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An Expert System Structured in Paraconsistent Annotated Logic for Analysis and Monitoring of the Level of Sea Water Pollutants

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1. Introduction

This chapter presents the development of a Expert System which was elaborated based on the Fundamentals of Paraconsistent Annotated Logic and aimed to help in the process of detection of physiological stress in organisms exposed to water pollution. The Paraconsistent Logic is a non-classical logic present as their main characteristics the acceptance of the contradiction in their structure. It is presented in this study the algorithms extracted from a type of Paraconsistent Logic nominated Paraconsistent Annotated Logic with annotation of two values PAL2v that are capable of simulating the applied methodology in Biology known as a neutral red retention assay. This method of biomarkers prepared with specific procedures has the goal of finding rates of exposure to marine pollution through the manipulation and study of cells from mussels. It was built a configuration of Paraconsistent Artificial Neural Network (PANN) composed of algorithms based on the principals of Paraconsistent Logic to compose the Expert System with the goal of simulating the biological method and help in the presentation of the cellular response. The process of analysis elaborated by the software consists of making a comparison with pre-established patterns through the Paraconsistent Network by biochemical/biological processes consolidated in the biology area and defined in the scope on the mussels cells' measures that presented determined behavior and biochemical reactions, as it is the biomarker of exposure and effect of marine pollution in the site of the samples collection. With this new approach of results, besides complete, they are presented as being more efficient by decreasing the points of uncertainty given by simple human observation. This way this work opens new fields for research of application of Artificial Intelligence techniques in the analysis and monitoring of the Marine Pollution.

2. The pollution problem

Used as man's source of food, raw material source and, afterwards, as a means of transportation, the oceans occupy practically 71% of the earth surface [NASCIMENTO et al 2002]. Nowadays, half of the world population is located in cities by the coast or in nearby

regions. As a consequence of this, the marine environment, mainly coastal, ends up being affected by the debris of the human population, bringing up the difficult problem of marine pollution. In Brazil, there are two types of prior actions of pollution that reach more than 8 thousand kilometers of coast [NASCIMENTO et al 2002]. The first type is the marine and coast contamination from sewage and garbage, whose environmental and social consequences are felt instantly. Besides that, there is the sediment discharge in rivers coming from the deforestation and bad usage of the soil that also contributes to the increase of contamination in coastal areas. The second type involves the contamination from chemical polluents, mainly hydrocarbonates of petroleum and other persistent organic components and trace metals.

2.1 Polluents

It is known that the problem with pollution is associated to the characteristics of toxicity, persistency and bioaccumulation of substances linked to matters of social and economical costs [SOS TERRA VIDA 2005]. Among the groups of potentially damaging substances to the marine environment there are the ones classified as domestic sewage, petroleum and derivatives, trace metals, radioactive and organochloride materials. Among these, the domestic sewage is the biggest problem worldwide, being a volume of polluent material as well as related to concrete problems that cause public health damage. Relating to petroleum and derivatives, which are a basic energetic resource for our civilization, the pollution is a consequence of the huge volume transported and produced annually. They are stable and persistent and they cannot be degraded or destroyed by any biological or chemical process. The insertion of heavy metals in the oceans is mainly due to the industrial effluents in coastal areas. The radioactive materials, that are also a polluent source in the marine environment, are a consequence of decades of radioactive dejects that were settled or stocked in an inadequate way when produced by the nuclear industry. The organochlorides are very stable organic components, not much soluble in water, but very soluble or associate in lipids; therefore, they are easily bioaccumulated in organic structures. These components are widely disseminated in the ecosystems and their toxic effects may cause hepatic disturbance and affect the immunological and reproductive system of aquatic organisms.

2.2 The biomarkers for environmental diagnosis

The cell structures can be biochemically affected in the presence of sub lethal polluent concentrations, non stabilizing the internal balance of the cell [NICHOLSON, 2001]. These biological effects cause organic damage in species that act in a lasting and persistent way because the mechanisms of adaptation to the modified environment suffer from exhaustion and cannot stimulate the perfect functioning of the systems anymore, which leads the organic structures to death.

Through the usage of sensible biomarkers, a previous detection of stress in sub lethal levels in aquatic organic structures may help in the evaluation and environmental diagnosis before several changes reach the ecosystem. Some efficient and practical techniques that are already adapted to the local sensible organic structures are available for application in the monitoring of marine pollution.

3. Evaluation techniques for marine pollution

One of the biological procedures that employ biomarkers to assess marine pollution through de determination of physiological stress in by evaluating the integrity of lysosomal

membrane is named Neutral Red Retention Assay [NICHOLSON, 2001]. This method consists in evaluating the environmental conditions and the bioavailability and effects of contaminants through the analysis of the biochemical and cellular answers of the local species before the animals suffer effects physiologically irreversible, reaching populations or even ecosystems. It can be verified that the toxicity of industrial effluents, the quality of the water and sediment in coastal ecosystems, the level of stress suffered by organic structures due to alterations in environmental conditions and the effect of substances or mixtures (synergism, addiction or antagonisms) having as variable the concentrations or time of exposure of these components.

3.1 Organism- test

The mussel used in the neutral red test for this procedure is the *Perna perna,* an organism of easy collection, with a bentonic habit that, for being sedentary and filter-feeding, it is potentially more subject to the action of toxic agents. Besides, these bivalves are tolerant for polluted environments; therefore, they accumulate in their tissues toxic substances that can be harmful to their own survival [KING, 2000].

The haemocytes of *Perna perna* showed the ability of discriminating impacted and non impacted areas through the integrity test of lysosomal membranes being able to be used as a quick and sensible biomarker in the detection of stress of beings as it is possible to have a correlation with chronic sub lethal effects.

3.2 Method of Neutral Red retention

The method used for analysis of time of retention of the neutral red dye [NICHOLSON, 2001] in haemocytes lysossome is described by Lowe [LOWE et al, 1995] as follows:

Using a hypodermic syringe of 2ml having 0,5ml of physiological solution, it is collected 0,5 ml of haemolymph of the posterior adductor muscle of the mussel. The content of the syringe is transferred to tubes of micro centrifuge of 2ml where it will be smoothly homogenized. 40 µl of this solution is put on a tube (haemolymph + physiological solution) over the surface of a slide treated previously with poly- L-lysine. These slides are incubated for 15 minutes in a dark and humid chamber. After the time of incubation, it is put over the slides 40 µl of solution of Neutral Red (NR). It is necessary 15 minutes more of incubation in the dark and humid chamber before starting the observations. In the first hour, the slides are examined every 15 minutes and in the second hour they are examined every 30 minutes. The final observation is performed after 180 minutes of exposure.

The NR retention time is obtained by the estimative of the proportion of cells showing liberation of dye for citosol and/or showing abnormalities in size, shape and color of lysosomes. At each time, the conditions are written down on a chart. It is important to point out that the slides must be observed on the microscope in the shortest time possible. This is to assure the consistency in the exam and because the neutral red is photosensitive. Once the lysosomes are responsible for the cellular digestion and gather a high concentration of contaminants, the destabilization of the lysosomal membrane in haemocytes exposed to expect environmental contaminants are affected faster by the toxin of the dye than healthy cells. Therefore, the necessary time to happen extravasations of Neutral Red dye for the citosol may reflect on the state of integrity on lysosomal membrane and this can be used as an indicator of exposure to conditions of environmental contamination [KING, 2000].

3.3 Presentation of results of the method of Neutral Red retention

The healthy haemocytes are bigger and present an irregular shape and once exposed to Neutral Red, the lysosomes can be seen as pink tinted small dots joined and the nucleus can be seen as a colorless sphere as the citosol [KING, 2000]. Stressed haemocytes tend to be spherical and smaller having bigger and darker lysosomes and citosol may be pink tinted because of the dye contained in the lysosomes. So, the criteria analyzed when observing the slides would be:

Criteria	Healthy Cells	Stressed Cells
Cells shapes	irregular	rounded
Cells sizes	large	smaller
Number of lysosomes	many	few
Size of lysosomes	small	Enlarged/ increased
Color of lysosomes	Pale red/ pink	Red or dark pink, orange, brown
Pseudopodes	Non visible	visible
Dye leak from cells	Non visible	visible

Table 1. Criteria evaluated

When more than 50% observed cells do not present sign of stress, it is used positive sign + in the table field according to the animal examined. When the cells present some sign of stress, the sign **+/-** can be used. The analysis finish when 50% of the cells or more show abnormal structure or dye leak for citosol and the negative sign – is used on the table [KING, 2000].

Organic Structures	Time(minute)					
	15	30	45	60	90	120
Control	+	+	+	+	+	+
Little stress	+	+	±	±	-	-
A lot of stress	±	-	-	-	-	-

Table 2. Table of results

4. Application of Paraconsistent Logics in the simulation of the technique of the method of neutral red retention

As shown on tables 1 and 2 in the method of neutral red retention, the procedure of identification of cells that present or not signals of stress is performed through systematic observations on the slides in an objective way and totally dependent on the Observer. This way of collecting data is subject to a high level of uncertainty to the biological method described. This way, it can be used techniques for the treatment of uncertainty with the goal of getting better results of efficiency of the method.

