A Paraconsistent Approach for Offer Evaluation in Multiagent Negotiation

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Abstract. This paper presents a *Paraconsistent Approach* based on a heuristic of multi-valued decrement list followed by formalization into Evidential Paraconsistent Logic to evaluate offers in a negotiation session. The mission of an organization stands for its goals and also leads corrections likely to occur in the posture adopted by the organization before the society. In order to fulfill the goals of the organization, this one needs to interact with other components of the society. Within an organization each individual responsible for the sale and purchase of either commodities or services detains knowledge concerning possible values of the criteria used to represent a determined commodity or service which may be either offered or accepted in a negotiation. So, a offer may be seen as an inconsistency aroused between the previous individual knowledge of the negotiator and the incoming offer. When compared to the *Utility Value Approach*, the Paraconsistent one converges toward the negotiation ending with fewer interactions.

1 Introduction

Within an organization, each individual responsible for the sale and purchase of commodities or services detains knowledge concerning possible values of the criteria used to represent a determined commodity or service which may be either offered or accepted in a negotiation. This knowledge is part of the organizational knowledge that stands for the "truth" about the world, the world from the organization's point of view. In a negotiation, an offer may arouse a conflict with the previous individual knowledge of the negotiator. This conflict may be seen as an intra-case inconsistency [1]. In the intra-case inconsistency the case which is stored in a base arouses contradiction with the previous knowledge of such case.

This work describes a new approach based on a multi-valued decrement list heuristic followed by formalization into Evidential Paraconsistent Logic (*EPL*) [2, 3] to evaluate offers in a negotiation. The *EPL* is used to represent the rules and offers that describe how consistent the offer is according to the individual knowledge of the negotiator. If an offer is consistent and is "true" for the negotiator, it is then accepted. The ARTOR — ARTificial ORganizations [4] — is a Multiagent System (*MAS*) which simulates the partnership of organizations

— each organization owns agents responsible for the operations of purchasing and selling either commodities or services. Within this *MAS* a new approach is undertaken by the supply executor agent and by the selection executor agent which are, respectively, responsible for the operations of purchase and sale.

Section 2 presents how a negotiation using the *Utility Value Approach* is achieved in the ARTOR. In section 3 the *Paraconsistent Approach* is detailed and explained. Section 4 presents the results of tests as well as the comparison between the *Paraconsistent Approach* and the *Utility Value Approach*. Finally, in section 5 some conclusions are inferred.

2 Negotiation in ARTOR

The ARTOR provides an environment which simulates a society of artificial organizations by accounting for both the intra-organizational and inter-organizational dimensions [4]. Each organization is composed of three classes of agents: the *cover agent* which stands for the organization, the *administrator agent* responsible for planning and coordination and the *executor agent* responsible for operational tasks. Another important component of the society is the *newsstand*, a public blackboard known by every organization. The *newsstand* is used for news exchanging — about business — among organizations.

2.1 Offer Evaluation

In the ARTOR, the commodity or service the organization is willing to sell is represented by a Criteria List (*CL*) [4]. The CL composed of Selection Criteria (*SC*) which determines the dimensions used to describe and assess the commodity or service. The *CL* is defined by[1]:

$CL_{product1}(SC_1, SC_2, ..., SC_n)$

each SC_i is the tuple $SC_i(Id_i, Vd_i, Tp_i, Va_i, Pr_i, Sm_i)$, where:

- Id_i: is the identification of the *SC*;
- Vd_i: is the value that satisfies the executor agent;
- Tp_i: contains information about the type of value. Represented by $(Tv_i : TUn_i : Un_i)$, where:
  - Tv_i: indicates the attribute domain which belongs to the set $\{discreet, continuous\}$;
  - TUn_i: type of value which may be $\{unit, real, date\}$;
  - Un_i: is the value of a unit. For instance, 30 for a unit of the date type.
- Va_i: is represented by the ordered pair (Vac_i, Fed_i), where:
  - Vac_i: is a list of valid values for SC_i if $Tv_i = discreet$. If $Tv_i = continuous$ then Va_i will be the ordered pair (Min, Max), where Min is the minimum value for the SC_i and Max maximum one;
  - $Fed_i \in \{left, right, none\}$, where:

[1] This representation of the *CL* was modified to bear continuous values.

