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Petri net Technique: A graphical Representation for the Robot Emmy II

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Abstract: The robot Emmy II is an autonomous robot, whose operation is based on the Paraconsistent Annotated Logic (PAL) with six logical states. Its control system, called as *Para*Control, is capable to deal with the uncertainty situations, of inconsistency and contradictory in a non-trivial way. Petri net (PN) as a graphical technique provides a uniform environment for modeling discrete event systems (DES). In this paper, PN will be used as an interpreter of *Para*Control by giving some graphical rules for Emmy's locomotion process.

Keywords: Robot Emmy II, Paraconsistent Annotated Logic, Logical States, *Para*Control, Petri nets, Discrete Event Systems.

Técnica de rede de Petri: Uma Representação Gráfica para o Robô Emmy II

Resumo: O robô Emmy II é um robô autônomo, o qual sua operação é baseada na Lógica Paraconsistente Anotada (LPA) com seis estados lógicos. O sistema de controle do Emmy, chamado de *Para*Control, é capaz de lhe dar com situações de incertezas, inconsistências e contradições de forma não-trivial. A rede de Petri (RdP) é uma técnica gráfica o qual provê um ambiente uniforme para modelagem de eventos de sistemas discretos (ESD). Neste artigo, serão usadas as técnicas de RdP como uma interprete do *Para*Control dando algumas regras gráficas no processo de locomoção da Emmy.

Palavras chave: Robô Emmy II, Lógica Paraconsistente Anotada, Estados Lógicos, *Para*Control, rede de Petri, Sistemas de Eventos Discretos.

1. Introduction

With the globalized market, the new developments in the field of science and technology have intensified daily. Because of the developments of information of things (IoT) and the cyber-physical systems (CPS), there is an increasing interest in robotics and its application in several fields globally.

In Japan, there are many applications of robots in industries, hospitals, etc. In Japan there is the concern about the use of robots to the social responsibility (*e.g. WL-16RIII, a robot for mobility*). In USA there are many applications of robots also in different fields. However, in USA there is a strong application of robots on the military field (*e.g. DARPA – Defense Advanced Research Projects Agency*). Germany (*e.g. KUKA*) is a famous leader of robots for industrial applications.

In Brazil, there are many robots coming from abroad (USA, Asia, Europe) and being used mainly in the automotive industry.

In this context, many universities in Brazil have being developing researches with robots by focusing on software and hardware. In this paper, the focus will be the robot Emmy II (figure 2).

The first version of the robot Emmy (figure 1) has being developed at the University of Santa Cecília by the professor João Inácio da Silva Filho and later it was updated by professor Claudio Rodrigo Torres from the Faculdade de Tecnologia Adib Moisés. The robot Emmy I and II are a robots developed to test and prove the functionality of the Paraconsistent Annotated Logic as a control system. For more details, read the section 2.4.

Figure 1. The Robot Emmy I
Source:http://www.paralogike.com.br/site/links/ver/29

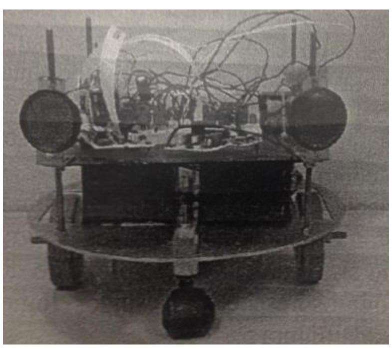

Figure 2. The Robot Emmy II
Source:Torres et al., 2007

The paper is organized as follows: Section 2 presents the literature review used to develop the work. Section 3 presents the methodology. In Section 4, the possible movements of the robot Emmy II is modeled with Petri net technique. Finally, section 5 presents the conclusion.

1. Literature Review

1.1 Paraconsistent Annoted Logic

The Paraconsistent Annotated Logic (PAL) belongs to the family of PLs and can be represented in a particular way, through a lattice of four vertices in which, intuitively, the constants annotation represented in its vertices will give connotations of extreme logical states to propositions (Da Silva Filho et al., 2010; Da Silva Filho, 2011; Abe and Da Silva Filho, 1998; Da Silva Filho and Rocco, 2008).

