elaborated the following considerations.

III. THE PARACONSISTENT LOGIC

The paraconsistent logic can be defined as follows: let T a theory grounded on the logic L, and it is supposed that the

1-4244-0136-4/06/$20.00 ©2006 IEEE

language in L and T contains a symbol for the denial (if there is more than one denial, one of them shall be chosen by its logic-mathematical characteristics) [2-5]. The theory T is said to be inconsistent if it holds contradictory theorems, i.e., such as the one is the denial of the other; in the opposite, T is said to be consistent. The theory T is said to be trivial if all the formulas of L (or all the closed formulas of L) are theorems of T; on the hypothesis, T is called non-trivial.

A logic L is called paraconsistent if it is the base for inconsistent theories, but non-trivial [6].

A logic L is denominated paracomplete if it can be the subjacent logic of theories in which the contradiction principle is broken, i.e., there are formulas that they and their denials are both false. In a precise manner, a logic is said to be paracomplete if there are in it maximal non-trivial theories that do not belong to a certain formula and its denial.

In the scope of the applications, an undesirable question of the classic logic is its fragility. As effect, it can be demonstrated that the presence of a contradiction in the classic logic makes trivial any theory based on it. As consequence, the classic logic is useless to manipulate the concept of inconsistency in a direct manner, hindering a non-trivial treatment in the presence of contradictions. As result, when we need to deal with inconsistencies in a direct manner, we need to use paraconsistent logics [5-8].

IV. DESCRIPTION OF THE CONTROL SYSTEM

The studied control system uses six logic states instead of 12 logic states used in Emmy's Paracontrol. In addition, it holds a speed control, which does not occurs in the robot Emmy [5,9]. The Paracontrol is a logic controller that provides the materialization of the Para-analyzer algorithm in an electric-electronic circuit. The Para-analyzer holds a structure based on the Evidential Paraconsistent Logic, which will be further detailed later, presents two inputs (one, the favorable evidence and other, the contrary evidence) and displays 12 states as outputs (including among them, the states true, false, inconsistent and paracomplete, in addition to "intermediary" states) that constitute decision taking states of robot Emmy.

As previously mentioned, Emmy holds two ultra-sonic sensors: one to determine the degree of favorable evidence and the other to determine the level of contrary evidence. With Paracontrol, Emmy can act adequately to certain "special" situations, such as the ones facing contradictory data: one sensor can detect an obstacle ahead (for example, a wall) while another one cannot detect any hurdle (for example, the robot can be heading to an open door). If this situation occurs, Emmy stops and turns 45° towards the unblocked direction. Therefore, if in the new measuring, there is no inconsistency, it can take another decision, for example, to move ahead, turning round the obstacle. The current paper presents some additional characteristics to the controller, able to be classified as sophistication and improvement in relation to the movement of the robot Emmy. The proposed control system, for which we will maintain the name Paracontrol, uses six (6) logic states and presents new commands that did not exist in Emmy:

1) Speed control in various actions: for example, detecting an obstacle ahead, the new *Paracontrol* allows the gradual breaking of the robot, permitting a "gentler halt". Moreover, when facing contradictory data such as the ones mentioned above, the robot turns "more gently".
2) The new controller allows backward movements. In certain situations, the robot can move backward or turn with one fixed wheel and the other one turning backwards, allowing the robot to perform gentler movements than Emmy's.
3) The combination of both characteristics above, more the others presented in the original prototype, makes the new prototype a robot with more sophisticated movements than the previous one; therefore, a is taken to meet he expectations of an autonomous moving robot.

The autonomous moving robot built with the new Paracontrol is denominated Emmy II.

V. THE PHYSICAL CONSTRUCTION OF THE AUTONOMOUS MOVING ROBOT EMMY II

The platform used to assemble the robot Emmy II holds approximately 25 cm of diameter and 23 cm of height. The main components of robot Emmy II are a microcontroller of the family 8051, two ultra-sound sensors and two continuous current motors. Figure 1 shows the basic structure of the robot Emmy II.

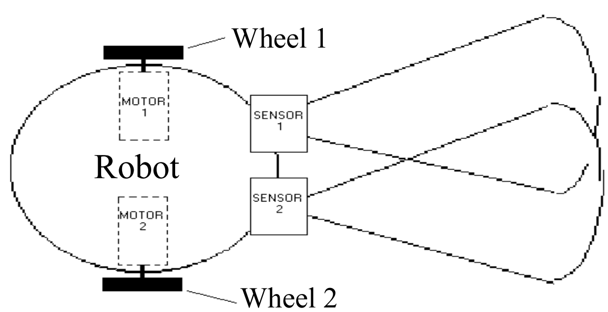

Fig 1. Basic Structure of the robot Emmy II.