    * $left$: the values that better satisfy are on the left of Vd_i;
    * $right$: the values that better satisfy are on the right of Vd_i;
    * $none$: any value satisfy.
- Pr_i: utility of the SC_i for organization;
- Sm_i: stands for the status of the SC according to the instantiation of the value, where:
  - grounded: the first offer using the SC_i will be made with a value;
  - free: the first bid using the SC_i will be made without a value.

The agents responsible for the negotiation use a Possibility Space (PS) — defined from a CL which contains the possible values for each SC — to evaluate and to create offers. A PS is defined by:

$$PS \in CL = D_{SC_1} \times D_{SC_i} \times ... \times D_{SC_n}$$

The PS may be represented by Table 1

	Size	**Model**	**Color**	**Price**	**Payment Term**	**Quantity**
Satisfy More				5	120	80
Satisfy	m, g	$sport, regular$	$blue, black$	10	90	65
Satisfy less				30	0	50

Table 1. Example of Possibility Space.

Each SC has a weight according to its utility for the organization — a type of SC may be more important than other. The utility, in Economics, is an analytical concept which represents a subjective pleasure, the advantage or the satisfaction derived from the consumption of commodities, and explains how consumers divide their limited resources among the commodities consumed [5].

The offer utility value is used to assess the offer and according to the result it will be either accepted or not. The offer utility value is defined by the sum of all utility values of the dimension instances of the CL:

$$offer\_utility = \sum_{i=0}^{j} instance\_utility_i.$$

The instance utility value is obtained as follows:

$$instance\_utility = (Pr_i \times relative\_instance\_value)$$

The relative instance value for a continuous SC is the relative position of the value in the domain of values Vaci of the SC_i. If the relative instance value is positioned on the side that better satisfies — the side indicated by Fed_i in relation to the value that satisfies Vd_i — the relative value will be positive, otherwise it will be negative. The relative instance value of a discreet value will be 1 if it exists in the domain of the values Vac_i, otherwise the relative value will be -1.

3 Offer Evaluation through the Paraconsistent Approach

The ParaLog_e [7, 8] is an interpreter of *EPL* based on *Annotated Paraconsistent Logic* [2, 3, 9]. The *EPL* is infinitely valued and its truth values belong to the lattice $\tau = \langle |\tau|, \leq \rangle$, where:

$$|\tau| = \{\mu 1 \in \Re | 0 \leq x \leq 1\} \times \{\mu 2 \in \Re | 0 \leq x \leq 1\}.$$

In the *EPL* a preposition p owns two annotated values $p : [\mu 1, \mu 2]$. The annotated value $\mu 1$ is the favorable evidence to p and the value $\mu 2$ is the contrary evidence to p — Figure 1.

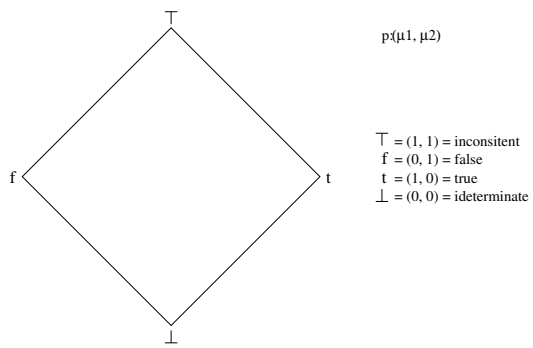

Fig. 1. Example of lattice with resolution four.

It is possible to obtain from the $[\mu 1, \mu 2]$ the Contradiction Degree (*CtD*) and the Certainty Degree (*CD*) in which the preposition lies [2]. The *CtD* stands for the distance between the inconsistent ($\top$) and the undetermined () truth values. The *CD* stands for the distance between the true (v) and the false (f) truth values.

In the paraconsistent approach the *PS* is a little different[2] from the *PS* presented in the previous session. Now each SC_i is the tuple $CS_i(Id_i, Tp_i, Va_i, Pr_i, Sm_i)$, where:

- Id_i: is the identification of the SC_i;
- Tp_i: contains information about the type of value. Represented by $(Tv_i : TUn_i : Un_i)$, where:
  - Tv_i: indicates the domain of the value that belongs to the set $\{discreet, continuos\}$;
  - TUn_i: is the type of value that may be $\{unit, real, date\}$;
  - Un_i: is the value of a unit. For instance 30 for a unit of the date type.