1.2 Paraconsistent Annoted Logic with annotation of two values (PAL2v)

According to Da Silva Filho et al. (2010); Abe and Da Silva Filho (1998); Da Silva Filho and Rocco (2008) it is possible to obtain through the PAL a representation about how much the notes, or evidences, express knowledge about a proposition *P*. This is accomplished using a lattice formed by ordered pairs of values (μ, λ), which comprise the annotation, as seen in figure 3.

In this representation, it is fixed an operator ~:

$|\tau| \rightarrow |\tau|$ where:

$\tau = \{(\mu, \lambda) \mid \mu, \lambda \in [0, 1] \subset \Re\}$.

If *P* is a basic formula, then:

$\sim[(\mu, \lambda)] = (\lambda, \mu)$ where, $\mu, \lambda \in [0, 1] \subset \Re\}$. .

Where ~ has the meaning of negation in PAL.

It is introduced the extreme logical Paraconsistent states which are the four vertices of the lattice with Favorable Degree of evidence μ and Unfavorable Degree of evidence λ. We read them in the following way (Da Silva Filho et al., 2010):

.$P_T = P_{(1, 1)} \rightarrow$ The annotation (μ, λ) = (1, 1) assigns intuitive reading that *P* is inconsistent.

.$P_t = P_{(1, 0)} \rightarrow$ The annotation (μ, λ) = (1, 0) assigns intuitive reading that *P* is true.

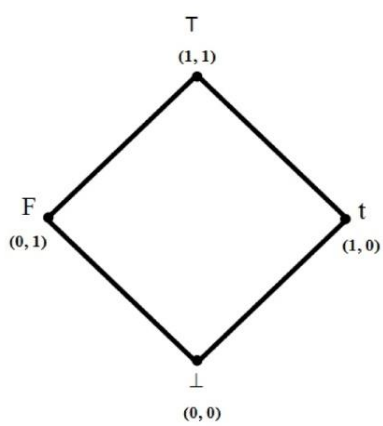

Figure 3. Lattice of four vertexes.

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.$P_F = P_{(0, 1)} \rightarrow$ The annotation (μ, λ) = (0, 1) assigns intuitive reading that *P* is false.

.$P_\perp = P_{(0, 0)} \rightarrow$ The annotation (μ, λ) = (0, 0) assigns intuitive reading that *P* is Indeterminate.

In the internal point of the lattice which is equidistant from all four vertices, we have the following interpretation:

.$P_I = P_{(0.5, 0.5)} \rightarrow$ The annotation (μ, λ) = (0.5, 0.5) assigns intuitive reading that *P* is undefined.

1.3 Petri net Technic

Petri net (PN) developed by Carl Adam Petri in 1962 are a graphical and mathematical modelling for describing and analysing Discrete Event Systems (DES) (Petri, 1962). PNs have been shown to be an effective tool for modelling complex and dynamic systems due to their ability to illustrate precedence, concurrent and asynchronous events and detect conflicts (Salimifard and Wright, 2001). Therefore, Petri formulated the basis for a theory of communication among asynchronous components of a computer system.

A simple description can be found in (Peterson, 1981) that says that PN is a mathematical representation of a system that is structured as a four-tuple; PN = (P, T, I, O), where P is the set of places, T is the set of transitions, I is the input function and O is the output function. P= {p1,p2,...,pn} is a finite set of places and n≥0.T={t1,t2,...,tm} is a finite set of transitions and m≥0. The set of places and the set of transitions are disjoint; P∩T=0 and P∪T/= 0. I:T→ P∞ is the input function, a mapping from bags of places to transitions. O:T→ P∞ is the output function, a mapping from transitions to bags of places. Furthermore, a PN is a directed bipartite graph (figure 4), in which the nodes represent transitions (i.e. events that may occur, represented by bars) and places (i.e. conditions, represented by circles). The directed arcs describe which places are pre- and/or postconditions for which transitions (signified by arrows).