The ultra-sound sensors are responsible for the verification of obstacles ahead. The signals generated by the sensors are sent to the microcontroller. The values of the level of favorable evidence (μ) and of the level of contrary evidence (λ) in the proposition "The front of the robot is free" are determined by the microcontroller with base in the signals received from the ultra-sound sensors. The microcontroller also determines the movement to be executed by the robot, that is, which motor shall be activated, with base in the decision from the Paracontrol.

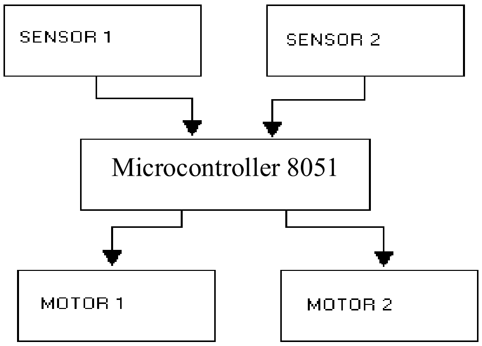

Fig. 2. Diagram in simplified blocks.

Figure 2 shows the diagram in simplified blocks of the autonomous moving robot Emmy II; while Figure 3 shows the frontal and the lower views of the robot

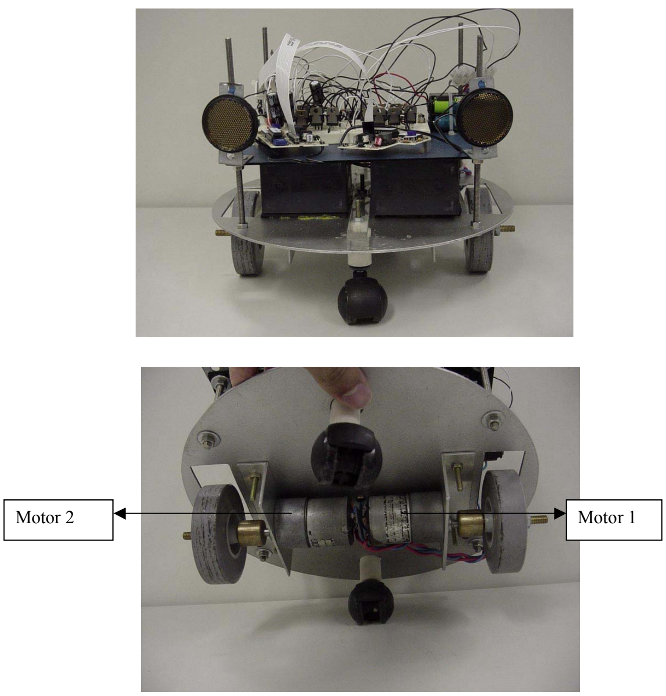

Fig. 3. The frontal and lower views of the robot Emmy II.

VI. PROGRAMMING OF THE ROBOT EMMY II

The main component of the robot Emmy II is the microcontroller 89C52 because it is responsible to determine the distances between the ultra-sound sensors and the obstacles located in front of the robot, to calculate the values of the levels of favorable evidence and contrary evidence in the proposition "The front of the robot is free", to execute the algorithm Para-analyzer and to generate signals to activate the motors. The program is stored in the intern memory of the microcontroller 89C52.

The possible movements in this robot are the following:

1. To head in a straight line. Motors 1 and 2 are activated forward at the same time with the same speed.
2. To go back in a straight line. Motors 1 and 2 are activated backward at the same time with the same speed.
3. To turn right. Only motor 1 is activated forward with motor 2 deactivated.
4. To turn left. Only motor 2 is activated forward with motor 1 deactivated
5. To turn right. Only motor 2 is activated backward with motor 1 deactivated.
6. To turn left. Only motor 1 is activated backward with motor 2 deactivated.

The signal from sensor S1 is considered as a level of favorable evidence and the signal from sensor S2 is considered as a level of contrary evidence in the proposition "The front of the robot is free". When there is an obstacle next to sensor S1, the level of favorable evidence is low and when the obstacle is far from sensor S1, the level of favorable evidence is high. On the other side, when there is an obstacle next to sensor S2, the level contrary evidence is high and when the obstacle is in front of sensor 2, the level of contrary evidence is low.

The robot decides which movement to choose based in the values of the level of favorable evidence, in the level of contrary evidence and in the proposed control system in accordance to the lattice with the respective extreme and non-extreme logic states in Figure 4.