[2] Due to the use of the EPL it is not necessary to use a reference value that indicates the satisfaction point to assess a SC. The evidential values associated to the SC indicate the negotiator?s satisfaction in relation to the instance value of this SC.

- Va_i: if $Tv_i = discreet$ then Va_i will contain a list of valid values for the SC_i. If $Tv_i = continuous$ then Va_i will be the ordered pair (S_less, S_more), where S_less is the value that less satisfies and S_more is the value that more satisfies;
- Pr_i: utility of the SC_i;
- Sm_i: stands for the status of the SC according to the instance value, where:
  - *grounded*: the first bid using the SC_i will be made with a value;
  - *free*: the first bid using the SC_i will be made without a value.

3.1 Paraconsistent Approach Architecture

The offer evaluatin by using the *Paraconsistent Approach* — see Figure 2 — begins when an offer is received by the agent executing the selection. First the offer is translated into facts that use the representation formalism of the *EPL* — Subsection 3.2. After this operation the rules of evaluation are created — Subsection 3.2 — having as a basis the facts. So it is obtained as output a text file that contains the facts that represent the offer and the rules of evaluation. The text file is loaded in the ParaLog_*e* and a query of the rules is made. The outcome of this query is the favorable evidence ($\mu 1$) and the contrary evidence ($\mu 2$) in relation to the offer. The *CD* and the *CtD* are obtained from $[\mu 1, \mu 2]$ and they are converted into discrete values by the algorithm Para-Analyzer — Subsection 3.3 — into resulting logical status. The resulting logical status is used to assess the offer. If the resulting logical status is t so the offer is accepted. Otherwise, a decrement value is chosen according to the resulting logical status and used in the creation of a counter-offer.

3.2 Translating Offers to the EPL Representation Formalism

In the ARTOR, the offer contained in a message of negotiation is a list composed of ordered pair (SC_ID, SC_Value). For instance:

```
[[color, black], [price, 5], [payment_term, 0], [quantity, 80]]
```

The *paraconsistent_mapping* module is responsible for translating the *SC's* of an offer into evidential facts. It is also responsible for creating the rules that will evaluate the offer. The value of a *SC* is mapped into evidential values $[\mu 1, \mu 2]$ according to the organization *PS* and the restrictions[3].

If the *SC* belongs to a discrete domain then the *SC* instance value is mapped into evidential values as follows:

- $SC\_ID(Value) : [1, 0]$ if $Value \in Va$;
- $SC\_ID(Value) : [0, 0]$ if $Value \notin Va$;
- $SC\_ID(Value) : [0, 1]$ if the value fits a restriction for the *SC*.

[3] The restrictions indicate, for a determined *SC*, which values are not accepted. The restriction may be applied to bigger, smaller or equal values to a determined value.

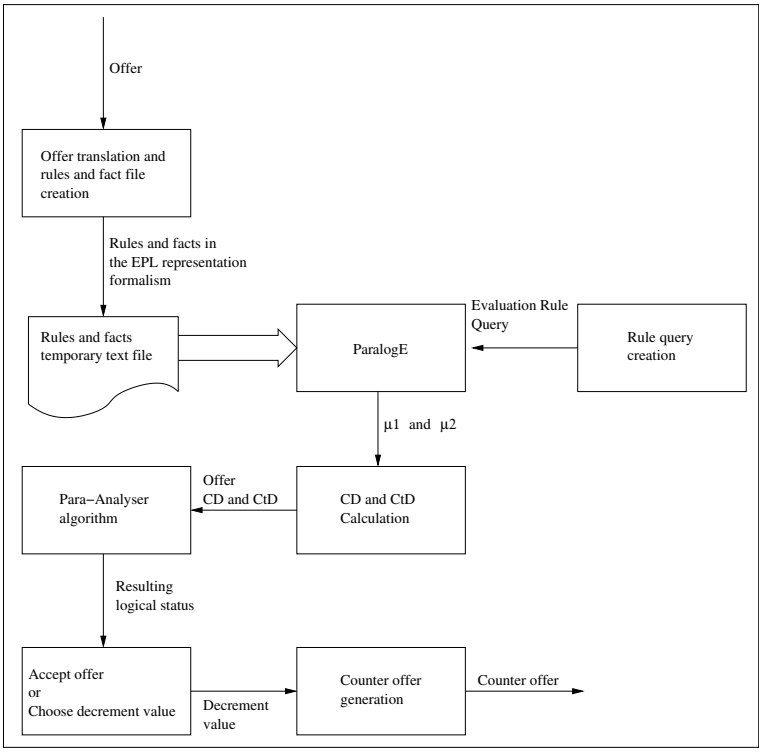

Fig. 2. Offer evaluation architecture through *Paraconsistent Approach*.