Recently, multiple theories and techniques of treatment of uncertain signs are being developed in Artificial Intelligence applying non-classic logics in the most varied areas [ABE, 1992] [DA COSTA et al, 1991]. The Paraconsistent Logic is a non-classic logic that has an important characteristic of presenting as a main advantage the capacity of treating appropriately contradictory information and, in some cases, there are significant advantages relating to the binary classic logic [DA SILVA FILHO et al, 2010]. In this work is used some

Algorithms extracted from Paraconsistent Annotated Logic that are interlinked in a Network of Paraconsistent Analysis [DA SILVA FILHO, 1999]. Thus, the Expert System uses the techniques of adequacy of these Networks to detect the level of pollution in the sea through the information obtained by the biological method that promotes the neutral red retention assay for the analysis of images in blood cells of mussels. There is a brief description of Paraconsistent Annotated Logic below and the algorithms that will be used in the Expert System.

4.1 Paraconsistent Annotated Logics

The Paraconsistent Annotated Logics are classes of Paraconsistent Logics that have a lattice associate and were introduced for the first time in programming logic by Subrahmanian [SUBRAHMANIAN, 1987]. The methods for treatment of uncertainty here presented use the fundamentals of an extension of Paraconsistent Annotated Logics named Paraconsistent Annotated Logic with annotations of two values (PAL2v) [DA SILVA FILHO, 1999] in which the principals are presented as follows.

4.2 The lattice associated to Paraconsistent Annotated Logic with annotation of two values

In Paraconsistent Annotated Logics PAL the proposed formulas come with annotations. Each annotation, belonging to a finite lattice τ, attributes values to its propositional corresponding formula [DA SILVA FILHO, 1999]. To obtain a bigger Power of representation about the annotations, or evidences, it is expressed the knowledge about a proposition, it is used a lattice formed by ordered pairs, such as:

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

In which case, it is fixed an operator ~: $|\tau| \rightarrow |\tau|$ where; ~ has the "meaning" of logic symbol of negation $\neg$ from the system that will be considered.

If P is a basic formula, the operator $\sim : |\tau| \rightarrow |\tau|$ is defined as:

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

It is considered then:

(μ, λ): An annotation of P.

$P_{(\mu, \lambda)}$: P where the levels of favorable and unfavorable Evidence compose an Annotation that attributes a logical connotation to Proposition P.

This way the association of one annotation (μ, λ) to a proposition P means that the *Degree of Evidence* favorable in P is μ, while the unfavorable *Degree of Evidence*, or contrary, is λ.

Intuitively, in such lattice we have:

$P_{(\mu, \lambda)} = P_{(1, 0)}$: indicating 'existence of total favorable evidence and null unfavorable evidence', attributing a connotation of *Truth* to P proposition.

$P_{(\mu, \lambda)} = P_{(0, 1)}$: indicating 'existence of null favorable evidence and total unfavorable evidence', attributing a connotation of Falseness to P proposition.

$P_{(\mu, \lambda)} = P_{(1, 1)}$: indicating 'existence of total favorable evidence and total unfavorable evidence' attributing a connotation of Inconsistency to P proposition.

$P_{(\mu, \lambda)} = P_{(0, 0)}$: indicating 'existence of null favorable evidence and null unfavorable evidence', attributing a connotation of Indetermination to P proposition.

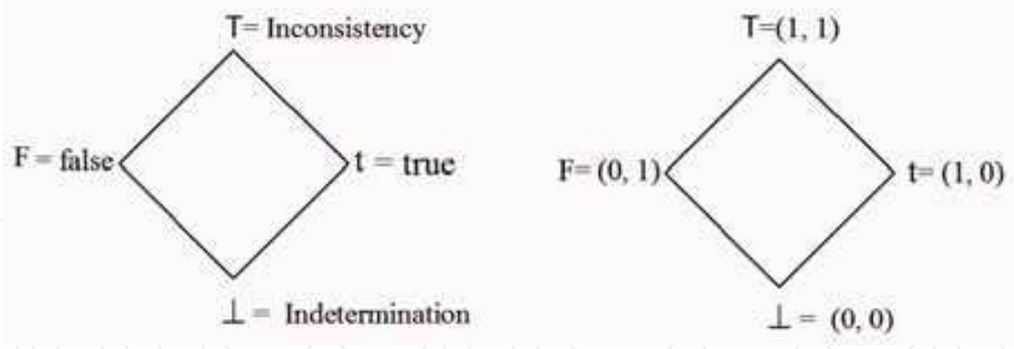


Fig. 1. Lattice associated to Paraconsistent Annotated Logics of annotation with two values PAL2v.

Through linear transformation in an unitary Square in a Cartesian Plan and the lattice represented by PAL2v we can reach the transformation [DA SILVA FILHO et al, 2010]:

$$T(\mathrm{x},\mathrm{y}) = (x - y, x + y - 1) \tag{1}$$

Relating the components of the transformation T(x, y) according to the usual terminology of PAL2v, as:

$x = \mu$ favorable Evidence Degree
$y = \lambda$ unfavorable Evidence Degree

The first term obtained in the ordered pair of the equation of transformation (1) is:

$$x - y = \mu - \lambda$$

which we name Certainty Degree D_C. So, the degree of certainty is obtained by:

$$D_C = \mu - \lambda \tag{2}$$

And its values, that belong to the set $\Re$, vary in a closed interval +1 and -1 and are in the horizontal axle of the lattice, which is named "Axle of the Degrees of Certainty". When D_C result in +1 it means that the logic state resulting in the Paraconsistent analysis is True t, and when D_C result in -1 it means that the logic state result in the analysis is False F.

The second term obtained in the ordered pair of the equation of transformation that is:

$$x + y - 1 = \mu + \lambda - 1$$

which is named Contradiction Degree D_{ct}. So, the Degree of Contradiction is obtained by:

$$D_{ct} = \mu + \lambda - 1 \tag{3}$$

And its values, that belong to the set $\Re$, vary in the closed interval +1 e -1 and are in the vertical axle vertical of the lattice, which is named "Axle of the Degrees of Contradiction". When D_{ct} result in +1 means the logic state of analysis is the Inconsistent $\top$, and when D_{ct} result in -1 meaning that the logic state resulting in the analysis is Indeterminate $\bot$.

In practice the values of the Degrees of Evidence μ and λ they are obtained of sources of information of the physical world through Interval of Interest, or Universe of Discourse, with units of physical greatness of normalized values. As the Degrees of Evidence are

independent, and whose values belong to the Set of the Real numbers, where they can vary in the interval between 0 and 1, then infinites logical states ε_τ are formed in the Lattice of LPA2v. The Paraconsistent Logical states are presented as:

$$\varepsilon_\tau = (D_C, D_{ct})$$

The result related to the Degree of Certainty D_C can be normalized becoming a Degree of Evidence that allows to be used as input for other LPA2v Algorithms. In that way, several propositions P1, P2,...can be analyzed through a a Network of Paraconsistent Analyses. The transformation of the Degree of Certainty in Degree of Evidence is made by the equation:

$$\mu_R = \frac{(\mu - \lambda) + 1}{2} \tag{4}$$

Were:

μ_R Resulting Evidence Degree
μ Favorable Evidence Degree
λ Unfavorable Evidence Degree

As example is considered the situation in that the measures made in the physical world present the following results:

$\mu = 0.89$ and $\lambda = 0.28$

Then the Degrees of Certainty and of Contradiction they are calculated by the equations (2) and (3), respectively:

$D_C = 0.89 - 0.28 = 0.61$

$D_{ct} = 0.89 + 0.28 - 1 = 0.17$

The Resulting Evidence Degree is calculated by the equation (4): $\mu_R = 0.805$

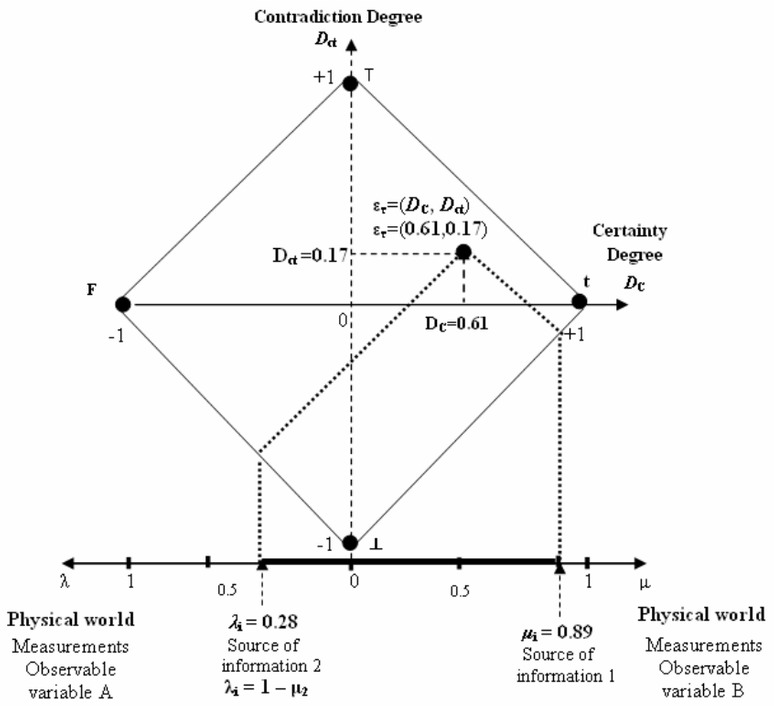


Fig. 2. Paraconsistent logical state ε_τ in the Lattice associated of the PAL2v.

