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New Advances in Intelligent Decision Technologies

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Results of the First KES International Symposium IDT 2009

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Preface

IDT (Intelligent Decision Technologies) seeks an interchange of research on intelligent systems and intelligent technologies which enhance or improve decision making in industry, government and academia. The focus is interdisciplinary in nature, and includes research on all aspects of intelligent decision technologies, from fundamental development to the applied system.

It constitutes a great honor and pleasure for us to publish the works and new research results of scholars from the First KES International Symposium on Intelligent Decision Technologies (KES IDT'09), hosted and organized by University of Hyogo in conjunction with KES International (Himeji, Japan, April, 2009). The symposium was concerned with theory, design, development, implementation, testing and evaluation of intelligent decision systems. Its topics included intelligent agents, fuzzy logic, multi-agent systems, artificial neural networks, genetic algorithms, expert systems, intelligent decision making support systems, information retrieval systems, geographic information systems, and knowledge management systems. These technologies have the potential to support decision making in many areas of management, international business, finance, accounting, marketing, healthcare, military applications, production, networks, traffic management, crisis response, and human interfaces.

In addition to this preface, this book contains 62 chapters, each based on a paper selected from a large number submitted for consideration for the symposium, from various countries from all over the world. Each paper was peer reviewed by at least two independent referees. The best were finally accepted based on the recommendations of the reviewers, in some cases after required revisions had been undertaken by the authors.

The book is organized as follows. Chapters 1 – 15 are devoted to Engineering of IDTs for Knowledge Management Systems, ; Chapters 16 and 17 are devoted to Intelligent Data Processing Techniques for Decision Making, ; Chapters 18, 19, 20, 21, 22, 23, 24 and 60 are devoted to Decision Making in a Dynamic Environments, ; Chapters 25 and 26 are devoted to Decision and Health, Chapters 27, 28, 29, 30 and 31 are devoted to Foundations and Applications of Intelligent Systems, ; Chapters 32, 33, 34 and 35 are devoted to Non-Classical Logics for Intelligent Decision Technologies, ; Chapters 36, 37, 38, 39 and 40 are devoted to Knowledge - Based Interface Systems, ; Chapters 41, 42 and 43 are devoted to IDT Based Anomaly Detection, ; Chapters 44, 45, 46, 47, 48 and 49 are devoted to Knowledge-Based Software Engineering and Medical Decision Support Systems, ; Chapters 50, 51, 52, 53 and 54 are devoted to Rough Sets and Decision

Making, ; Chapters 55, 56, 57, 58, 59, 61 and 62 are devoted to Decision Making in a Changing Financial and Social Environment.

We wish to express our sincere gratitude to the plenary speakers, invited session chairs, delegates from all over the world, the authors of various chapters and reviewers for their marvelous contributions. For their sponsorship with the symposium, we express our great thanks to Himeji City and Himeji Convention Bureau. We would like to express our sincere thanks to Mr. Peter Cushion of KES International for his help with organizational issues. We would also like to express our special thanks to all of the Springer-Verlag editorial team members for their editorial support. Last, we would like to express our gratitude to the Local Organizing Committee and students at University of Hyogo for their assist.

We hope and believe that this volume will contribute to ideas for novel research and the advanced in the work of researchers, practitioners, professors and research students who are interested in knowledge-based and intelligent engineering systems.

Kazumi Nakamatsu
Gloria Phillips-Wren
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Contents

Autonomous Mobile Robot Emmy III

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João Inácio Da Silva Filho, and Helga Gonzaga Martins

Abstract. This work presents some improvements regarding to the autonomous mobile robot Emmy based on Paraconsistent Annotated Evidential Logic Eτ. A discussion on navigation system is presented.

Keywords: Automation, paraconsistent logic, robotics, navigation system, logic controller.

1 Introduction

It is well known the use of non-classical logics in automation and robotics. In real applications, classical logic is inadequate for several reasons. The main point is that all concepts of real world encompass some imprecision degree. In order to overcome these limitations, several alternative systems were proposed. Maybe the most successful non-classical system is the so-called Fuzzy set theory [16]. In this work we employ another promising non-classical logic, namely the paraconsistent annotated systems. They've inspired applications in a variety of themes. Particularly in robotics, it was built some interesting autonomous mobile robots that can manipulate imprecise, inconsistent and paracomplete data. One of the robot series dubbed Emmy[1], based on a particular annotated system, namely, the paraconsistent annotated evidential logic Eτ [1], began with the 1st prototype studied in [2], [3]. Subsequently, some improvements were made in its 2nd prototype Emmy II [4] and in this paper we sketch the 3rd prototype discussing a navigation system.

