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Paraconsistent Algorithm Extractor of Contradiction Effects—*ParaExtr$_{ctr}$*

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ABSTRACT

Nowadays networks of analyses based in non-classic logics are used with success in the treatment of uncertainties. The characteristic of accepting the contradiction in his structure is the main cause of the methodologies based in Paraconsistent Logic is ideals for applications in systems of analyses and decision making. In this work we presented an algorithm based in Paraconsistent logic capable to extract in a gradual way the effects of the contradiction in originated signals of information of uncertain knowledge database. The Algorithm Paraconsistent Extractor of Contradiction effects—ParaExtr$_{ctr}$ is formed with base in fundamental concepts of the Paraconsistent Annotated Logic with annotation of two values (PAL2v) it can be applied in filters of networks of analyses of signal information where uncertain and contradictory signals can be present. The process of extraction of the effect of the contradiction is always begun by the largest inconsistency degree among two signals that belong to the group that is in analysis. In the end of the analysis it is found a consensus value. In this work we presented numeric example and one example of application of the ParaExtr$_{ctr}$ in Load Profile Forecast used in support to decision of the operation in an Electric Power System, but his application potentiality is demonstrated in several fields of the Artificial Intelligence.

Keywords: *Algorithm*, *Non-Classic Logic*, *Paraconsistent Annotated Logic*

1. Introduction

The contradictions or inconsistencies are common when we described parts of the real world; however most of the Expert systems for decision making are based in the binary classic logic. In spite of the classic logic to be the base of the whole current technology, it is limited by rigid binary laws and their algorithms present difficulties to treat complex systems conveniently where the signals of information are just constituted of evidences [1-3]. Acting in a faithful way the existent limits in the real world the signals constitutes evidences arrivals of several sources, that bring joined several situations ambiguous, or contradictory that they are unable of be accepted by the classic logic [4,5]. To solve problems, and to give appropriate form of treatment front the situations no recognized by the classic logic, every day has been used new methods for applications of logics denominated non-classic, among them, the paraconsistent logics [6,7]. In-that work we presented an algorithm built from a special type of logic denominated Paraconsistent Annotated Logic (PAL) and whose main foundations will be described to proceed.

2. The Paraconsistent Logic

Paraconsistent logics (PLs) belong to the class of the non-classic logics and were idealized by the need of finding means of giving appropriate treatments to the contradictory situations [8]. In many studies [5,9] and [10] the PLs presented results that make possible to consider the inconsistencies in his structure in a no trivial way and for that, that logic type is shown more favorable in the resolution of problems caused by situations of contradictions that appear when we worked with the real world. Among the several types of Paraconsistent Logics exists a class of Paraconsistente Annotated Logic (PAL) that have an associated Lattice and were introduced for the first time in logical programming by Subrahmanian [10-12]. The Paraconsistent Algorithm Extractor of Contradiction ef-

fects—*ParaExtr*$_{ctr}$ uses the methods of uncertainty treatment based in an extension of the Paraconsistent Logic denominated of Paraconsistent Annotated Logic with annotation of two values (PAL2v) [3,13].

2.1. The Lattice Associated to the Paraconsistent Annotated Logic

In the Paraconsistent Annotated Logic (PAL) the propositional formulas come accompanied of annotations [3,10,12]. Each annotation, belonging to a Lattice finite τ attributes values to his correspondent propositional formula. To obtain a larger representation a Lattice associated at LPA is used (**Figure 1**).

The representation of paraconsistent logical state is formed by pairs orderly, such that:

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

An operator is considered ~: |τ|, where the operator ~ it constitutes the "meaning" of the logical negation symbol of the system that will be analyzed [3,9,11].

If *P* is a basic formula, then the operator ~: |τ|, it is defined as:

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

It is considered then: (μ, λ) an Annotation of *P*.

The orderly pair's first element represents the Evidence Degree that is favorable to the proposition *P*, and the second element represents the Evidence Degree that is unfavorable or contrary to the same proposition [3]. This way, the intuitive idea of the association of an annotation to a proposition $P_{(\mu, \lambda)}$ means that the evidence degree favorable to *P* is μ, while the evidence degree unfavorable or contrary to *P* is λ.