In practice the value of the Degree it can return in the equation that established the Interval of Interest of the physical greatness for the decision making. The figure 2 shows a Paraconsistent logical state ε_τ that is constituted by the pair (D_C, D_{ct}) formed starting from the two degrees of evidence μ and λ given as example.

4.3 Artificial Paraconsistent neural cells

In the Paraconsistent analysis the main objective is to know the value, or degree of certainty, it can be assured that the proposition is False or True. So, it is considered as a result only the analysis of the value of certainty D_C. The value of degree of contradiction D_{ct} is an indicator that informs the measure of inconsistency about the information signals. If there is a low value of certainty or much inconsistency the result is undefined [DA SILVA FILHO et al, 2010]. In practice it is used values limits that help in the conclusions after the analysis of the proposition P. The Algorithm of the PAL2v Logic using values external limits is described to proceed.

4.3.1 Algorithm of the Paraconsistent Annotated Logic with annotation of two values

The Algorithm makes a paraconsistent analysis using only the equations obtained (2) e (3) of the lattice associated to PAL2v compared to the external limits:

*/ Input Variables */ μ, λ

The values for external limits:

$V_{icc,}$ Limit value for inferior certainty, such as: $-1 \leq V_{icc} \leq 0$

$V_{scc,,}$ Limit value for superior certainty, such as: $0 \leq V_{scc} \leq 1$

$V_{icct,}$ Limit value for inferior contradiction, such as: $-1 \leq V_{icct} \leq 0$

$V_{scct,,}$ Limit value for superior certainty, such as: $0 \leq V_{scct} \leq 1$

/Output Variables

Output Digital = S_1

Output Analogical = S_{2a}

Output Analogical = S_{2b}

*/Mathematics expressions */ as :

$D_C = \mu - \lambda$

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

*/determination of the extreme logic states */

If $D_C \geq V_{scc}$ then $S_1 =$ t

If $D_C \leq V_{icc}$ then $S_1 =$ F

If $D_{ct} \geq V_{scct}$ then $S_1 =$ T

If $D_{ct} \leq V_{icct}$ then $S_1 = \perp$

Otherwise $S_1 =$ I Non definition

$D_{ct} = S_{2a}$ and $D_C = S_{2b}$

*/ *End* */

The values for externally adjusted control are limits that will serve as reference for analysis.

This LPA2v algorithm can be represented as a block that we name the Basic Paraconsistent Artificial Neural Cell- *b*PANC. The Paraconsistent Neural cells (PANCs) comprise the basic elements of the Artificial Neural Paraconsistent Networks [DA SILVA et al, 2010]. To compose it, it is used a basic Paraconsistent Artificial Cell a (*b*PANC).

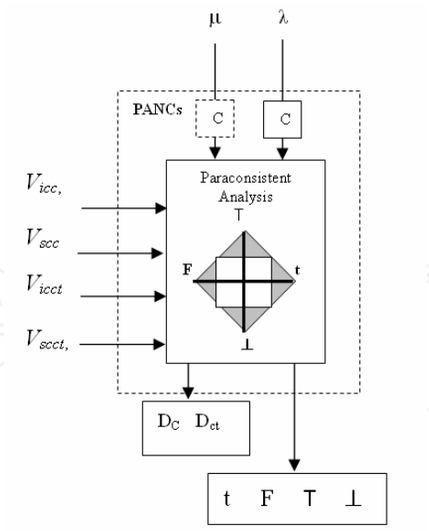


Fig. 3. The Basic Paraconsistent Artificial Neural Cell *b*PANC.

4.4 The learning Paraconsistent Neural Artificial cell for - *l*PANC

The cells for learning are used in Paraconsistent Neural Network as units of memory and pattern sensors in primary layers [DA SILVA FILHO, 2001]. For instance, an *l*PANC can be trained to learn a pattern using the method of Paraconsistent analysis applied through an LPA2v algorithm. In the process of learning where it is used as pattern the real values between 0 and 1 it is considered an equation to calculate the results of the successive values of degrees of belief $\mu_{r(k)}$ until it reaches value 1. So, for an initial value of degree $\mu_{r\,(k)}$, they obtain values $\mu_{r\,(k+1)}$ until the $\mu_{r\,(k+1)}$ =1.

Considering a process of learning of the pattern of True, therefore, the value of start 1, the equation for learning is:

$$\mu_{E(K+1)} = \frac{\left\{\mu_1 - (\mu_{E(K)C})l_F\right\} + 1}{2} \tag{4}$$

where:

$\mu_{E(k)C} = 1 - \mu_{E(k)}$ being l_F = learning Factor $0 \leq l_F \leq 1$

And for the process of learning of the pattern of Falseness, therefore, value of start 0, the equation is:

$$\mu_{E(K+1)} = \frac{\left\{\mu_{1C} - (\mu_{E(K)C})l_F\right\} + 1}{2} \tag{5}$$

where:

$\mu_{1c} = 1 - \mu_1$ being l_F = learning Factor $0 \leq l_F \leq 1$

For the two cases it is considered the cell that is completely trained when: $\mu_{E(k+1)} = 1$.

The learning Factor l_F is a real value, equal or higher than 0, got arbitrarily through external adjustments. The higher the value of l_F higher is the learning process of the cell. If l_F =1 we say that the cell has a natural capacity for learning. The natural capacity decreases as the l_F adjustment gets closer to 0.

4.4.1 Algorithm of the learning Paraconsistent Artificial Neural cell

The lPANC algorithm that makes the learning the pattern True is shown as follows:

1- Start: $\mu_{Er} = 1/2$ */ Output of the virgin cell */
2- Define: $l_F = C_1$ where $0 \leq C_1 \leq 1$ */ Insert the value as factor for learning */
3- Do: $\mu_2 = \mu_{Er}$ */ It connects the output of the cell in the input of the unfavorable evidence degree */
4- Do: $\mu_{2c} = 1 - \mu_2$ */ It applies the Complement Operator in the value of the input of the unfavorable evidence degree */
5- Do: $\mu_1 = 1$ */ it is applied the pattern of Truth */
6- Calculate the D_C value: $D_C = \mu_1 - \mu_{2C}$ */ It is calculated the degree of certainty*/
7- Do: $\mu_{er} = \frac{(D_C)C_1 + 1}{2}$ */the degree of evidence is found resulting the output through the equation (4) of Paraconsistent analysis */
8- If $\mu_{Er} \neq 1$ return to step 3
9- Stop.

The figure 4 shows the symbol of the *l*PANC and the characteristic curve of output for different values of learning Factor (l_F).

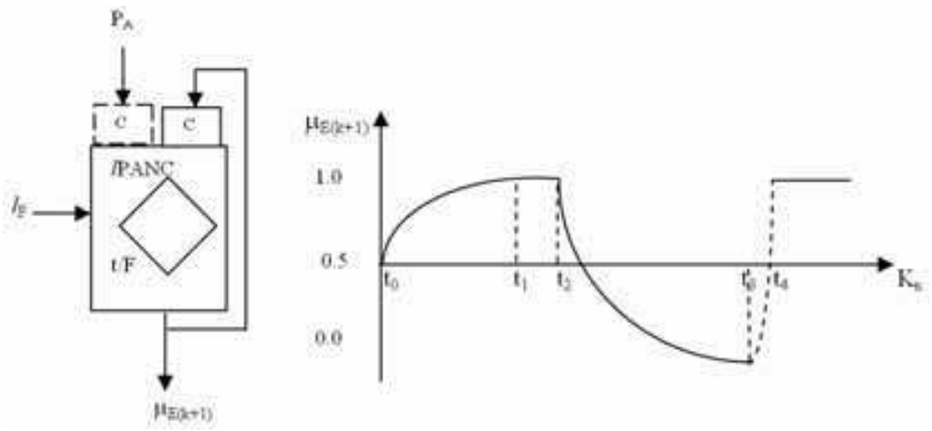


Fig. 4. Simplified symbol and the characteristic output graph of the Learning Paraconsistent Artificial Neural Cell (lPANC).

4.5 The Paraconsistent Artificial Neural Cell of Simple Logical Connection – $PANC_{siLC}$

The Paraconsistent Artificial Neural Cell of Simple Logical Connection ($PANC_{SiLC}$) has the function of establishing logical connectives between representative signals of Degrees of Evidence. The main logical connection cells are those that do the operation of the maximization OR and of the minimization AND. For maximization, initially, a simple analysis is done through the equation of the Degree of Evidence, which will inform which of the two input signals is of higher value. With this information, the cell representative algorithm establishes the output signal. The utilized equation and the conditions that determine the output for a maximization process are exposed as follows.

Consider the input variables:

μ_{1A}, such that: $0 \leq \mu_{1A} \leq 1$, and μ_{1B}, such that: $0 \leq \mu_{1B} \leq 1$.