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[1] The name Emmy is in homage to the mathematician Emmy Nöether (1882-1935). Such name was proposed by N.C.A. da Costa and communicated to J.M. Abe in 1999, University of Sao Paulo.

K. Nakamatsu et al. (Eds.): New Advan. in Intel. Decision Techno., SCI 199, pp. 317–327.
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2 Paraconsistent, Paracomplete, and Non-alethic Logics

In what follows, we sketch the non-classical logics discussed in the paper, establishing some conventions and definitions.

Let *T* be a theory whose underlying logic is *L*. *T* is called inconsistent when it contains theorems of the form *A* and ¬*A* (the negation of *A*). If *T* is not inconsistent, it is called *consistent*. *T* is said to be *trivial* if all formulas of the language of *T* are also theorems of *T*. Otherwise, *T* is called *non-trivial*. When *L* is classical logic (or one of several others, such as intuitionistic logic), *T* is inconsistent if *T* is trivial. So, in trivial theories the extensions of the concepts of formula and theorem coincide. Paraconsistent *logic* is a logic that can be used as the basis for inconsistent but non-trivial theories. A *theory* is called *paraconsistent* if its underlying logic is a paraconsistent logic. Issues such as those described above have been appreciated by many logicians. In 1910, the Russian logician Nikolaj A. Vasil'év (1880-1940) and the Polish logician Jan Łukasiewicz (1878-1956) independently glimpsed the possibility of developing such logics. Nevertheless, Stanislaw Jaśkowski (1996-1965) was in 1948 effectively the first logician to develop a paraconsistent system, at the propositional level [9]. His system is known as 'discussive propositional calculus'. Independently, some years later, the Brazilian logician Newton C.A. da Costa (1929-) constructed for the first time hierarchies of paraconsistent propositional calculi C_i, $1 \leq i \leq \omega$ of paraconsistent first-order predicate calculi (with and without equality), of paraconsistent description calculi, and paraconsistent higher-order logics (systems NF_i, $1 \leq i \leq \omega$). Also, independently of Da Costa [10], David Nelson (1918-2003) [11] has considered a paraconsistent logic as a version of his known as constructive logics with strong negation.

Nowadays, paraconsistent logic has established a distinctive position in a variety of fields of knowledge.

Another important class of non-classical logics are the paracomplete logics. A logical system is called *paracomplete* if it can function as the underlying logic of theories in which there are formulas such that these formulas and their negations are simultaneously false. Intuitionistic logic and several systems of many-valued logics are paracomplete in this sense (and the dual of intuitionistic logic, Brouwerian logic, is therefore paraconsistent).

As a consequence, paraconsistent theories do not satisfy the principle of non-contradiction, which can be stated as follows: of two contradictory propositions, i.e., one of which is the negation of the other, one must be false. And, paracomplete theories do not satisfy the principle of the excluded middle, formulated in the following form: of two contradictory propositions, one must be true.

Finally, logics which are simultaneously paraconsistent and paracomplete are called *non-alethic logics*.

3 Paraconsistent Annotated Evidential Logic Eτ

Annotated logics are a family of non-classical logics initially used in logic programming by [12]. An extensive study of annotated logics was made in [1]. Some applications are summarized in [13]. In view of the applicability of annotated logics to differing formalisms in computer science, it has become essential to study these logics more carefully, mainly from the foundational point of view.

In general, annotated logics are a kind of paraconsistent, paracomplete, and non-alethic logic. The latter systems are among the most original and imaginative systems of non-classical logic developed in the past century.

The atomic formulas of the logic $E\tau$ are of the type $p_{(\mu, \lambda)}$, where $(\mu, \lambda) \in [0, 1]^2$ and [0, 1] is the real unitary interval (p denotes a propositional variable). $p_{(\mu, \lambda)}$ can be intuitively read: "It is assumed that p's favorable evidence is μ and contrary evidence is λ." Thus, $p_{(1.0, 0.0)}$ can be read as a true proposition, $p_{(0.0, 1.0)}$ as false, $p_{(1.0, 1.0)}$ as inconsistent, $p_{(0.0, 0.0)}$ as paracomplete, and $p_{(0.5, 0.5)}$ as an indefinite proposition.