Through the methods presented in [3], a system using the Paraconsistent Annotated Logic receives signals of information in the form of degrees of evidence with values that vary from 0 to 1. These values can be placed in two representing axes of finite lattice (**Figure 2(a)**) were calculating the Certainty Degree (D_C) and the Contradiction Degree (D_{ct}) through the equations:

$$D_{ct} = \mu + \lambda - 1 \quad (1)$$

and

$$D_C = \mu - \lambda \quad (2)$$

The Contradiction Degree value (D_{ct}) is an indicative of the inconsistency measure and the certainty degree value (D_C) is considered as the result of the analysis.

3. The Paraconsistent Analysis Nodes—PAN

The element capable of treating a signal that is composed of one degree of favorable evidence and another of unfavorable evidence (μ_{1a}, μ_{2a}), and provide in its output a Resulting Evidence Degree, is called basic Paraconsistent

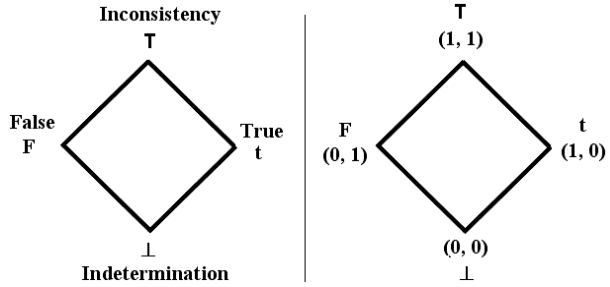

Figure 1. Finite lattice of the PAL2v four states with values.

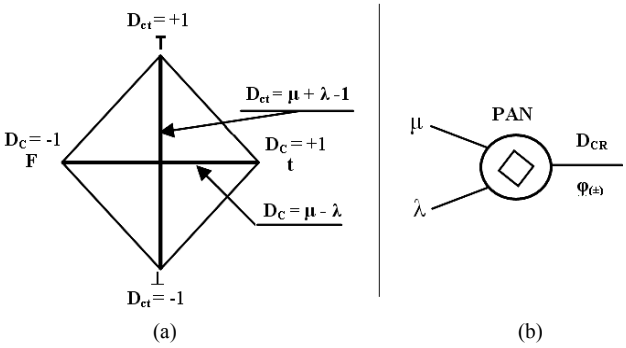

Figure 2. Finite lattice of PAL2v and symbol of the paraconsistent analyzer node—PAN.

Analysis Node (PANb). **Figure 2(b)** shows the representtation of a PANb with two inputs of evidence degree:

μ_1 = favorable Evidence Degree of information source 1.

λ = unfavorable Evidence Degree.

where: $\lambda = 1 - \mu_2$

μ_2 is a favorable Evidence Degree of information source 2.

A lattice description uses the values obtained by the equation results in the Paraconsistent Analyzer Node Algorithm [3,13,14] that can be written in a reduced form, as follows:

1) Enter with the input values.

μ*/ favorable evidence Degree $0 \le \mu \le 1$

λ*/ unfavorable evidence Degree $0 \le \lambda \le 1$

2) Calculate the Contradiction Degree.

$$D_{ct} = \mu + \lambda - 1$$

3) Calculate the Certainty Degree.

$$D_C = \mu - \lambda$$

4) Calculate the distance *d* of the Paraconsistent logical state into Lattice.

$$d = \sqrt{(1 - |D_C|)^2 + D_{ct}^2}$$

5) Compute the output signal.

If $d \ge 1$ Then do S1 = 0.5 and

S2 = φ: Indefinite logical state

and go to the steep 10

Or else go to the next step

6) Calculate the real Certainty Degree.

$$If \quad D_C > 0 \qquad D_{CR} = (1 - d)$$
$$If \quad D_C < 0 \qquad D_{CR} = (d - 1)$$

7) Present the output.