The main feature of a PN is that its state is a vector of nonnegative integers. Another key feature of PNs is their capacity to graphically represent and visualize primitives such as parallelism, concurrency, synchronization, mutual exclusion, etc. Considering the supply chains, PNs and their variations have been applied to model supply chains due to its characteristic of DES (Villani et al., 2007; Miyagi et al., 2009).

According to Martins (2010), some of the special characteristics of states in a dynamic system are coherence, similar direction, simultaneous and making a decision. The states can be successfully designed by PNs. Based on the figure 5(a), we see that transition t2 can fire just after t1 is fired. This situation shows priority condition *"t2 after t1"*.

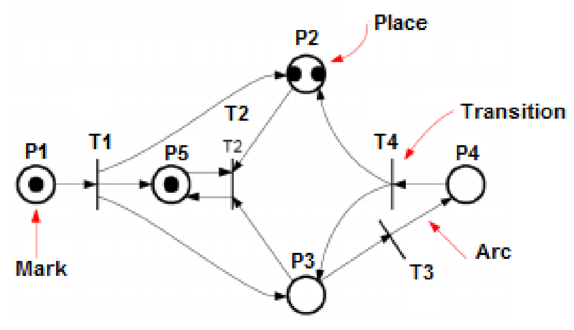

Figure 4. A Petri net representation.
Source: Peterson (1981)

For a dynamic system, priority condition is significant. Causal connections including operations are stated by Petri net. Based on figure 5(b), although Transition t1 and t2 are enable, if any transition is fired, other transition will be disabled.

A probabilistic approaching or a nondeterministic way using suitable probabilities to this conflicting transition can cope with the resulting conflict.

Based on figure 5 (c), Transition t1 and t2 are in concurrency. In system interactions, concurrency is a significant feature.

A required condition of which transition can be concurrent emphasize that forking transition of depositing a Mark (or token) in at least two out places existed. Based on figure 5 (d), considering a dynamic system, an incident often consists of resources, synchronization of which can be arranged by transitions.

Only if p1 and p2 has a mark (or token), t1 can be enabled. Based o figure 5 (e), due to constraints on the mutual used resources, if they cannot be carried out simultaneously, two processes are mutually exclusive.

Based on figure 5 (f), an inhibitor arc is introduced, wich creates a way between a transition and an input place. This arc is emphasized by using a small circle. If the numbers of mark (or token) of every input place should be equal to or greater than weight of arc, a transition is considered enabled. An inhibitor arc which connects a input place arc linked transition by a normal arc. If there are not marks (or tokens), there is not connection from inhibitor arc to transition. When it compares to places connected with a normal way, firing rule of the transition is the same. Nevertheless, the firing of transition does not turn into inhibitor arc which is linked places. To activate *t1*, *p1* should include a mark (or token). However, to activate *t2*, *p2* should include a mark (or token) and p1 should include no mark (or token). This approaching present that t1 has precedence on t2.

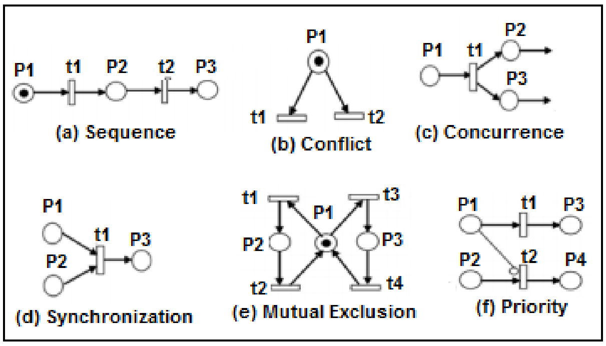

Figure 5. Basic principles of Petri net to design system

2.4 The Robot Emmy II and its Control System "*Para*Control"

The Emmy's robot is the first robot in the world developed with a control system based on PAL (*Para*Control). It was part of a doctoral thesis of professor João Inácio da Silva Filho (Da Silva Filho, 1999). Recently, the robot Emmy I was updated by professor Claudio Rodrigo Torres (Torres et al., 2007).