The Resultant Degree of Evidence is calculated by doing:

$\mu_{1A} = \mu_1$ and $\lambda_2 = 1 - \mu_{1B}$

$$\mu_E = \frac{(\mu_1 - \lambda_2) + 1}{2}$$

To determine the higher value input:

If: $\mu_E > 0.5 \rightarrow \mu_{1A} \geq \mu_{1B} \rightarrow$ The output is μ_{1A}

If: $\mu_E < 0.5 \rightarrow \mu_{1A} < \mu_{1B} \rightarrow$ The output is μ_{1B}

Figure 5 shows representative figure and the simplified symbol of $PANC_{SiLC}$, which does the maximization between the two Degrees of Evidence signals μ_{1A} and μ_{1B}.

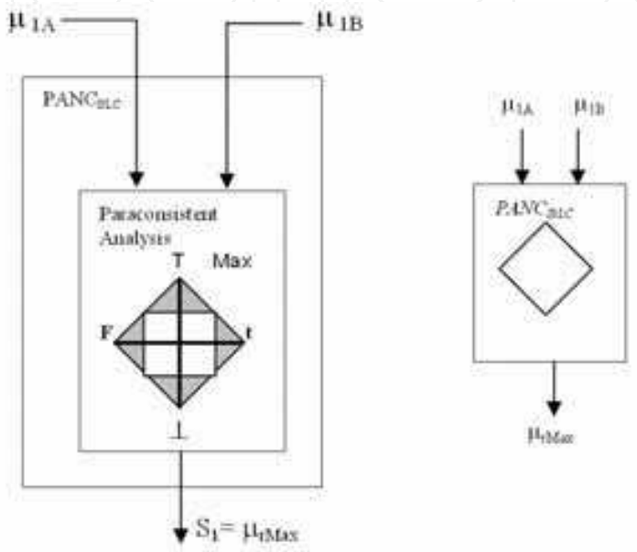


Fig. 5. Symbol of Paraconsistent Artificial Neural Cell of Simple Logical Connection ($PANC_{SiLC}$) in the maximization process (OR).

4.6 The Paraconsistent Artificial Neural cell of Equality Detection– $PANC_{ED}$

A Paraconsistent Artificial Neural Cell of Equality Detection ($PANC_{ED}$) consists of a Paraconsistent Artificial Neural Cell whose main function is to compare two values of Degrees of Evidence applied at the inputs and to generate a response relative to the equality in the closed interval between 0.0 and 1.0. Thus a $PANC_{ED}$ is a cell that supplies a Resultant Degree of Evidence that expresses an equality factor between two values applied at the inputs.

In a Paraconsistent Artificial Neural Network, the result of this comparison maybe utilized as recognition signal for a certain pattern one wishes to find or recognize in certain parts of the network. Therefore, the use of this cell is important in the function of pattern classification by PANNet.

To form the $PANC_{ED}$, the Normalized Degree of Contradiction will be calculated and its value will be compared to the Contradiction Tolerance Factor - Ctr_{TF}. This will define three output values, as follows:

- If the comparison done with the Contradiction Tolerance Factor Ctr_{TF} results in True, it means that the signals are considered equal. The signal at the output will be 1.0, indicating that the pattern was recognized.

- If the comparison done with the Contradiction Tolerance Factor Ctr_{TF} results in False, it means that the signals are considered unequal. The signal at the output will be 0.0, indicating that the pattern was not recognized.

Paraconsistent Artificial Neural Cell of Decision ($PANC_D$) has the main function of working as a decision node. Hence, the $PANC_{ED}$ may be described by means of an algorithm through the following equations from the fundamentals of PAL2v.

Consider the Degrees of Evidence applied at the inputs:

μ_{1A}, such that: $0 \leq \mu_{1A} \leq 1$ and μ_{1B}, such that: $0 \leq \mu_{1B} \leq 1$

The Unfavorable Degree of Evidence calculated by: $\lambda = 1 - \mu_{1B}$

The limit value:

Ctr_{TF} - Contradiction Tolerance Factor, such that: $0 \leq Ctr_{TF} \leq 1$

The Normalized Degree of Contradiction will be calculated by:

$$\mu_{ctr} = \frac{\mu_{1A} + \lambda}{2}$$

The limit values maximum and minimum recognition computed as the limit values, Superior and Inferior Contradiction Control:

$$Ctr_{CSV} = \frac{1 + Ctr_{TF}}{2}$$

and

$$Ctr_{CIV} = \frac{1 - Ctr_{TF}}{2}$$

The logical estate of output S_1 is obtained through comparisons done as follows:

If: $\mu_{ctr} = 0$ then: $S_1 = 1$ */Recognized Pattern*/

Else: $S_1 = 0$ */False*/

4.7 The Paraconsistent Artificial Neural cell of Decision– $PANC_D$

Paraconsistent Artificial Neural Cell of Decision ($PANC_D$) has the main function of working as a decision node in Paraconsistent Analysis Artificial Neural Networks. This cell receives input two signals. These are resulting signals from the analysis performed by other cells that compose the Network.

The output result will establish a conclusion of the analysis. Thus, a $PANC_D$ will only present one of the three values as result of the analysis:

a. Value 1, representing the conclusion "True"
b. Value 0, representing the conclusion "False"
c. Value 0.5, representing the conclusion "*Indefinition*".

The Decision Cell has one single external adjustment and it may be described by means of an algorithm. With the presented concepts, a mathematical model of a Paraconsistent Artificial Neural Cell of Decision is developed from the equations:

Consider input variables:

μ_1, such that: $0 \leq \mu_1 \leq 1$ and μ_2, such that: $0 \leq \mu_2 \leq 1$

Dec_{TF} - Decision Tolerance Factor such that: $0 \leq Dec_{TF} \leq 1$

The Unfavorable Degree of Evidence is obtained through

$$\lambda = 1 - \mu_2$$

The Resultant Degree of Evidence calculated by: $\mu_E = \frac{(\mu_1 - \lambda) + 1}{2}$

The *Falsehood* and *Truth* Limit Values: $T_{LV} = \frac{1 + Dec_{TF}}{2}$ and $F_{LV} = \frac{1 - Dec_{TF}}{2}$

Where: T_{LV} = *Truth Limit* Values

F_{LV} = *Falsehood Limit* Values

The logical states of output S_1 and S_2 are obtained through the comparisons carried out as follows:

If: $\mu_E \geq T_{LV}$ then: S1= 1 */True*/

If: $\mu_E \leq F_{LV}$ then: S1= 0 */False*/

Else: S1 = 0.5 */Indefinition*/

With these observations, we will describe a Paraconsistent Artificial Neural Cell of Decision utilizing the input and output variables along with the adjustment signals.

The representation of a Paraconsistent Artificial Neural Cell of Decision ($PANC_D$) with its simplified symbol is in figure 6.

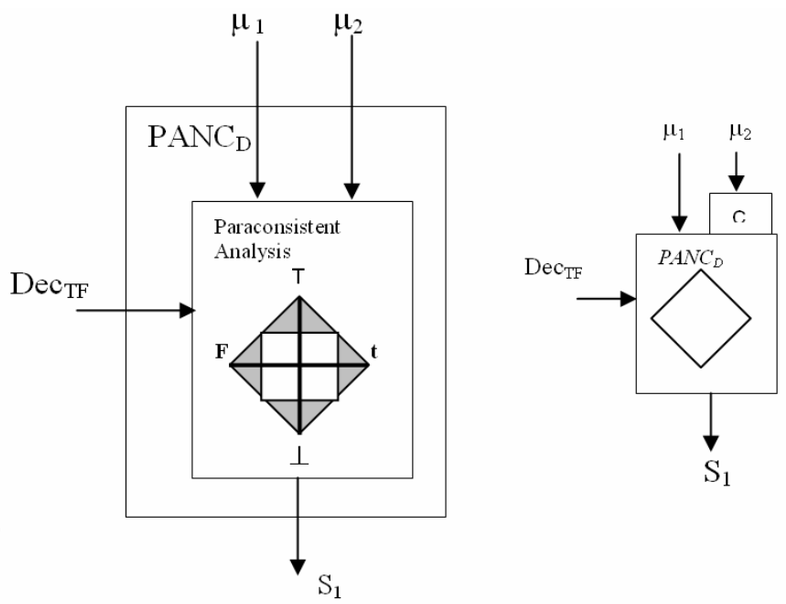


Fig. 6. Paraconsistent Artificial Neural Cell of Decision ($PANC_D$) with its simplified symbol

5. The expert system for analysis of marine pollution

The development of the application using Paraconsistent Artificial Neural network can be divided in parts to show the necessary steps for its achievement.