Do $S1 = D_{CR}$

8) Calculate the real Evidence Degree.

$$\mu_{ER} = \frac{D_{CR} + 1}{2}$$

9) Present the output.

Do $S1 = \mu_{ER}$ and $S2 = D_{ct}$

10) End.

The Systems with the Paraconsistent Analysis Nodes (PAN) deal with the received signals through algorithms, and present the signals with a Certainty Degree value and a Contradiction Degree value in the output [3].

4. The Paraconsistent Algorithm Extractor of Contradiction Effects—*ParaExtr*$_{ctr}$

The Paraconsistent Algorithm Extractor of Contradiction effects (*ParaExtr*$_{ctr}$) is composed by connections among PANs. This configuration forms a Paraconsistent Analyze Network capable to extract the effects of the contradictt-ion in gradual way of the signals of information that come from Uncertain Knowledge Database. The hypothesis of extraction of the effects of the contradiction has as principle that; if the first treated signals are the most contradictory, then the result of the paraconsistent analysis will converge for a consensual value. In his typical operation the *ParaExtr*$_{ctr}$ receives a group of signals of information represented by Degrees of Evidence (μ_E) the regarding certain proposition *P* and, independently of other external information, it makes paraconsistent analysis in their values where, gradually, it is going extracting the effects from the contradiction to remain as output a single resulting Real Evidence Degree μ_{ER}.

The μ_{ER} is the representative value of the group of input signals after the process of extraction of the effects of the contradiction. The **Figure 3** shows the representation of the algorithm Extractor of Contradiction effects that uses a network of three PANs.

The description of the *ParaExtr*$_{ctr}$ Algorithm is shown to proceed.

1) Present *n* values of Evidence Degrees that it composes the group in study.

$G\mu = (\mu_A, \mu_B, \mu_C, \cdots, \mu_n)$ */Evidence Degrees $0 \leq \mu \leq 1$*/

2) Select the largest value among the Evidence Degrees of the group in study.

$$\mu_{maxA} = \max(\mu_A, \mu_B, \mu_C, \cdots, \mu_n)$$

3) Consider the largest value among the Evidence Degrees of the group in study in favorable Evidence Degree.

$$\mu_{maxA} = \mu_{sel}$$

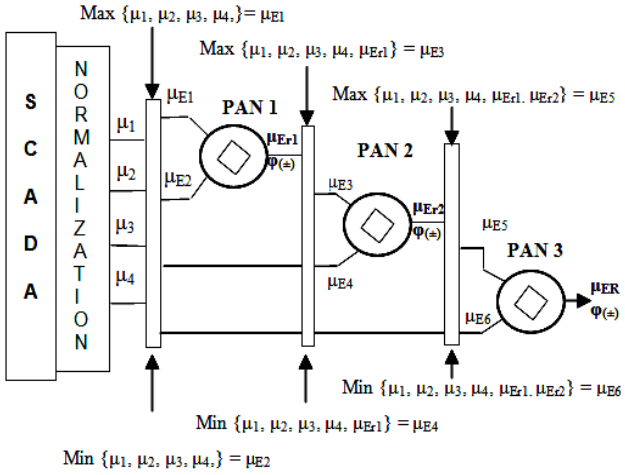

Figure 3. Paraconsistent algorithm extractor of contradiction effects (*ParaExtr*$_{ctr}$).

4) Consider the smallest value among the Evidence Degrees of the group in study in favorable Evidence Degree.

$$\mu_{minA} = \min(\mu_A, \mu_B, \mu_C, \cdots, \mu_n)$$

5) Transform the smallest value among the Evidence Degrees of the group in study in unfavorable Evidence Degree.

$$1 - \mu_{minA} = \lambda_{sel}$$

6) Make the Paraconsistent analysis among the selected values:

$\mu_{R1} = \mu_{sel} \lozenge \lambda_{sel}$ */where $\lozenge$ is a paraconsistent action of the PAN */

7) Increase the obtained value μ_{R1} in the group in study, excluding of this the two values μ_{max} and μ_{min}, selected previously.