Also we introduce: Uncertainty Degree: $Gun(\mu, \lambda) = \mu + \lambda - 1$; Certainty Degree: $G_{ce}(\mu, \lambda) = \mu - \lambda$ $(0 \leq \mu, \lambda \leq 1)$; an order relation is defined on [0, 1]2: $(\mu1, \lambda1) \leq (\mu2, \lambda2) \Leftrightarrow \mu1 \leq \mu2$ and $\lambda1 \leq \lambda2$, constituting a lattice that will be symbolized by τ. With the uncertainty and certainty degrees we can get the following 12 output states: extreme state and non-extreme states, showed in the Table 1.

Table 1 Extreme and Non-extreme states

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

All states are represented in the next figure.

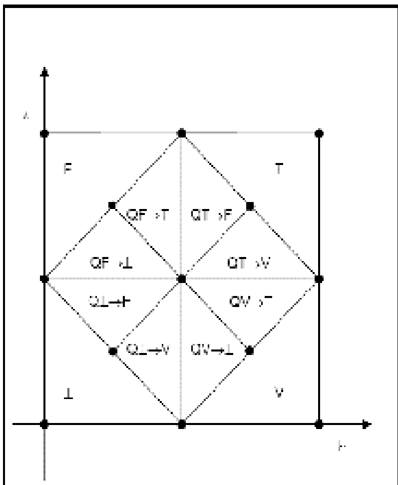

Fig. 1 Lattice τ

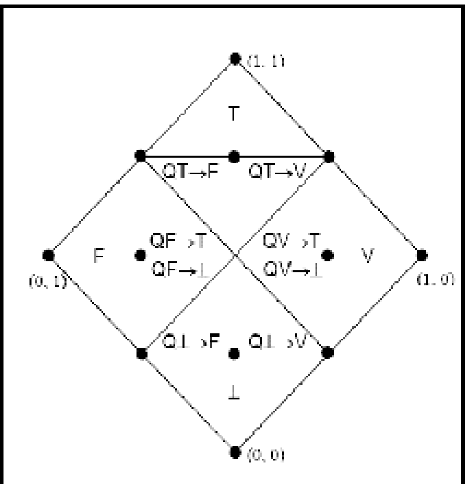

Fig. 2 Lattice τ - Hasse diagram

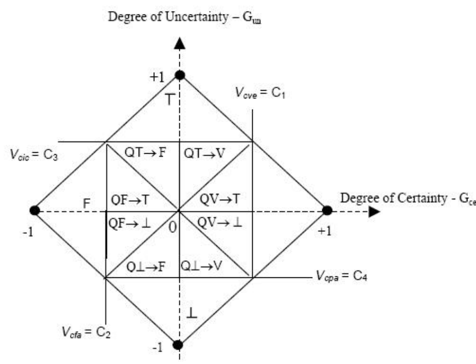

Figure 3. Certainty and Uncertainty degrees

3 Paracontrol - Logical Controller

The Paracontrol [20] is an electronic materialization of the Para-analyzer algorithm [2], [15], which is basically an electronic circuitry, which treats logical signals in a context of logic Eτ. Such circuitry compares logical values and determines domains of a state lattice corresponding to output value. Favorable evidence and contrary evidence degrees are represented by voltage. Certainty and Uncertainty degrees are determined by analyze of operational amplifiers. The Paracontrol comprises both analogical and digital systems and it can be externally adjusted by applying positive and negative voltages. The Paracontrol was tested in real-life experiments with an autonomous mobile robot Emmy, whose favorable/contrary evidences coincide with the values of ultrasonic sensors and distances are represented by continuous values of voltage.

4 The Autonomous Mobile Robot Emmy

The controller Paracontrol was applied in this series of autonomous mobile robots. In some previous works [2], [19] is presented the autonomous mobile robot Emmy. The figure 4 shows the autonomous mobile robot Emmy. The Emmy robot consists of a circular mobile platform of aluminum 30 cm in diameter and 60 cm height. While moving in a non-structured environment the robot Emmy gets information about presence/absence of obstacles using the sonar system called Parasonic [3].

Figure 4. The autonomous mobile robot Emmy

5 Robot Emmy II

Searching the Paracontrol, the robot Emmy controller, we perceived that the robot movements could be bettered by programming conveniently the no extreme logic state outs. This new Paracontrol version also is used to control an autonomous mobile robot named as Emmy II [4].

The platform used to assemble the Emmy II robot measures approximately 23cm height and 25cm of diameter (circular format). The main components of Emmy II are a microcontroller from 8051 family, two ultrasonic sensors, and two DC motors. The figure 5 shows an Emmy II robot simplified block diagram.