The robot Emmy II has two ultrasonic sensors (S1) and (S2) that avoid collisions (Figure 6). The *Para*Control is the brain of the Emmy's robot, that means, it is in charge of all the itinerary of movements based on the concepts of the Paraconsistent Annotated Logic with annotation of two valus (PAL2v). The robot Emmy II is based on six logical states: State V (true), state F (false), state ⊥ (Paracomplete), state ⊤ (Inconsistent), state QF→⊤ (almost false tending to inconsistent) and state QF→⊥ (almost false tending to paracomplete).

The possible movements of the robot Emmy II are also described on table 1. For each state, the perspective decision is:

<u>State V (True):</u> goes to front. The motors 1 and 2 receive orders to go straight to front;

<u>State F (False):</u> goes to back. The motors 1 and 2 receive orders to go straight to back;

<u>State ⊥ (Paracomplete):</u> spining 45 degress to the right. Only the motor 1 receives orders to go straight to front;

<u>State ⊤ (Inconsistent):</u> spining 45 degrees to the left. Only the motor 2 receives orders to go straight to front;

<u>State QF→⊤ (almost false tending to inconsistent):</u> spining 45 degress to the right. Only the motor 2 receives orders to go straight to back;

<u>State QF→⊥ (almost false tending to paracomplete):</u> spining 45 degress to the left. Only the motor 1 receives orders to go straight to back.

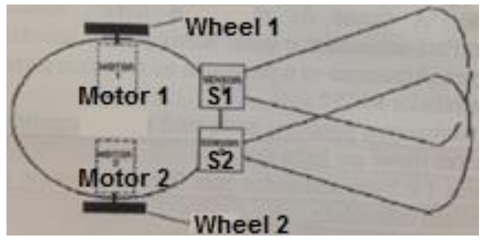

Figure 6. The basic structure of the Robot Emmy II
Source: Torres et al., 2007.

When the state is True (V), that means that the front of the robot is free. Therefore, the robot can move straight to front. When the state is Incosistent (*T*), μ and λ receives high values, that means that the sensor 1 is far away from an obstacle and the sensor 2 is near an obstacle. Thus, the action will be spining 45 degrees to the right side by giving orders only to the motor 2 to move straight to front.

When the state is Paracomplete (⊥), μ and λ receives low values. That means that the sensor 1 is near an obstacle and the sensor 2 is far away from an obstacle. Thus, the action will be spining 45 degrees to the right side by giving orders only to the motor 1 to move straight to front. When the False (F), both sensors are very near an obstacle and the action is to move straight to back.

When the state is Almost false tending to inconsistent (QF→⊤), the front of the robot keep being near an obstacle, where the obstacle is not near as the false state (F) and the left side of the robot is a little bit far from the obstacle if compared to the right side. Thus, the decision is spining to the left side, giving orders only to the motor 1 to go straight to back.

When the state is Almost false tending to paracomplete (QF→⊥), the front of the robot keep being near an obstacle, where the obstacle in not near as the false state (F) and the right side is a little bit far from the obstacle if compared to the left side. Thus, the decision is spining to the right side, giving orders only to the motor 2 to go straight to back.

2. Methodology

In this section it is presented the methodology based on the principles of the Petri net (figure 5), such as: sequential execution, conflict, concurrency, synchronization, and mutual exclusive. For modeling of the movement of Emmy II, it is necessary to focus on the *Para*Control logic to define places and transitions (table 1) of possible itinerary. Furthermore, for using Petri net technique as an effective technique, users should follow rules which are accessibility and reversibility of PN net.

Table 1. Interpretation of places and transitions related to the possible movements of the robot Emmy II.