$G\mu = (\mu_A, \mu_B, \mu_C, \cdots, \mu_n, \mu_{R1}) - (\mu_{maxA}, \mu_{minA})$

8) Return to the item 2 until that the Group in study has only 1 element resulting from the analyses.

Go to item 2 until $G\mu = (\mu_{ER})$

5. Application forms of the *ParaExtr*$_{ctr}$ Algorithm

For the paraconsistent analysis that it uses the *ParaExtr*$_{ctr}$ Algorithm the information signals in the form of measures of physical greatness are obtained in uncertain database. That information is representatives of attributes gotten usually through subjective answers that just generate evidences regarding the analyzed proposition *P*. In that way, the obtained information can come represented by resulting numbers of quantitative analyses exposed in tables and in the percentile form. To receive the treatment through the *ParaExtr*$_{ctr}$ Algorithm the values of the Database are normalized inside of an Interval of Interest—or Discourse Universe—resulting in Evidences Degrees valued between 0 and 1. At the end of the analysis made

by the *ParaExtr*$_{ctr}$ Algorithm the Resulting Evidence Degree will be the real representative of the group composed by n Degrees of Evidence applied in the inputs. With the value of the Resulting Evidence Degree a process of undo normalization can be made to recover it resulting as measure of the analyzed greatness. The **Figure 4** presents the flow of signals in the paraconsistent analysis with *ParaExtr*$_{ctr}$ Algorithm.

5.1. Explanatory Example of Use of the *ParaExtr*$_{ctr}$ Algorithm

We presented to follow an example of application of the *ParaExtr*$_{ctr}$ Algorithm treating contradictory values obtained in a Database of an Electric Power System [15,16]. Consider that a Database presents values of the greatness electric of potency in the form of measurements obtained in quilowatts (Kw). An example of different measurements in the monitored points is shown in the **Table 1**.

The monitored points are obtained of different type of measuring devices. These measurement devices should bring measures of same values and, in some cases, different values. This happen by several reasons, as differences of quality of the measure devices, flaws in the obtaining of the values and mistakes of readings. In this process, in certain instant can happen that contradictory values exist in the t_1 time, or in t_2, or in t_3 and in t_4.

The definition of the Universe of Discourse and the variation of the greatness in the interval will be important for the generation of the Evidence Degrees.

For that explanatory example we will consider a Universe of Discourse of 5.0 up to 9.0 Kw with linear variation. The **Table 2** shows the result of the application of the *ParaExtr*$_{ctr}$ Algorithm in the extraction of the contradiction effects in the four signals in each one of the time t and in four times t_1, t_2, t_3 and t_4.

5.2. The *ParaExtr*$_{ctr}$ Algorithm Applied in Forecast of Load Profile of Electric Power Systems

The innovative form of doing treatment of signals allows

Table 1. Measured different values in four monitored points.

Monitored points	A	B	C	D
Measurement instants	t_1	t_2	t_3	t_4
Measured values (Kw)	7.800	7.900	6.800	8.300
	7.956	8.900	7.200	7.300
	6.960	8.100	7.100	9.300
	7.750	7.180	8.100	8.700

Table 2. Evidence Degrees in four monitored points and the Resultant Evidence Degree after extract the effects of contradiction.

Monitored points	A	B	C	D
Measurement instants	t_1	t_2	t_3	t_4
Evidence Degrees μ_n Universe Discourse 5.0 Kw → 9.0 Kw Lineal variation	0.7000	0.7250	0.4500	0.8250
	0.7390	0.9750	0.5500	05750
	0.4900	0.7750	0.5250	1.0000
	0.6895	0.5450	0.7750	0.9250
***ParaExtr*$_{ctr}$ Algorithm action**				
Resultant Evidence Degrees to each instant t	μ_{ER1}	μ_{ER2}	μ_{ER3}	μ_{ER4}
	0.6648	**0.7235**	**0.5508**	**0.8018**
Resultant Evidence Degrees in four instants: t_1, t_2, t_3 and t_4	**0.67531313**			