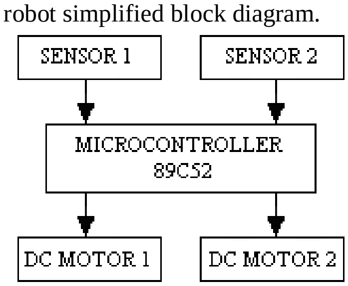

Figure 5. Emmy II robot simplified block diagram.

The ultrasonic sensors are responsible for verifying whether there is any obstacle in front of the robot. The signals generated by the sensors are sent to the microcontroller. These signals are used to determine the favorable evidence degree value (μ) and the contrary evidence degree value (λ) on the proposition “The front of the robot is free”.

The Paracontrol, recorded in the internal memory of the microcontroller, uses the evidence degrees in order to determine the robot movements. The microcontroller is also responsible for applying power to the DC motors.

Figure 6 shows the Emmy II mechanical structure.

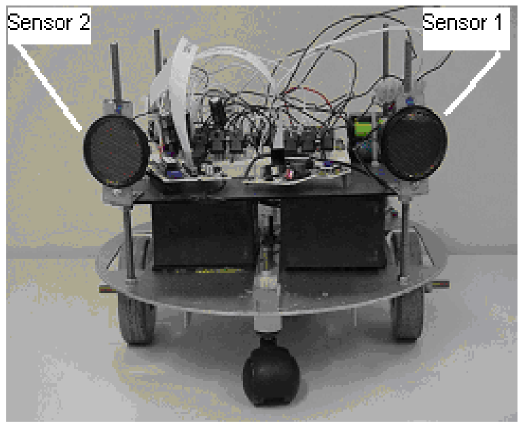

Figure 6. Emmy II Mechanical Structure.

Figure 7 shows the decision state lattice that the Emmy II robot uses to determine the movement to perform.

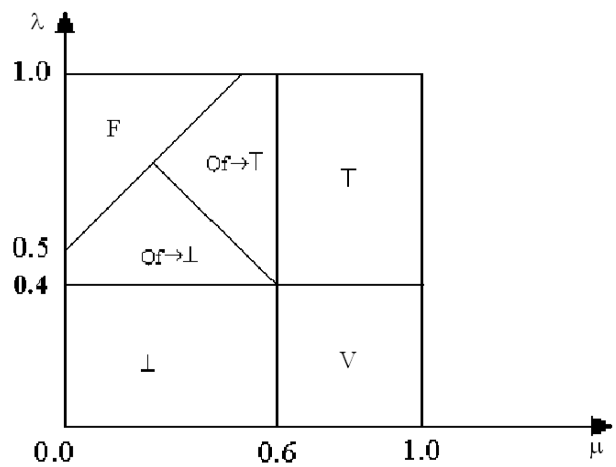

Figure 7. Logical output lattice of Emmy II

Table 2 shows the actions related to each possible logic state. Each robot movement lasts approximately 0,4 seconds.

Table 2. Logical states and action

Symbol	State	Action
V	True	Robot goes ahead
F	False	Robot goes back
$\perp$	Paracomplete	Robot turns right
T	Inconsistent	Robot turns left
QF$\rightarrow\perp$	Quasi-false tending to paracomplete	Robot turns right
QF$\rightarrow$T	Quasi-true tending to inconsistent	Robot turns left

6 Autonomous Mobile Robot Emmy III

The aim of the Emmy III autonomous mobile robot is to be able to move from an origin point to an end point, both predetermined, in a non-structured environment. We'll do it in steps. First, the robot must be able to move from a point to another in an environment without any obstacle. This environment is divided in cells [6] and a planning system gives the sequence of cells the robot must follow to reach the end cell. This idea was applied in [7], [8]. The second step is an evolving of 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 have to be avoided. This sensor system will use Paraconsistent Annotated Logic to handle information captured by the sensors. The Emmy III structure is:

Sensing system - The robot's environment is composed by a set of cells. On the other hand, the sensing system has to determine the environment with enough precision, but the information captured by the sensors always has an inherent imprecision, which leads to an uncertainty regarding to the position actually the robot is in. In order to manipulate this kind of information, the sensing system is based on the Paraconsistent Annotated Evidential Logic Eτ, which captures the information generated by the sensors using favorable and contrary evidences degrees as seen in the logical controller Paracontrol.