5.1 Description of the functions of the process for computer analysis for marine pollution

The computer program that composes the Expert System allows the following functions in the process of analysis:

5.a) The classification and identification of the patterns of cells of the bioindicator through the data obtained through analysis of images of the test of retention of the neutral red dye.
5.b) The analysis of the information through the Paraconsistent algorithm of the network simulating the test process of retention of the neutral red colorant.
5.c) Presentation of the Results through the Degrees of Evidence resulting according to the methodology of PAL2v.
The figures 7 and 8 show through diagrams the blocks of action of the Expert System in the treatment of the input signals:

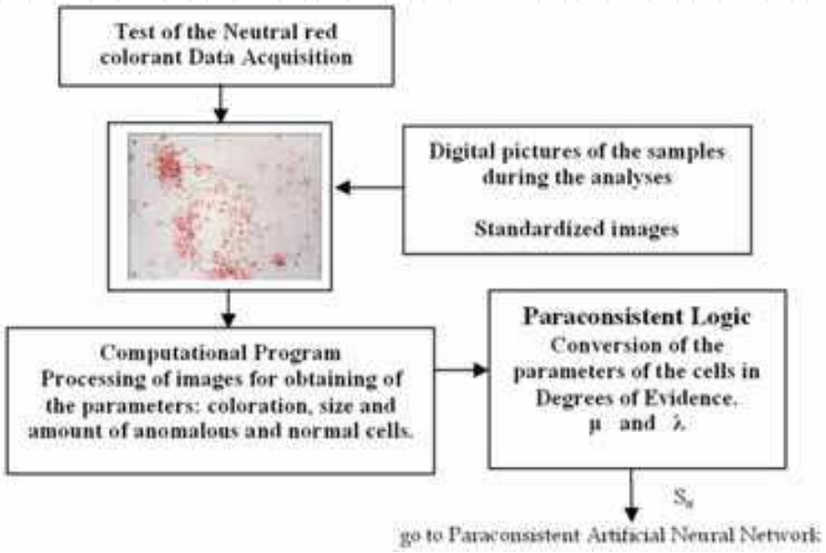


Fig. 7. Diagram of extraction of attributes from a slide of the test of the neutral red colorant of blood cells of mussels

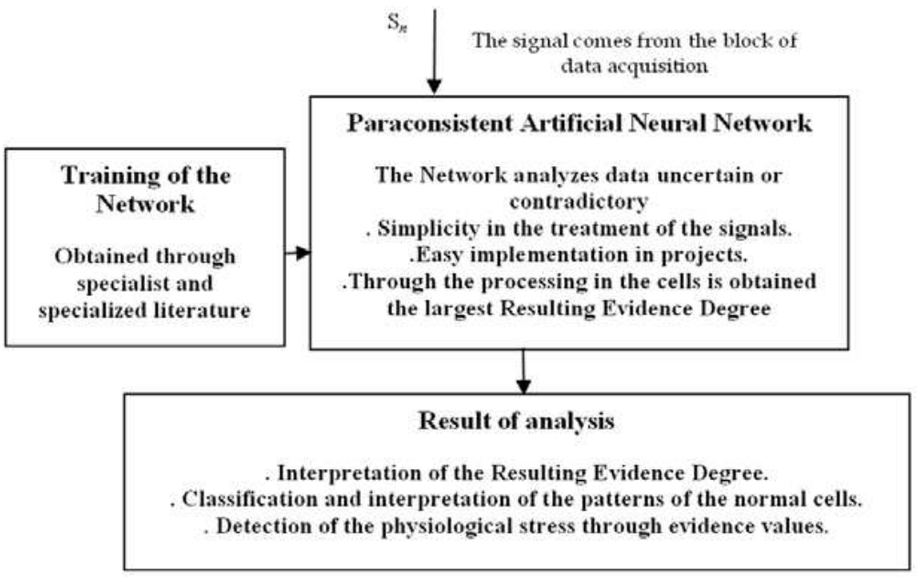


Fig. 8. Diagram in blocks of the Expert system with Paraconsistent Artificial Neural Networks applied to the method of obtaining the physiological stress cells.

5.2 Dada collection and separation in sets

The first steps of the process of development of the Paraconsistent Artificial Neural Network refer to the data collection related to the problem and its separation into a set of training and a set of tests. Following this there are the procedures of the parameters of the biological method for building the sets that were the same used in biology, such as, coloration and size of cells, time of reaction to the dye and quantity of stressed cells.

5.3 Detailed process for obtaining of the evidence degrees

The learning process links to a pattern of values of the Degrees of Evidence obtained starting from an analysis accomplished with mollusks from non polluted areas. The determination of the physiological stress will base on the amount and in the time of reaction of the cells in the presence of the Neutral Red Dye.

The pattern generates a vector that can be approximate to a straight line, without there are losses of information. As it was seen, the first observation of the analysis begins to the 15 minutes and it presents the minimum percentage of stressed cells. And the observation concludes when 50% of the cells of the sample present stress signs. Therefore, in order to normalize the evidence degree of pollution for counting of cells in relation to the time of analysis, it was obtained a straight line equation to make possible the analysis through the concepts of the Paraconsistent Annotated Logic. In that way, the equation can be elaborated with base in the example of the graph 1 (figure 9), obtained of the existent literature, where the time of 15 minutes is interpreted as evidence degree equal at one ($\mu = 1$), and the time of 180 minutes as evidence degree equal at zero ($\mu = 0$).

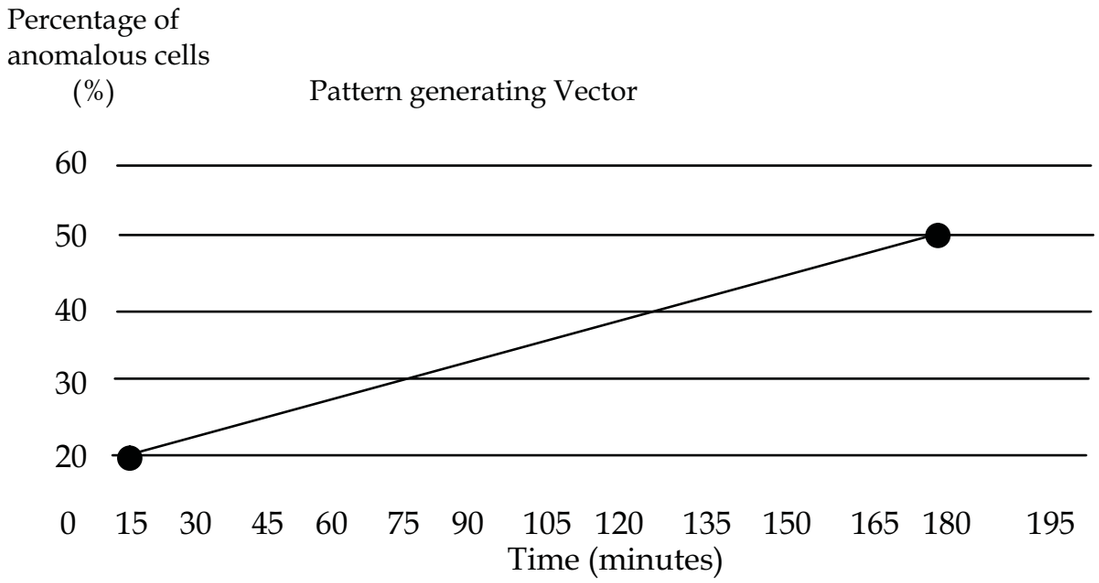


Fig. 9. Graph demonstrating example of a pattern of reference of an area no polluted.

This way, the mathematical equation that represents the pattern in function of the time of occurrence for 50% of stressed cells will have the form:

$$f(x) = ax + b \quad .$$

$$\left| \begin{array}{ll} 1 = 15a + b & \text{beginning of the analysis} \\ 0 = 180a + b & \text{end of the analysis} \end{array} \right.$$

Of the mathematical system, be obtained the values for:

$a = -1/165$ and $b = 180/165$ resulting in the function: $f(x) = \frac{-1}{165}x + \frac{180}{165}$

It is verified that this function will return the value of the evidence degree normalized in function of the final time of the test, and in relation to the pattern of an area no polluted.

The conversion in degree of evidence of the amount of cells for the analysis is also necessary. For that it is related to the degree of total evidence the total amount of cells and the percentage of cells stressed in the beginning (10%), and at the end of the test (50%).

$$\left| \begin{array}{ll} 1 = 0.5\text{x}Uda + b & \text{end of the analysis} \\ 0 = 0.1\text{x}Uda + b & \text{beginning of the analysis} \end{array} \right.$$

With the resolution of the mathematical system, it is had: $a = (1/4)Ud$ and $b = -0.25$ and the equation in the following way: $f(x) = \frac{1}{0.4\text{x}Ud}x - 0.25$

Therefore, x represents the number of cells stressed in relation to the Universe of Discourse (Ud) of the cells analyzed during this analysis. With the due information, we will obtain the favorable evidence degree, one of the inputs of the Paraconsistent Neural network. After the processing of the information of the analyses with the obtaining of the evidence degrees, the data will go by a Lattice denominated of the Paraconsistent Classifier, which will accomplish a separation in groups, according to table 3 to proceed.

EVIDENCE DEGREE (μ)	GROUP
$0 \leq \mu \leq 0.25$	G_1
$0.26 \leq \mu \leq 0.50$	G_2
$0.51 \leq \mu \leq 0{,}75$	G_3
$0.76 \leq \mu \leq 1$	G_4

Table 3. Table of separation of groups in agreement with the evidence degree.

To adapt the values the degrees of evidences of each level they will be multiplied by a factor: m/n, where m = number of samples of the group and n = total number of samples. In other words, the group that to possess larger number of samples will present a degree of larger evidence.