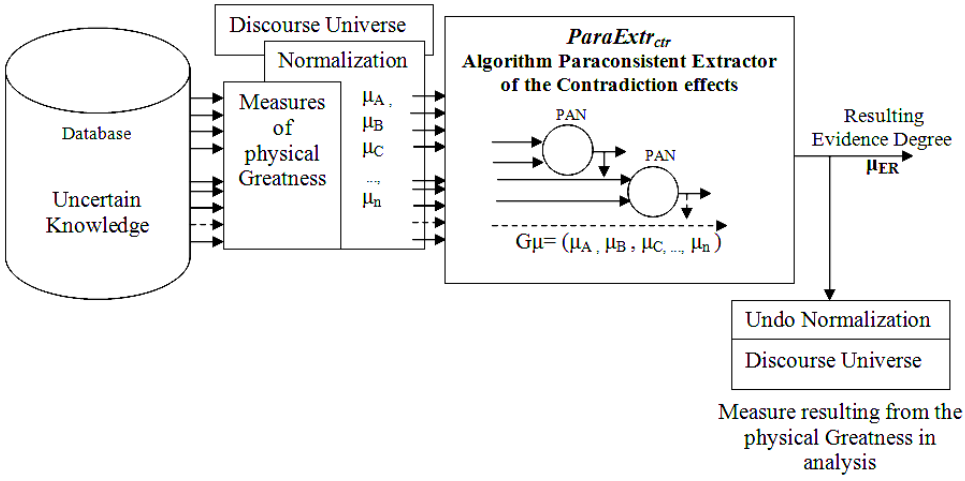

Figure 4. Signals flow in an application of the paraconsistent algorithm extractor of contradiction effects (*ParaExtr*$_{ctr}$).

that the *ParaExtr*$_{ctr}$ Algorithm can be applied in several fields where it is necessary the use of Artificial Intelligence techniques. As a real application in AI systems it is mentioned as example, a forecast accomplished in the Substation ETD Pattern 40/60 MVA of the Power Electric System of concessionary of Electric power that acts in Brazil [2,15].

In this study, as source of information for the forecast, is used a historic database where are considered the values of load that are related to the secondary windings of the two input transformers.

The four signals, that bring the values regarding to the three phases (RST), receive the paraconsistent logical treatment by the *ParaExtr*$_{ctr}$ Algorithm in the beginning forecast.

Once obtained the values of the load, these are normalized and they will be inside of the closed interval [0,1] in the set of the real numbers. In that way, the data will be ready for the treatment according to the PAL2v foundations.

The extraction of the contradiction effect in three phases (RST), are shown in the graph on the **Figure 5**.

The normalized values of the three phases are applied in the module of the *ParaExtr*$_{ctr}$ Algorithm and, after the paraconsistent treatment logical results in an only value of Evidence Degree of the load profile. In this way the graphic scenery of the electric load Profile is created according to shown in **Figure 6**.

Several tests were made comparing the values of the historic database with the values obtained through the *ParaExtr*$_{ctr}$ Algorithm, showing a great approach of the real results. Now this Load Profile Forecast System is