Planning system - The objective is to build a planning system able to determine a path linking an initial point to an end point in a non-structured environment with some obstacles. For this, the environment is divided in 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 an environment without any obstacle, that is, an environment with all cells free. In the second step the sensing system informs the planning system the cells that have objects in.

Physical Construction - The Emmy III mechanical part must perform the schedule determined by the planning system. It must know the cell it is in, therefore, a monitoring position makes part of this construction. In the process, for each cell that the robot reaches, the possible error of position should be considered. In the items 7 and 8 is described two 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 in cells. This first version considers all cells free. Then it asks for the initial point and the aimed point.

After that a sequence of movements is given in a screen. Also a sequence of pulses is sent to the step motors that are responsible for moving the physical platform of the robot. So, the robot moves from the initial point to the aimed point.

Figure 8 shows the planning system screen.

Figure 8 – Planning system screen.

The physical construction of the first prototype of the Emmy III robot is basically composed of a circular platform of approximately 286 mm of diameter and two-step motors. The figure 9 shows the Emmy III first prototype. The planning system is recorded in a notebook. And the communication between the notebook and the physical construction is made through the parallel port. A potency driver is responsible to get the pulses from the notebook and send them to the step motors that are responsible for moving the robot.

Figure 9. The first prototype of Emmy III robot

8 Second Prototype of the Autonomous Mobile Robot Emmy III

Similarly to the first prototype, the second prototype of the autonomous mobile robot Emmy III is basically composed of a planning system and a mechanical structure. The planning system is recorded in any personal computer and the communication between the personal computer and the mechanical construction is done through an USB port. The planning system considers the environment around the robot divided in cells. So, it is necessary to inform the planning system the cell the robot is in and the aimed cell. The answer of the planning system is a sequence of cells that the robot must follow to go from the origin cell to the aimed cell.

The planning system considers all cells free. Figure 10 shows the screen of the planning system.

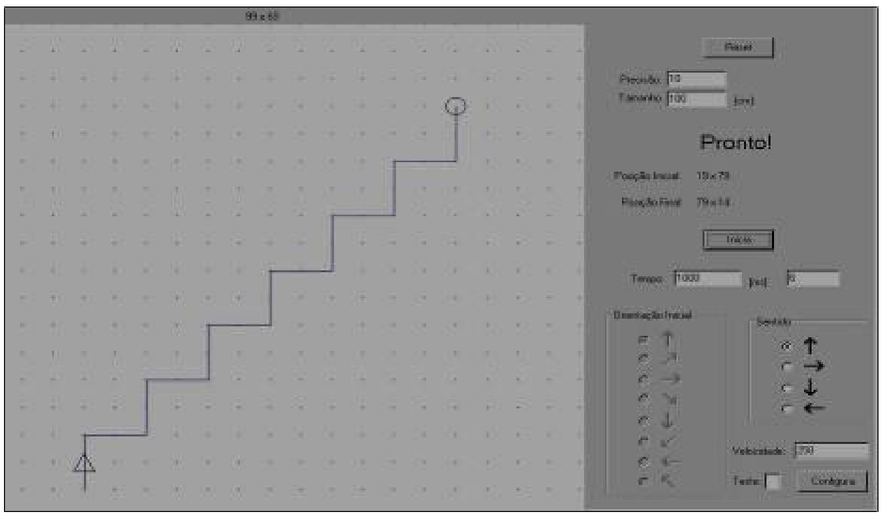

Figure 10. The output of the planning system - Emmy III.

Figure 11 shows the mechanical structure of Emmy III second prototype.

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 in its axis and there is a free wheel. There is an electronic circuitry on the steel structure. The main device of the electronic circuitry is the microcontroller PIC18F4550 that is responsible for receiving the schedule from the planning system and activates the DC motors. Also there is a potency driver between the microcontroller and the DC motors.

9 Conclusions

In this work we've studied the third prototype of the Emmy III autonomous mobile robot. The main concern is its navigating route planning, i.e. Emmy III is able to move from an origin point to an end point in a non-structured environment.

Two prototypes of this robot' version were built and tested. They are composed of a planning system and a mechanical structure and they were able to move from an origin point to an end point in an environment without any obstacle. Both of them had a satisfactory performance.

The next step is to build a mobile robot with the same characteristics of the described prototypes but adding a sensing system. So we expect that this new prototype will be able to move from an origin point to an end point in a non-structured environment with obstacles. The sensing system also is based on the context of Paraconsistent Annotated Evidential Logic Eτ. We hope to say more in forthcoming papers.

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