If the SC belongs to the continuous domain then the SC instance value is mapped into evidential values as follows:

- $SC\_ID(Value) : [\mu 1, \mu 2]$ is equal to e, where $e \in E$ ($e = [\mu 1, \mu 2]$) according to the index k obtained by the function $P(x)$;
- $SC\_ID(Value) : [1, 0]$ if $S\_less \leq S\_more$ and $Value > S\_less$ and $Value > S\_more$;
- $SC\_ID(Value) : [0, 1]$ if $S\_less \leq S\_more$ and $Value < S\_less$ and $Value < S\_more$;
- $SC\_ID(Value) : [1, 0]$ if $S\_less > S\_more$ and $Value < S\_less$ and $Value < S\_more$;
- $SC\_ID(Value) : [0, 1]$ if $S\_less > S\_more$ and $Value > S\_less$ and $Value > S\_more$;
- $SC\_ID(Value) : [0, 1]$ if the value fits a restriction for the SC.

The function $P(x)$ returns the index k which is associated to the element e ($e = [\mu 1, \mu 2]$) — belonging to the set E — which corresponds to the evidential values, of the instance value, in relation to the PS contained in the individual knowledge base of the negotiator agent. The function $P(x)$ is defined by:

- $P(x) = -1$ if $x < S\_less$;
- $P(x) = 0$ if $x = S\_less$;
- $P(x) = \frac{10}{\frac{(S\_more - S\_less)}{Vd}} \times \frac{(Value\_SC - S\_less)}{Vd}$ if:
  - $S\_less \leq x \leq S\_more$;
  - $S\_less \geq x \geq S\_more$.
- $P(x) = 10$ if $x \geq S\_more$.

The evidential values contained in the set E were created through an idiosyncratic heuristic. The set E used in this work corresponds to $E = \{-1-0 : 1, 0-0 : 0, 1-0.1 : 0.0, 2-0.2 : 0.8, 3-0.3 : 0.7, 4-0.4 : 0.6, 5-0.5 : 0.5, 6-0.6 : 0.4, 7-0.7 : 0.3, 8-0.8 : 0.2, 9-0.9 : 0.1, 10-1 : 0\}$.

The offer evaluation in the *Paraconsistent Approach* uses a set of rules which are composed of the facts that represent the *SC's* of an offer. As in the facts, a rule represented on the formalism of the *LPE* also owns associated evidential values. The facts are grouped in the rules according to their utility for the organization. Three zones of utility that group the facts were defined, and are defined by the *utility_zone*/2 predicate:

```
utility_zone(high, [10, 9, 8]).
utility_zone(mid, [7, 6, 5]).
utility_zone(low, [4, 3, 2, 1]).
```

Thus, the respect for the utility of the facts is guaranteed. For instance, a fact that represents a *SC* with low utility and fulfills perfectly what the organizations seeks, will not have much influence on the offer acceptance.

After grouping of the facts in the rules, the evidential values of the rules are obtained in a similar manner to the one used to find the evidential values of the facts. The *rule_evidences*/2 predicate represents all possible combinations of evidential values that may be used in the rules:

```
rule_evidences(Utl, L).
```

There are ten *rule_evidences*/2 predicates and each one corresponds to a utility (*Utl*)[4] associated to a set L, which contains the evidential values[5] to be mapped into a rule. The set L, used for the mapping of a determined rule, will be chosen according to the *SC* of bigger utility. Because, the *SC* of bigger utility dominates the other *SC's* which compose the rule.

Once the set L — associated to a utility — was chosen, the rule will take the evidential values indicated by the element l ($l = [\rho 1, \rho 2]$) of the set L. The element l is found through the index j ($0 \leq i \leq 10$) through the function $R(x)$:

$$R(x) = \frac{10}{N} \times (\sum_{i=0}^{n} Ev1_i)$$

[4] In this work it was assumed that the minimum utility is 1 and the maximum one is 10.