Only after this process it is that the resulting evidence degrees of each group will be the input data for the Paraconsistent Artificial Neurall Cells. After a processing, the net will obtain as answer a degree of final evidence related at the standard time, which will demonstrate the correlation to the pollution level and a degree of contrary evidence. In a visual way the intersection of the Resulting Certainty Degree (Dc) and the Resulting Contradiction Degree (Dct) it will represent an area into Lattice and it will show the level of corresponding pollution.

5.4 Configuration of network

The definition of the network configuration was done in parts. First, it was defined the parameters of the algorithm of treatment and the way the calculation of the degrees of reaction of the samples through the mathematics were obtained by a pattern of reference. After that, it was done a classification and separation in groups using a Paraconsistent network with cells of detection of equality. These cells that make the network are the ones for decision, maximization, selection, passage and detection of equality cells. In the end of the analysis, the network makes a configuration capable of returning the resulting degree of evidence and a degree of result contradiction, which for the presentation of results will be related to the Unitary Square in the Cartesian Plan that defines regions obtained through levels of pollution.

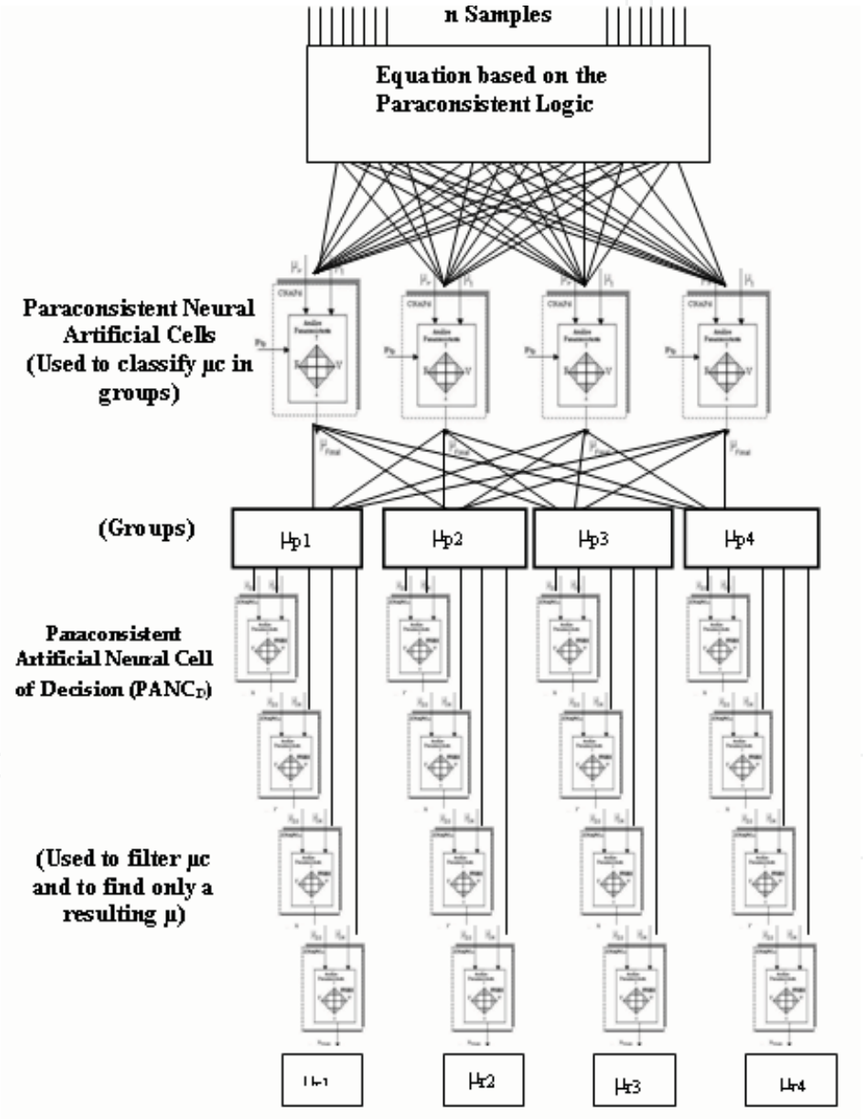


Fig. 10. The Paraconsistent network configuration.

The next figure 11 shows the flow chart with the main steps of the treatment of signals.

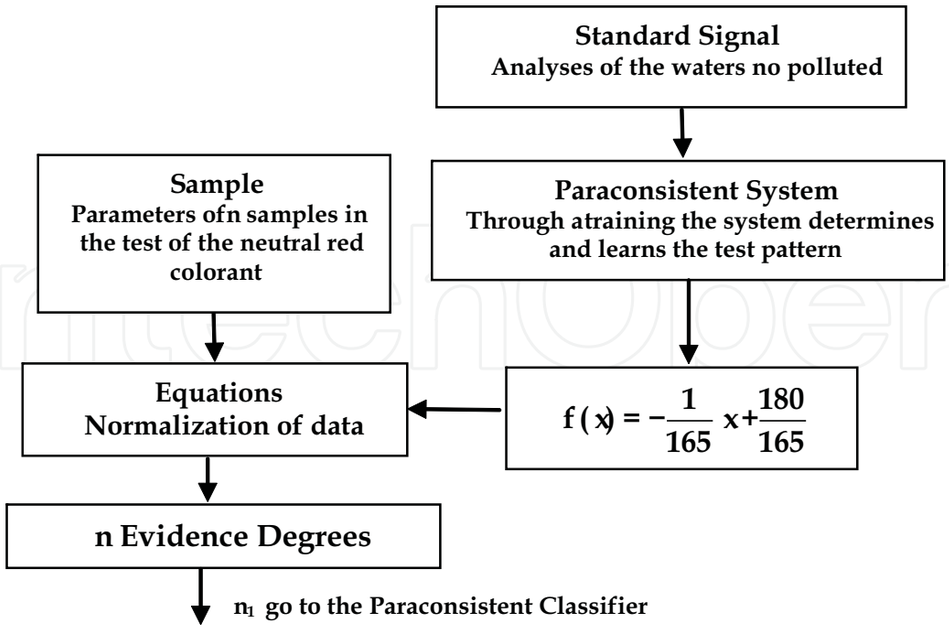


Fig. 11. Paraconsistent treatment of the signals collected through the analysis of the slides.

The figure 12 shows the configuration of the cells for that second stage of treatment of information signals.

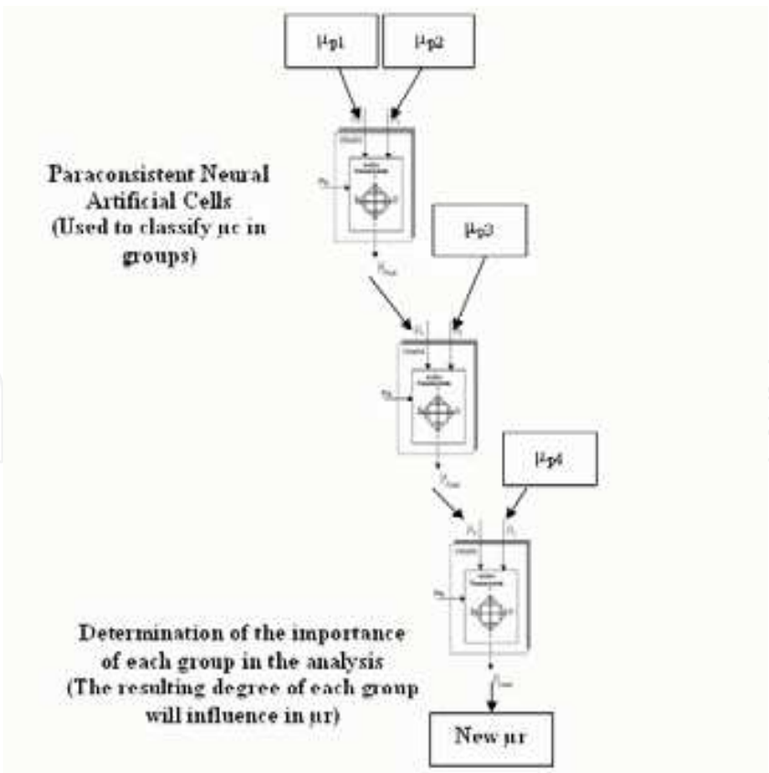


Fig. 12. Second Stage of the Paraconsistent Network - Treatment of the Contradictions.

The stage that concludes the analyses is composed of one more network of Paraconsistent Artificial neural Cells than it promotes the connection, classification through maximization processes. That whole finalization process is made making an analysis in the contradictions until that they are obtained the final values for the classification of the level of sea pollution. In the figure 13 is shown the diagram of blocks with the actions of that final stage of the Paraconsistent analyses that induce to the result that simulates the method for analysis of the time of retention of the Neutral Red Colorant through the Paraconsistent Annotated Logic.