NAME	TYPE	DESCRIPTION
P1	Place	Interpreted data to move.
T1	Transition	Process data to move.
P2	Place	Move straight to front.
T2	Transition	Transmit the signal to motors 1 and 2 at the same time.
P3	Place	Move straight to back.
T3	Transition	Transmit the signal to motors 1 and 2 at the same time.
P4	Place	Spinning 45 degrees to the right side to go to straight to front.
T4	Transition	Transmit the signal only to motor 1 to go straight to front.
P5	Place	Spinning 45 degrees to the left side to go to straight front.
T5	Transition	Transmit the signal only to motor 2 to go straight to front.
P6	Place	Keep moving straight to front.
T6	Transition	Transmit the signal to motors 1 and 2 at the same time.
P7	Place	Stop completely.
T7	Transition	Process data to stop.
P8	Place	Spinning 45 degrees to the right side to go straight to back.
T8	Transition	Transmit the signal only to motor 2 to go straight to back.
P9	Place	Spinning 45 degrees to the left side to go straight to back.
T9	Transition	Transmit the signal only to motor 1 to go straight to back.
P10	Place	Keep moving straight to back.
T10	Transition	Transmit the signal to motors 1 and 2 at the same time.

When PN is considered to examine for some errors, the user have to be interested in basic functions which is operated, including particular transitions, which reduces ther possibility of having fails of mobile robot. In the table 1 above, modeled PN has ten different places and ten transitions (from P1 to P10 and from T1 to T10). First of all, the system holds oneself ready to take data from sensors, after initializing processes are completed. Secondly, this data is interpreted on control unit. Finally, interpreted data activates the movements according to the *Para*Control logic.

Once the system has been initialized, after the determination of current situation, the Emmy's robot decides where to go in terms of speed and direction. This information is then interpreted, if the "ready" place (P1) includes also a usable mark (or token), to activate "process the data" transition T1.

Via these interpreted data, control board motors of movement, so locomotion of mechanism occurs.

When an obstacle is in front, the robot spin to the right or to the left, going straight to front or going straight to back to avoid a collision with a certain object.

3. The Modeling Application

In this section it will be described the method application of a PN modeling based on the Table 1. There are two different activities to consider, "go to front" (P2) and "go to back" (P3). In this case, to avoid conflict of interests, PN fire the mark (or token) based on rules by considering the decisions of the robot Emmy II.

If the decision is "go to front", it can happen P3, P4, P5, P6, P7 and if the decision is "go to back", it can happen P8, P9, P10, P7.

Following the identification steps from table 1, places and transitions are described on the PN model of the figure 7.

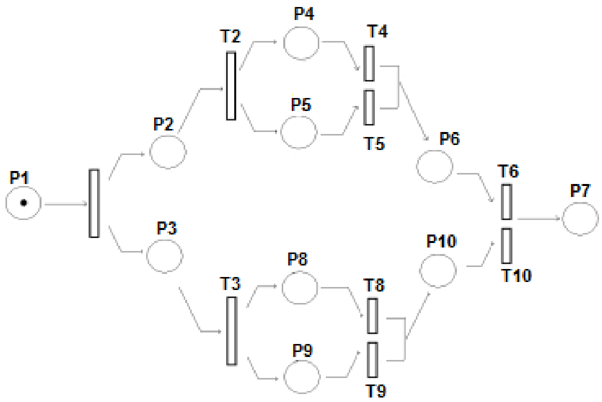

Figure 7. The Petri net model of the Emmy's possible movements

For normal itinerary by not considering any obstacle, the robot Emmy moves straight to front. If any obstacle appears, the robot Emmy turns to the right side or to the left side by spinning (it depends of the obstacle direction to the right or to the left sides) in order to go straight to front side or straight to back side. It stops completely if it there is no option to move or if the order is a full stop.

4. Conclusion

This paper applies Petri net technique to represent graphically the possible movements of the robot Emmy II, which are based on Emmy's Control System also called *Para*Control. Furthermore, Emmy's possible movements are based on six logical states: State V (true), state F (false), state ⊥ (Paracomplete), state T (Inconsistent), state QF→T (almost false tending to inconsistent) and state QF→⊥ (almost false tending to paracomplete), which are presented on Table 1. Based on figure 7, it was simulated the construction of the Petri net model for the possible Emmy's movement (from P1 to P10 and from T1 to T10). Thus, this paper contributes to the research group from the LaboLPA – *Laboratory of the Paraconsistent Annotated Logic* from the University of Santa Cecília (UNISANTA) by developing an interpretation of the *Para*Control movements to the robot Emmy II by using the Petri net technique.

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