[5] The values of the evidential values contained in the set L were also created from a idiosyncratic heuristic.

In $R(x)$, N indicates the quantity of facts the rule owns, and $Ev1_i$ is the favorable evidence of each fact belonging to this rule.

The output of the *paraconsistent_mapping* module is a temporary text file[6] which contains the *SC's* of an offer and the respective evaluation rules.

3.3 Offer Evaluation Through the Para-Analyzer Algorithm

The offer evaluation is made by the Para-analyzer algorithm [2], the Para-analyzer algorithm input is the *Ctd* and the *CD* — see Section 3 — and the output is a logical status. It is possible to define a lattice with more logical statuses than the basic set — $\mid \tau \mid= \{\top, t, f, \bot\}$. The more logical statuses the greater the precision in the analysis of the *CtD* and of the *CD*. This work uses a lattice with 12 logical statuses — Figure 3.

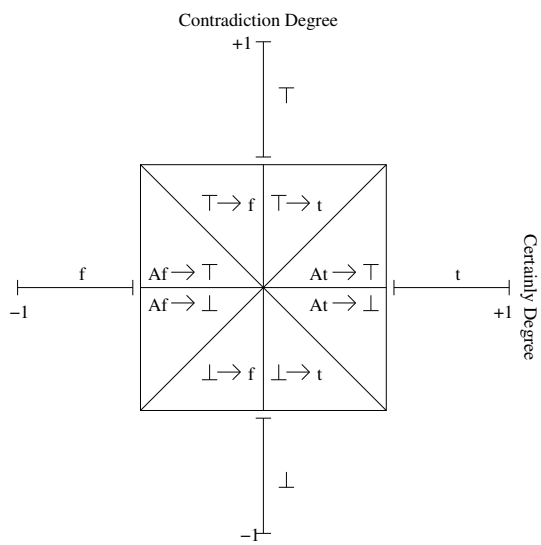

Fig. 3. Lattice with 12 logical status represented in the *CtD* and *CD* graphic.

Where:

- $\top$: inconsistent;
- $\top \rightarrow t$: inconsistent toward truth;
- $\top \rightarrow f$: inconsistent toward false;
- t: truth;
- $At \rightarrow \top$: almost truth toward inconsistent;
- $At \rightarrow \bot$: almost truth toward indeterminate;

[6] Every time the negotiator agent receives an offer the file is erased.

- f: false;
- $Af \rightarrow \top$: almost false toward inconsistent;
- $Af \rightarrow \perp$: almost false toward indeterminate;
- $\perp$: indeterminate;
- $\perp \rightarrow t$: indeterminate toward truth;
- $\perp \rightarrow f$: indeterminate toward false;

The Para-Analyzer algorithm achieves a discretization of the *CtD* and of the *CD* interpolating them in the lattice and the convergence point is the resulting logical status. The sensibility of extreme values may be regulated by using the control limits — see Figure 4. There are four limit values:

- *Sccv*: *Superior Certainly Control Value* limits the *CD* next to the truth;
- *Iccv*: *Inferior Certainly Control Value* limits the *CD* next to the false;
- *Sctcv*: *Superior Contradiction Control Value* limits the *CtD* next to the inconsistent;
- *Ictcv*: *Inferior Contradiction Control Value* limits the *CtD* next to the indeterminate;

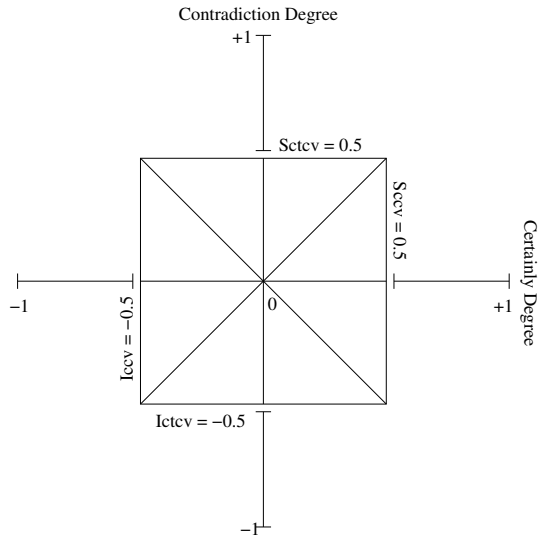

Fig. 4. Example of Control limits set to 0.5 represented in the *CtD* and *CD* graphic.