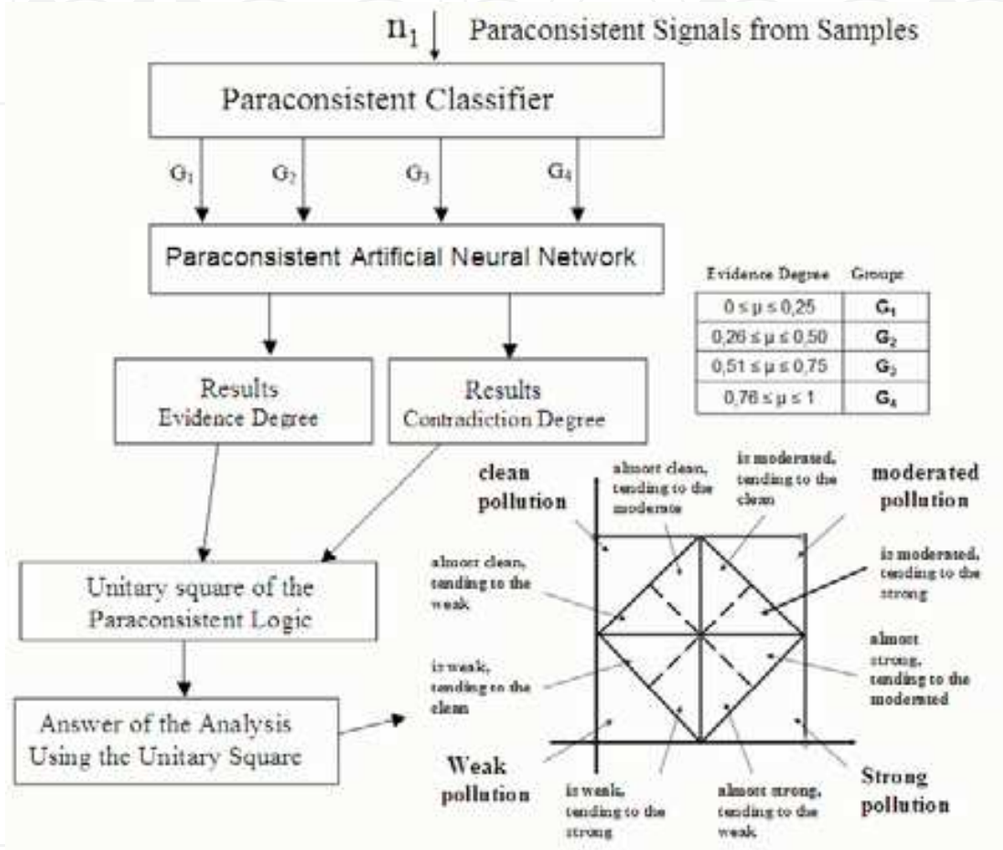


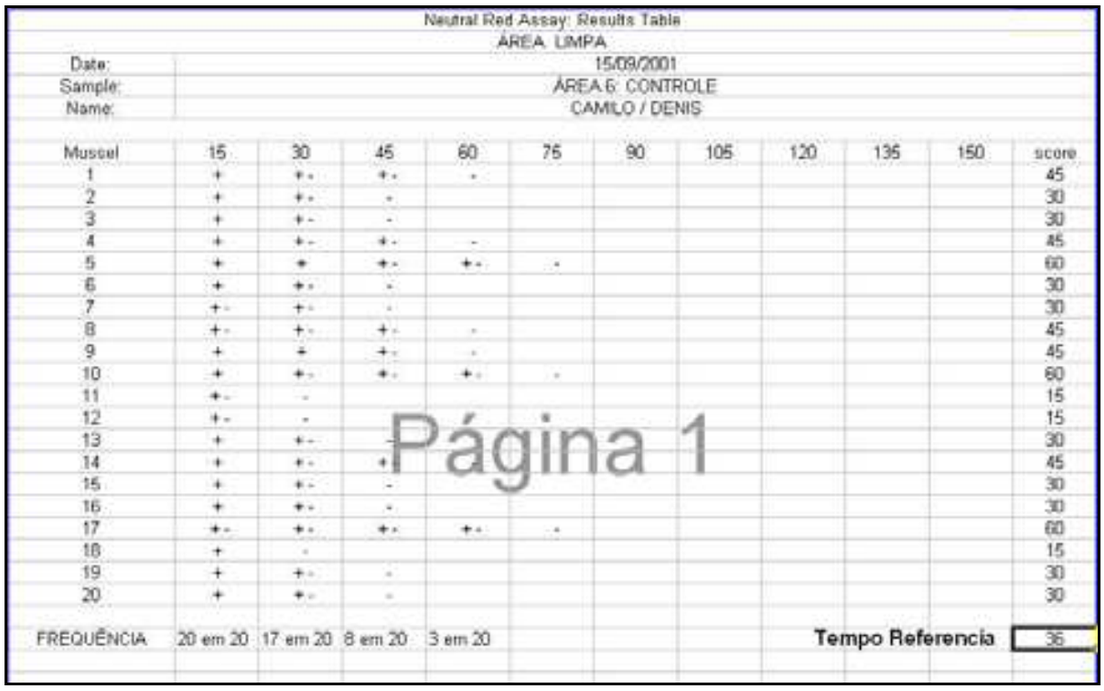
Fig. 13. Final Treatment and presentation of the results after classification and analysis of the Paraconsistent Signals.

5.4 Tests

During this stage, it was performed a set of test using a historical data base, which allowed determining the performance of the network. On the tests it was verified a good performance of the network obtaining a good indication for the system of decision of the Specialist System.

5.5 Results

After the analysis were performed and compared with the traditional method used in the biology process, we can observe that the final results are imminent. It was verified that the bigger differences between the two techniques are where the area is considered non polluted therefore, mussels were not exposed to pollution because the differences are



Neutral Red Assay: Results Table

ÁREA UMPA

Date: 15/09/2001

Sample: ÁREA 6 CONTROLE

Name: CAMILO / DENIS

Mussel	15	30	45	60	75	90	105	120	135	150	score
1	+	+ -	+ -	-							45
2	+	+ -	-								30
3	+	+ -	-								30
4	+	+ -	+ -	-							45
5	+	+	+ -	+ -	-						60
6	+	+ -	-								30
7	+ -	+ -	-								30
8	+ -	+ -	+ -	-							45
9	+	+	+ -	-							45
10	+	+ -	+ -	+ -	-						60
11	+ -	-									15
12	+ -	-									15
13	+	+ -	-								30
14	+	+ -	+								45
15	+	+ -	-								30
16	+	+ -	-								30
17	+ -	+ -	+ -	+ -	-						60
18	+	-									15
19	+	+ -	-								30
20	+	+ -	-								30
FREQUÊNCIA	20 em 20	17 em 20	8 em 20	3 em 20					Tempo Referencia		36

Página 1

Fig. 14. Presentation of result of analysis 1 of the pattern of reference done through the traditional method. Pr = 38min with the positive and negative signs of the observations made by the human operator.

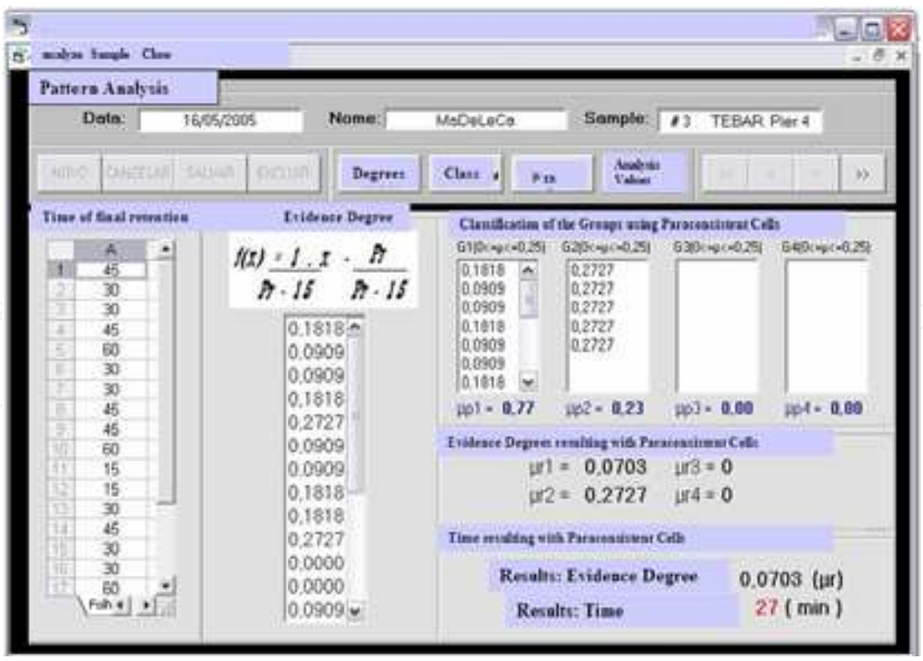


Fig. 15. Presentation of the result of analysis 1 of the pattern of reference done with the software elaborated with Paraconsistent Logic. Pr = 27min with the results in the form of Degrees of Evidence and classification of the tenor of sea pollution.



Fig. 16. Presentation of the result of analysis 2 of samples done through the traditional method. Tr = 10min with the positive and negative signs of the observations made by the human operator.