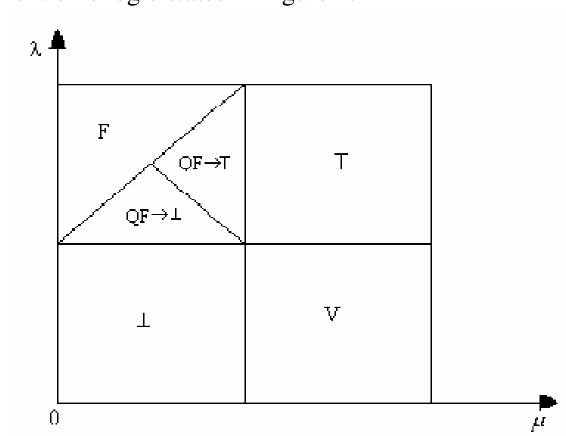

Fig. 4. Lattice with the logic states used by the robot Emmy II.

The verification of the values of the level of favorable evidence and the level of contrary evidence, decision taking and motors' moving is performed sequentially. Such sequence of actions is almost imperceptible when observing the robot moving.

For each state, the respective decision is the following:

- State V: To go ahead. Motors 1 and 2 are activated forward at the same time.
- State F: To go back. Motors 1 and 2 are activated backward at the same time.
- State ⊥: To turn left. Only motor 1 is activated ahead. Motor 2 remains deactivated.

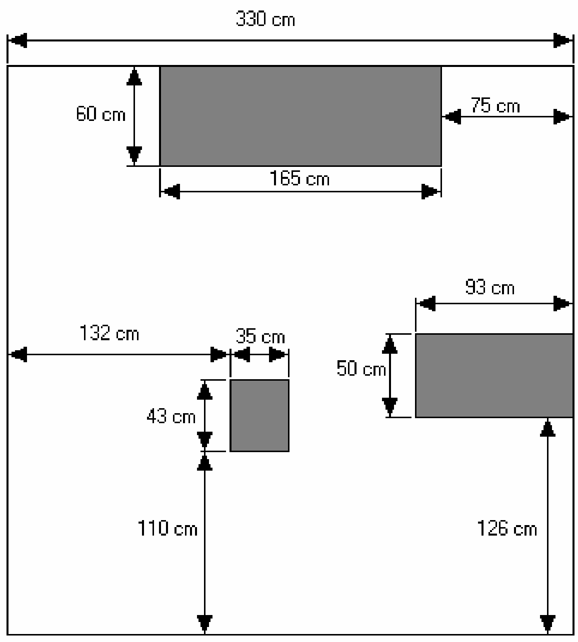

Fig. 5. Tests environment of the robot Emmy II

- State T: To turn left. Only motor 2 is activated ahead. Motor 1 remains deactivated.
- State QF→⊥: To turn right. Only motor 2 is activated backward. Motor 1 remains deactivated.
- State QF→T: To turn left. Only motor 1 is activated backward. Motor 2 remains deactivated.

The reasons for the choices are the following. When the state is True (T), it means that the front of the robot shall be free. Therefore, the robot can go ahead.

In the Inconsistency state (T), μ and λ assume high values (i.e., belonging to the region T). This means that S1 is far of an obstacle and S2 is next to an obstacle, in this occasion, the left side is freer than the right one. Therefore, the recommended action is to turn left. Only motor 2 is activated ahead and motor 1 remains deactivated.

When the state of Paracompleteness (⊥), μ and λ assume low values. This means that S1 is next to an obstacle and S2 is far from an obstacle. In this occasion, the right side is freer than the left one. Therefore, the decision shall be to turn right. Only motor 1 is activated ahead and motor 2 remains deactivated.

In the Falseness (F), an obstacle close to the robot hinders the front of the robot. Therefore, the decision is to draw back.

In the Almost-Falseness state tending to the Inconsistent (QF→T), the front of the robot continues hindered, with the following characteristics: the obstacle is not so close as it is in the Falsehood and the left side is freer that the right one. The decision is to turn right, activating only the motor 1 backward and maintaining motor 2 deactivated.

In the Almost-falseness state tending to Paracomplete (QF→⊥), the front of the robot continues hindered, in the following way: the obstacle is not so close as in the falseness and the right side is freer than the left one. The decision is to turn right, activating only motor 2 backwards and maintaining motor 2 deactivated

VII. TESTS

With the aim of verifying the functionality of the robot Emmy II, four tests were carried out. Those tests are basically done by counting how many times the robot crashes against an obstacle when the robot moves in a determined environment. The Figure 6 shows the environment where the tests with the robot Emmy II were performed.