In this work the value used for the *Sccv* was 0.6, and for the other superior and inferior limits 0.5 and −0.5, respectively. According to tests, the increase of the *Sccv* corresponds to an increase of the minimum utility so that the organization accepts the offer. The increase of the *Iccv* corresponds to a decrement in the relaxation when an organization offer anew.

Each resulting logical status may be used to generate either simple or complex actions in the agent. In this piece of work the resulting logical status determines the decrement value which will be used to generate a new offer or counter-offer. The closer a resulting logical status of an offer is to the state t the smaller the decrement to be used in the counter-offer will be.

4 Results From Tests

The scenario used in the tests describes an organization that wishes to buy a determined product in the market. To achieve it the organization broadcasts an announcement urging the society and all organizations interested in providing such a product to contact and begin negotiations. There are two situations that were approached in the tests:

- An organization responds to the announcement;
- Two organizations respond to the announcement.

In the situations presented above, both offer evaluation approaches were used for the organization that wishes to buy the product as well as for the supplier ones — see Table 2.

Consumer Org.	**Supplier Org. 1**	**Supplier Org. 2**
Utility Value	Utility Value	—
Utility Value	Paraconsistent	—
Paraconsistent	Utility Value	—
Paraconsistent	Paraconsistent	—
Utility Value	Paraconsistent	Utility Value
Paraconsistent	Paraconsistent	Utility Value

Table 2. Use of the approaches in possible situations of the scenario used in the tests.

The values[7] contained in the *PS's* of the organizations were the same ones used in both approaches. The Consumer organization (*CO*) uses the values presented in Table 3 while the Supplier organizations (*SO*) use the values present in Table 4.

According to the strategy used, the initial offer made by the *CO* is the maximization of the continuous values contained in its *PS* — see Table 5. For discrete values the choice is at random, once any value of the set satisfies the *CO*.

In the tests, the negotiation session was limited to a number of 50 interactions. If at the end of a session a *SO* does not make an offer that the *CO* accepts, so the negotiation is closed without winners.

[7] For *SC's* that belong to the continuous domain, the first value corresponds to the value that satisfies less and the second value corresponds to the value that satisfies more.

CS	Possible Values	Priority
Size	$\{M, L\}$	1
Model	$\{sport, regular\}$	1
Color	$\{blue, black\}$	1
Price	$\{5, 30\}$	10
Payment Term	$\{0, 120\}$	7
Quantity	$\{50, 80\}$	4

Table 3. Values used in the *EP* of the *CO*.

CS	Possible Values	Priority
Size	$\{S, M\}$	4
Model	$\{sport, regular\}$	4
Color	$\{blue, black\}$	4
Price	$\{5, 40\}$	5
Payment Term	$\{0, 120\}$	5
Quantity	$\{50, 80\}$	10

Table 4. Values used in the *EP* of the *SO's*.

CS	Value
Size	M
Model	*sport*
Color	*blue*
Price	5
Payment Term	120
Quantity	80

Table 5. Values used in the initial offer made by the *CO*.

4.1 Scenario with two Organizations that Use the Same Offer Evaluation approach

The values of decrement used in the tests with the *Utility Value Approach* are 5, 10 and 15[8]. In the tests all the combinations of organizations and values of decrement were used. In the first tests the *CO* sets the decrement and the *SO* assumes a different decrement at each negotiation session — see Tables 6, 7 and 8. The approach used in the tests is the utility value one.

CO	*SO*	Interactions	Utility	Result	Accepted Offer
5	5	23	-4	contracted	[m, sport, blue, 6, 120, 52]
5	10	12	-9	contracted	[m, sport, blacko, 8, 120, 56]
5	15	24	-28	contracted	[m, sport, blue, 10, 120, 56]

Table 6. Results of negotiation between the *CO* with decrement value set at 5 and the *SO* with several decrement values, both using the *Utiliti Value Approach*.