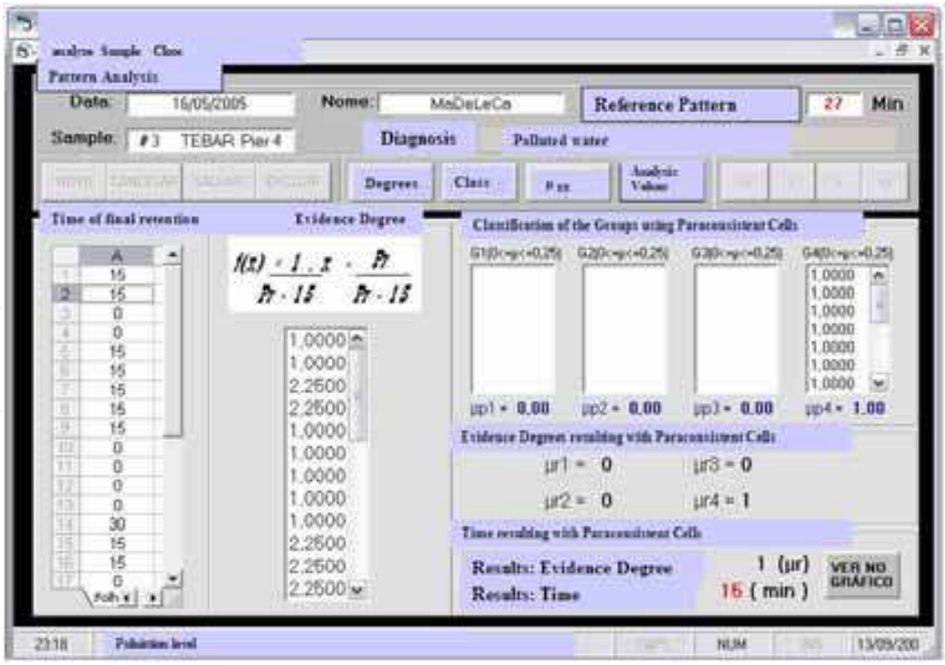


Fig. 17. Presentation of the results of analysis 2 of samples done through the software elaborated with Paraconsistent Logic. Tr= 15min with the results in the form of Degrees of Evidence and classification of the tenor of sea pollution.

outstanding in these conditions due to the pattern process that happens only with an arithmetic average of the analysis while the Paraconsistent Neural Artificial Network always takes into consideration the existing contradictions. Later studies are being performed for the comparison between the two methods of presentation, which can take to a better comparison of the amount. The following images show the ways of presenting the two methods, one done the traditional way and the other through the screen of data of the software of Paraconsistent Logic.
It is verified that the screens of the Software of the Paraconsistent Expert System brings the values of the Degrees of Evidence obtained and other necessary information for the decision making. To these values other relevant information are joined capable to aid in the decision making in a much more contusing way than the traditional system.

5.6 Integration

With the trained and evaluated network, this was integrated into an operational environment of the application. Aiming a more efficient solution, this system is easy to be used, as it has a convenient interface and an easy acquisition of the data through electronic charts and interfaces with units of processing of signals or patterned files.

6. Conclusion

The investigations about different applications of non-classic logic in the treatment of Uncertainties have originated Expert Systems that contribute in important areas of Artificial Intelligence. This chapter aimed to show a new approach to the analysis of exposure and effects of pollution in marine organisms connecting to the technique of Artificial Intelligence that applies Paraconsistent Annotated Logic to simulate the biological method that promotes the assay with neutral red. The biological method that uses a traditional technique through human observation when counting the cells and empirical calculations presents good results in its end. However, the counting of the stressed cells through observation of the human being is a source of high degree of uncertainty and obtaining results can be improved through specific computer programs that use non-classical logic for interpretation. It was checked in this work that the usage of a Expert System based in Paraconsistent Logic to get the levels of physiological stress associated with marine pollution simulating the method of retention of the Neutral Red dye was shown to be more efficient because it substitutes several points of uncertainty in the process that may affect the precision of the test. Although the first version of the Paraconsistent software used presented results which when compared to the traditional process showed that it has more precision in the counting of cells as well as the manipulation of contradictory and non consistent data through the neural net, minimizing the failures the most according to the human observation. This work also shows the importance of the investigations that search for new theories based in non-classical logic, such as the Paraconsistent Logic here presented that are capable of being applied in the usage of the technique of biomarkers. It is important that these new ways of approaching bring conditions to optimize the elaboration of a computer environment with the objective of using modern technological ways and this way getting results closer to the reality and more trustworthy.

7. Acknowledgment

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8. References

ABE, J. M [1992] "Fundamentos da Lógica Anotada" (Foundations of Annotated Logics), in Portuguese, Ph D thesis, University of São Paulo, FFLCH/USP - São Paulo, 1992.

BISHOP, C.M. [1995] Neural Networks for Pattern Recognition. 1.ed. Oxford University Press, 1995.

BLAIR[1988] Blair H.A. and Subrahmanian, V.S. Paraconsistent Foundations for Logic Programming, Journal of Non-Classical Logic, 5,2, 45-43,1988

DA COSTA et al [1991] "Remarks on Annotated Logic" *Zeitschrift fur Mathematische Logik und Grundlagen der Mathematik*, Vol.37, 561-570, 1991.

DA SILVA FILHO et al [2010] Da Silva Filho, J. I., Lambert-Torres, G., Abe, J. M. *Uncertainty Treatment Using Paraconsistent Logic - Introducing Paraconsistent Artificial Neural Networks*. IOS Press, p.328 pp.. *Volume 211 Frontiers in Artificial Intelligence and Applications ISBN 978-1-60750-557-0 (print) ISBN 978-1-60750-558-7 (online) Library of Congress Control Number: 2010926677 doi: 10.3233/978-1-60750-558-7-i,* Amsterdam, Netherlands, 2010.

DA SILVA FILHO [1999] Da Silva Filho, J.I., Métodos de interpretação da Lógica Paraconsistente Anotada com anotação com dois valores LPA2v com construção de Algoritmo e implementação de Circuitos Eletrônicos, EPUSP, in Portuguese, Ph D thesis, São Paulo, 1999. 185 p.

DA SILVA FILHO et al[2006] Da Silva Filho, J.I., Rocco, A, Mario, M.C. Ferrara, L.F.P. *"Annotated Paraconsistent logic applied to an expert System Dedicated for supporting in an Electric Power Transmission Systems Re-Establishment"* IEEE Power Engineering Society - PSC 2006 Power System Conference and Exposition pp. 2212-2220, ISBN-1- 4244-0178-X – Atlanta USA - 2006.

FERRARA et al[2005] Ferrara, L.F.P., Yamanaka, K., Da Silva Filho. A system of recognition of characters based on Paraconsistent artificial neural network/. Advances in Logic Based Intelligent Systems. IOS Press. pp. 127-134, vol.132, 2005.

HALLIDAY [1973] halliday, J.S., The Characterization of Vector cardiograms for Pattern Recognition – Master Thesis, MIT, Cambridge, 1973.

LOWE et al [1995] Lowe, D. M. et al Contaminant – induced lysosomal membrane damage in blood cells of mussels Mytilus galloprovincialis from Venice lagoon: an in vitro study. Mar. Ecol. Prog. Ser., 1995. 196 p.

NASCIMENTO et al [2002] Nascimento,I.A, Métodos em Ecotoxologia Marinha Aplicações no Brasil, in portuguese, Editora: Artes Gráficas e Indústrias Ltda, 2002.262 p.

NICHOLSON [2001] Nicholson, S. Ecocytological and toxicological responses to cooper in *Perna viridis* (L.) (Bivalvia: Mytilidae) haemocyte lysosomal membranes, *Chemosphere*, 2001, 45 (4-5): 407 p.

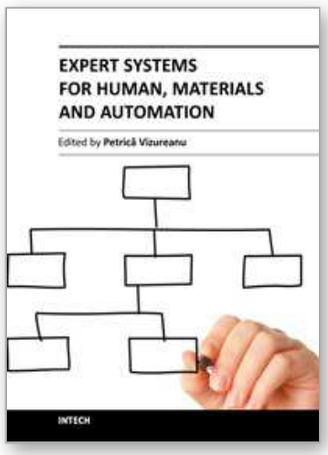
HEBB [1949] Hebb, D. O. The Organization of Behavior, W*iley,* New York, 1949.

SOS TERRA VIDA [2005] - Organização não governamental SOS Terra Vida. Poluição Marinha, 15 fev. 2005. in portuguese, available in: http://www.sosterravida.hpg.ig.com.br/poluicao.html. Access in 25 abr. 2008.

KING [2000] King, R, Rapid assessments of marine pollution – Biological techniques. Plymouth Environmental Research Center, University of Plymouth, UK, 2000. 37 p.

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Expert Systems for Human, Materials and Automation

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The ability to create intelligent machines has intrigued humans since ancient times, and today with the advent of the computer and 50 years of research into AI programming techniques, the dream of smart machines is becoming a reality. The concept of human-computer interfaces has been undergoing changes over the years. In carrying out the most important tasks is the lack of formalized application methods, mathematical models and advanced computer support. The evolution of biological systems to adapt to their environment has fascinated and challenged scientists to increase their level of understanding of the functional characteristics of such systems. This book has 19 chapters and explain that the expert systems are products of the artificial intelligence, branch of computer science that seeks to develop intelligent programs for human, materials and automation.

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