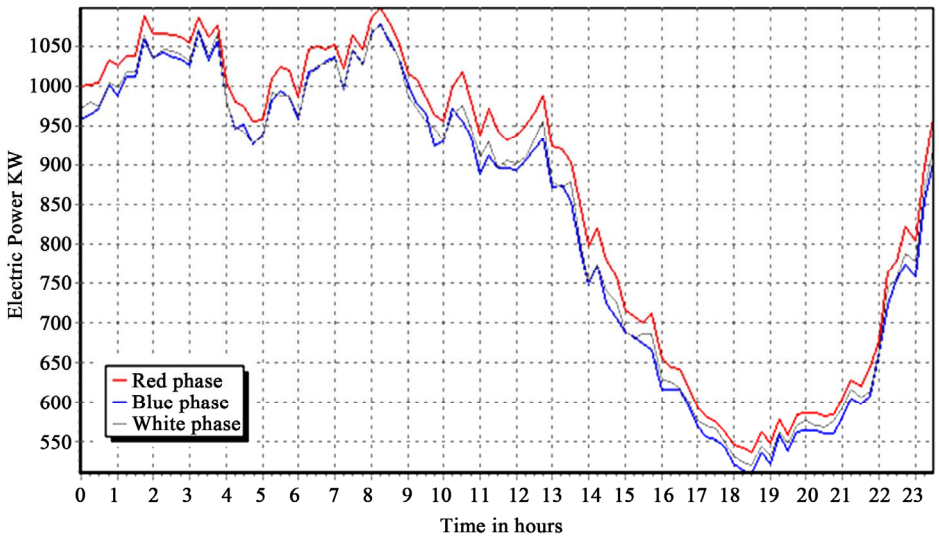

Figure 5. Values graphs of three signals that received treatment of the *ParaExtr*$_{ctr}$ algorithm and they will serve as reference for the elaboration of forecast of profiles loads in the Power Electric System.

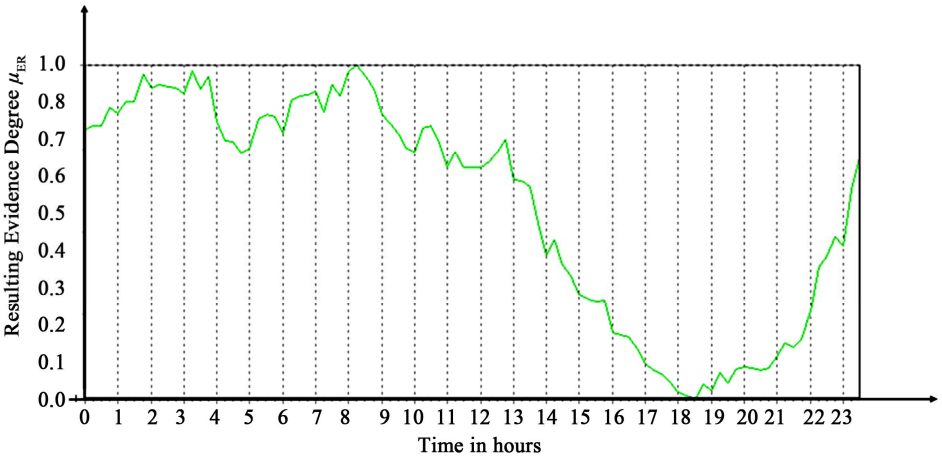

Figure 6. Result graph of the load profile forecast using the *ParaExtr*$_{ctr}$ algorithm where the curve is made with values of resulting evidence degrees.

being used for training and support to the operation of Power Electric System in Eletropaulo Company—Brazil.

6. Conclusions

In this work we presented the *ParaExtr*$_{ctr}$ Algorithm that is capable to extract contradiction effects in groups of evidence signals the regarding certain Proposition through basic concepts of the Paraconsistent Logic. In the end of the analysis, the *ParaExtr*$_{ctr}$ Algorithm presents as result a Real Evidence Degree representative of the Evidence Degree group. In that process of Paraconsistent analysis the *ParaExtr*$_{ctr}$ Algorithm uses the denominated PAN-Paraconsistent Analysis Nodes. In a gradual way the PANs filter the effects of the contradiction in the signals of information until that it is found the Degree of Evidence resulting from the group. The results demonstrate that the *ParaExtr*$_{ctr}$ algorithm has capacity to remove of database the values tuneless or contradictory.

The extraction process reduces the effects of the inconsistencies and it presents as answer a closer representative value of the reality. In that way, with the *ParaExtr*$_{ctr}$ Algorithm new structures and different configurations of networks of analyses can be formed for treatment of Uncertainties.

The methods used in this work are based in a special Paraconsistent logic denominated of PAL2v and they have been applied with success in the determination of patterns, and in making decision systems, as well as in different areas of the knowledge where are necessary the performance of Intelligent Systems.

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