CO	*SO*	Interactions	Utility	Result	Accepted Offer
10	5	24	-5	contracted	[m, sport, black, 6, 120, 52]
10	10	16	-8	contracted	[m, sport, blue, 8, 120, 56]
10	15	32	-29	contracted	[m, sport, black, 10, 120, 56]

Table 7. Results of negotiation between the *CO* with decrement value set at 10 and the *SO* with several decrement values, both using the *Utiliti Value Approach*.

CO	*SO*	Interactions	Utility	Result	Accepted Offer
15	5	21	-5	contracted	[m, sport, black, 6, 120, 52]
15	10	14	-8	contracted	[m, sport, blue, 8, 120, 56]
15	15	28	-27	contracted	[m, sport, blue, 10, 120, 56]

Table 8. Results of negotiation between the *CO* with decrement value set at 15 and the *SO* with several decrement values, both using the *Utiliti Value Approach*.

In the *Paraconsistent Approach* the decrement values used were $2-10$, $5-15$, $4-20$[9]. Similarly to the tests carried out for the value approach, the *CO* sets the decrement values in each test while the *CO* uses each of the decrement values in the tests — see Tables 9, 10 e 11.

[8] The values are idiosyncratic

[9] Where, $2-10 = \{2, 4, 6, 8, 10\}$, $5-15 = \{5, 7, 10, 13, 15\}$ and $4-20 = \{4, 8, 12, 16, 20\}$.

CO	*SO*	Interactions	*CD*	Result	Accepted Offer
2-10	2-10	12	0.6	contracted	[m, sporte, blue, 11, 120, 56]
2-10	5-15	7	0.7	contracted	[m, regular, blue, 8, 120, 56]
2-10	4-20	5	0.8	contracted	[m, sport, blue, 8, 120, 64]

Table 9. Results of negotiation between the *CO* with decrement value ranging $2-10$and the *SO* with several decrement values, both using the *Paraconsistent Approach*.

CO	*SO*	Interactions	*CD*	Result	Accepted Offer
5-15	2-10	11	0.6	contracted	[m, regular, black, 11, 120, 56]
5-15	5-15	7	0.7	contracted	[m, sport, blue, 8, 120, 56]
5-15	4-20	5	0.8	contracted	[m, regular, black, 8, 120, 64]

Table 10. Results of negotiation between the *CO* with decrement value ranging $5-15$ and the *SO* with several decrement values, both using the *Paraconsistent Approach*.

4.2 Scenario with two Organizations that used Different Approaches for Offer Evaluation

In the first part of the tests the *CO* uses the *Utility Value Approach* while the *SO* uses the Paraconsistent one — see Tables 12, 13 e 14.

In this part of the tests the *CO* uses the *Paraconsistent Approach* while the *SO* uses the utility value one — see Tables 15, 16 e 17.

4.3 Scenario with Three Organizations

For this scenario the decrement values used by the *CO* and *SO?s* were chosen through the analysis of the results of previous negotiation sessions[10] — see Sections 4.1 and 4.2. The decrement value of the *CO* chosen for the value approach was 5 and for the paraconsistent one $5-15$, because the latter presents a better gain — see Tables 6, 7 and 8 — in relation to price and term for payment that have the two highest utilities for the *CO* — see Tables 3. For the *SO* (*SOU*) which uses the valuated approach the decrement value chosen was 15, and for the *SO* (*SOP*) which uses the paraconsistent approach the range of values was

[10] The same *PS* was used for both *SO's*

CO	*SO*	Interactions	*CD*	Result	Accepted Offer
4-20	2-10	10	0.6	contracted	[m, sport, blue, 11, 120, 56]
4-20	5-15	7	0.7	contracted	[m, sport, black, 8, 120, 56]
4-20	4-20	5	0.8	contracted	[m, sport, black, 8, 120, 64]

Table 11. Results of negotiation between the *CO* with decrement value ranging $4-20$ and the *SO* with several decrement values, both using the *Paraconsistent Approach*.

CO	*SO*	Interactions	Utility	Result	Accepted Offer
5	2-10	13	-18	contracted	[m, sport, blue, 9, 120, 56]
5	5-15	12	-8	contracted	[m, sport, blue, 8, 120, 56]
5	4-20	8	44	contracted	[m, sport, blue, 6, 120, 64]

Table 12. Results of negotiation between the *CO* with decrement value set at 5 and the *SO* with several decrement values.