The time and the result of each test are the following:

- Test 1: Time: 3 minutes and 50 seconds. Result: 13 collisions.
- Test 2: Time: 3 minutes and 10 seconds. Result: 7 collisions.
- Test 3: Time: 3 minutes and 30 seconds. Result: 10 collisions.
- Test 4: Time: 2 minutes and 45 seconds. Result: 10 collisions.

The ultra-sound sensors used by the robot Emmy II do not detect obstacles from a 7.5 cm distance or less. The ultra-sound sensors emit sound waves and wait for the return of such waves (echo) to determine the distance between the obstacle and the sensor, but not always these waves return, sometimes they reflect to another direction. Those are the main causes for the collisions occurred during the tests. This can be solved with the placement of more sensors and some modifications in the Paracontrol.

The causes of the collisions are the following:

- Test 1: Total of collisions: 13.
  Collisions caused by the reflex of sound waves: 4.
  Collisions caused by the proximity to an obstacle: 9.
- Test 2: Total of collisions: 7.
  Collisions caused by the reflex of sound waves: 2.
  Collisions caused by the proximity to an obstacle: 5.
- Test 3: Total of collisions: 10.
  Collisions caused by the reflex of sound waves: 5.
  Collisions caused by the proximity to an obstacle: 5.
- Test 4: Total of collisions: 10.
  Collisions caused by the reflex of sound waves: 4.
  Collisions caused by the proximity to an obstacle: 6.

Another possibility of collision exists when the falseness state is detected. In this situation, the robot goes backward for 0.4 seconds, as there are no sensors behind it, the possibility of collision is high.

VIII. CONCLUSIONS

In the current article, a new version of the Paracontrol (paraconsistent logic controller) based in the evidential paraconsistent logic Eτ was submitted to appreciation. It was implemented the Paracontrol in an autonomous moving robot which was denominated Emmy II. The news is that such controller allows the speed control of the movements of the robot and enables adjustments through the software. The robot Emmy II executes backwards movements, which were not possible in the robot Emmy.

The running of the robot Emmy II showed to be very satisfactory. There, we could accomplish the implementation of an autonomous moving robot without external supervision and with its movement in a non-structured environment at a relatively low cost.

The controllers based in the paraconsistent noted logic are able to manipulate the uncertainty, contradiction and paracompleteness in an efficient way, rendering possible new researches with interesting outlooks.

IX. ACKNOWLEDGMENT

The authors gratefully acknowledge the CNPq, a Brazilian research funding agency, CAPES, in the form of research scholarships, and FAPEMIG, a Minas Gerais State research funding agency, which supported this work.

X. REFERENCES

[1] J.M. Abe - *Fundations of Anotated Logic*, Ph. D. Thesis, University of San Paulo, São Paulo, Brazil, 1992.

[2] N.D. Belnap. A Useful Four-valued Logic: How a computer should think. In A.R. Anderson, N.D. Belnap,and J.M. Dunn, editors, *Entailment: The Logic of Relevance and Necessity*. Princeton University Press, 1992.

[3] G. Priest. Paraconsistent Belief Revision. In *Theoria*, volume 67. 2001.

[4] G. Priest. Paraconsistent Logic. In D. Gabbay and F. Guenthner, editors, *Handbook of Philosophical Logic*, Volume 6. Kluwer Academic Publishers, 2nd edition, 2002.

[5] J.I. da Silva Filho – *Methods of Paraconsistent Logic Aplications with Two Values LPA2v*, Ph. D. Thesis, University of San Paulo, São Paulo, Brazil,1999.

[6] G. Lambert-Torres, J.M. Abe, M.L. Mucheroni & P.E. Cruvinel – *Advances in Intelligent Systems and Robotics*, IOS Press, 2 volumes, Vol. I: 217p e Vol. II: 240 p.,ISBN 1 58603 386-7, Amsterdam, Holanda, 2003.

[7] N.C.A. da Costa, J.M. Abe & V.S. Subrahmanian – "Remarks on Annotated Logic", *Zeitschrift fur Mathematische Logik und Grundlagen der Mathematik*, Vol.37, pp.561-570, 1991.

[8] N.C.A. da Costa. *On the Theory of Inconsistent Formal Systems*. Notre Dame Journal of Formal Logic, 15(4), 1974.

[9] J.M. Abe & J.I. Da Silva Filho, *Frontiers in Artificial Intelligence and Its Applications*, IOS Press, Amsterdan, Ohmsha, Tokyo, Vol. 71, ISBN 1 58603 206 2 (IOS Press), 4 274 90476 8 C3000 (Ohmsha), ISSN 0922-6389, 287p., 2001.