CO	*SO*	Interactions	Utility	Result	Accepted Offer
10	2-10	16	12	contracted	[m, sport, blue, 6, 120, 56]
10	5-15	8	2	contracted	[m, regular, black, 7, 120, 56]
10	4-20	7	45	contracted	[m, regular, blue, 6, 120, 64]

Table 13. Results of negotiation between the *CO* with decrement value set at 10 and the *SO* with several decrement values.

CO	*SO*	Interactions	Utility	Result	Accepted Offer
15	2-10	14	23	contracted	[m, regular, blue, 5, 120, 56]
15	5-15	21	-19	contracted	[m, sport, black, 9, 120, 56]
15	4-20	6	53	contracted	[m, sport, black, 5, 120, 64]

Table 14. Results of negotiation between the *CO* with decrement value set at 15 and the *SO* with several decrement values.

CO	*SO*	Interactions	*CD*	Result	Accepted Offer
2-10	5	16	0.6	contracted	[m, sporte, blue, 10, 120, 52]
2-10	10	9	0.7	contracted	[m, sporte, black, 8, 120, 56]
2-10	15	6	0.6	contracted	[m, sporte, black, 10, 120, 56]

Table 15. Results of negotiation between the *CO* with decrement value ranging $2-10$ and the *SO* with several decrement values.

CO	*SO*	Interactions	*CD*	Result	Accepted Offer
5-15	5	16	0.6	contracted	[m, sport, blue, 10, 120, 52]
5-15	10	9	0.7	contracted	[m, sport, black, 8, 120, 56]
5-15	15	6	0.6	contracted	[m, regular, blue, 10, 120, 56]

Table 16. Results of negotiation between the *CO* with decrement value ranging $5-15$ and the *SO* with several decrement values.

CO	*SO*	Interactions	*CD*	Result	Accepted Offer
4-20	5	16	0.6	contracted	[m, regular, blue, 10, 120, 52]
4-20	10	9	0.7	contracted	[m, sport, blue, 8, 120, 56]
4-20	15	6	0.6	contracted	[m, sport, blue, 10, 120, 56]

Table 17. Results of negotiation between the *CO* with decrement value ranging $4-20$ and the *SO* with several decrement values.

$4 - 20$. Both values of the *SO?s* present — see Tables 6, 7 and 8 — a gain in quantity which is the *SC* the one which has more utility — see Table 4 — for these organizations. The Table 18 presents the results of this scenario.

CO	*SOP*	*SOU*	Interactions	*Utility/CD*	Winner	Accepted Offer
5	4-20	15	8	44	*SOP*	[m, sport, blue, 6, 120, 64]
5-15	4-20	15	5	0.8	*SOP*	[m, sport, blue, 8, 120, 64]

Table 18. Results of negotiation between the *CO* and *SOP* and *SOU*.

5 Conclusions

The *Paraconsistent Approach* converges toward the end of negotiation with fewer interactions when compared to the value approach — see Table 18. Due to the very nature of a negotiation, it is impossible to infer that the result obtained was the best one. In the tests carried out one could observe that the selection agent that used the *Utility Value Approach* obtained a bigger utility for itself when it negotiated with a supplier agent that used the same approach — see Table 6. However, the same agent obtained an even better result when it negotiated with a supplier agent that used the *Paraconsistent Approach* — see Table 12, in this case both organizations succeeded because the negotiation was ended with fewer interactions and both the *CO* and *SO* reached the best utility in the last offer, the same happens when both agents uses the *Paraconsistent Approach* — see Table 18.

The use of the *EPL* in this work is due to the formalism representation offered to the problem. The gain in the approach is due to the use of a list of decrements instead of a set one. The *ELP* allows that the list of decrements to be used in a suitable manner, according to a logical interpretation. The *EPL* provides an interpretation which is closer to the one of the human beings in the case of an offer evaluation or counter-offer evaluation in relation to what the person wants in a determined negotiation.

The results obtained in this work may be improved if different decrement values and evidential values are used, besides the use of different actions in relation to the resulting logical statuses. The time of an offer evaluation using the *Paraconsistent Approach* is 654 milliseconds and the average time of an offer evaluation using the *Utility Value Approach* is 2 milliseconds. As this work aimed at developing a new approach, there was not interest in optimizing the time.

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