PARACONSISTENT DESCRIPTION OF CHANGE

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ABSTRACT: The aim of this paper is to present a description of change in the framework of tense logic. After considering some examples of using the intervals, we present the main principles of the logic of inconsistent reasoning. Then we built a tense interval paraconsistent semantics and discuss some of its possible applications.

Keywords: change, interval semantics, paraconsistent logic.

Many authors pointed out the fundamental character of the problem of states separation. In particular, N.C.A. da Costa has specified this problem in the following words:

> (...) a countless set (...) of continuums, temporal and nontemporal, would be mentioned which broach the same problem, such, for example, as a drawing of the hard boundary between children and adults, between the alive and the dead, and also between the other pairs of relevant changeable qualities in everyday language and even in empirical sciences (Da Costa 1982, p. 121).

L.A. Zadeh and his followers have made significant contribution to the solution of this problem (cf. Zadeh 1973) by developing a formal theory of *fuzzy* objects. This theory is based on the concept of a fuzzy set. A set M is fuzzy if there is at least one object which belongs to M in degree which is not equal to 1.

An analysis of fuzzy situations shows that the propositions describing them are inconsistent. The resources of classical logic are insufficient to present formally such situations. However, it is possible to construct the logical calculi which allow inconsistent propositions as parts of our theory. In these calculi the inconsistency does not spread on the whole theory, does not destroy it. Thus, the claim of consistency is in a sense relative.

A theory is *inconsistent with respect to an operator of negation* $\sim$ if and only if for some expression C, both C and $\sim C$ are theorems of the theory. A theory is *inconsistent* if and only if it is inconsistent with respect to some of its negation operators. A theory is *contradictory* if and only if it is in consistent and closed under conjunction introduction. (Any contradictory theory contains theorems of the form $A \wedge \sim A$.) A theory is *trivial* or *absolute inconsistent* if and only if each formula of its language is a theorem of the theory (Peña 1980, pp. 238-239).

In the logical systems of inconsistent propositions a nonderivability of some formula is not an earmark of consistency. Existence of such a formula testifies merely a nontriviality of a system. But the nontriviality does not imply consistency here, as it does in classical logic. Classical two-valued Frege-Russell logic eliminates paradoxical expressions out of its formalisms. "The logic of paradox" has a different task: to infer all possible consequences from the paradoxical expressions.

Two main approaches maintain this strategy: either a localization of the law of non-contradiction or preservation of its validity. Paraconsistent logic exploits the first approach and asserts that not all paradoxes are antinomies, not all paradoxes destroy a formal system. Such non-antinomycal paradoxes are "true paradoxes". The "untrue" paradoxes are, from the point of view of paraconsistent logic, self-inconsistent statements. If such a statement is present in a formal system, the system its trivial. The second approach is represented by the fuzzy contradictory logic. It treats some paradoxes as false, others as both true and false simultaneously:

> (...) every contradiction or antinomy (...) *is false*, although *some* contradictions are true, since some sentences may be *both* true and false (Peña 1980, p. 240).

An antinomysity is in such a case not an earmark of triviality of a formal system.

A formalisation of inconsistent reasoning claims a modification of an operator of negation. One of the ways to do this is to weaken the classical negation. A modified operator does not submit to the law of non-contradiction. This method is justified by the fact that the classical negation operator is not an adequate representative of the natural language negation. However, in order to keep the logical power of a formal system, it is better not to weaken it by removing or localizing the laws of non-contradiction and of the excluded middle. Contradictorial infinitely-valued fuzzy logic gives us a possibility to study the situation of fuzziness without weakening the logic. The laws of non-contradiction and of the excluded middle remain valid for each operator of negation which is present in such a logic. This is the principal advantage of the inconsistent fuzzy theories in comparison with the ordinary fuzzy theories.

One of the reasons to develop the fuzzy contradictorial formal systems was the intention

> To conceive every *body* as the set of its parts, that is to say: as an object which is individuated merely by the degrees of membership of all its parts to it, so that certain relations' holding between its members (its parts) is not a further requirement for the body's individuation, but a mere result arising from the existence of the body itself; when a body is broken up and then rearranged, the result may be *another* body, because (some of) the parts may belong to the new object to an extent different from the one to which they belonged to the former body (Peña 1980, pp. 242-243).

In the thirtieth J.N. Woodger (1937) has built an original axiomatic theory with relation "to be a part" as a primitive notion. He ascribed spatial and time senses to this relation. In terms of relation " to be a part" and the relation of time precedence the concepts "sum of parts", "moment", "organized units" (as a cell or an organism) and "instant part of an organized unity" were defined. Theis makes it possible to formalize the biological relations which arise from a model of cell division. The special kind of continuous change, a branching continuum, was formally expressed.

J.-M. Laforge used as the concept "to be a fragment of physical aggregate" (F) and the concept of the territory of physical compound (T) as initial concepts for description of the physical space-time. As he put it:

> The territory is what completely overlap a class of the objects having common mathematical or other well-defined property (Laforge 1978, p. 35).

He considered a propositional calculus extended by the constants F and T a logic of territories. A transformation of a physical compound, realizing in the breaking up and a subsequent joining up of the parts, can break a topological structure of the physical compound, but does not break an invariance of the relations F and T. This circumstance provides the fundamental character of these relations. In terms of F and T the pseudo-topology of physical compound is built. The concept of boundary, dividing set of points, is replaced by the concept of pseudo-boundary. The pseudo-boundary of the fragment *A* of the certain physical compound is a class of fragments that intersect *A* and its complement. An object belonging to the pseudo-boundary of the fragment *A* has properties of the objects from the fragment *A* and from its complement.

To study the properties of time it is crucial to develop a theory of the objects change which may be represented as a change in degree of the membership of the parts of the changing objects. It is important namely in the case when an implementation of the relations between the parts of a body is not a presupposition of its individualization. Such an implementation is determined by the existence of the body.

Already Aristotle was aware of the serious problems which arise when we use the objects that do not possess temporal extent. He used intervals to analyze the problems of time and change. Aristotle insisted upon the continuity of movement and ascribed the attribute of continuity to time. He assumed the infinite divisibility of the periods of time (Aristotle 1950, 219 a 10, 218 a 5). According to his interpretation of inconsistency, one part of the changing thing is in one state, whereas the other part is in another state (Aristotle 1950b, 1005 b 20; Aristotle 1950, 234 b 15). The inconsistent propositions correspond to different periods of time. However, Aristotle considered the changes of quality to occur at once. He solved the problem of transition, assuming that the moment of transition has to be taken as the first moment of the next state (Aristotle 1950, 253 b 25, 263 b 15-30).

First of all, it looks quite disputable to construct a period of time with the help of the instants which do not have any duration.[1] Moreover, recent investigations show that the moments cannot be applied to the study of the phenomenal continuums. There are qualitative changes of certain type which do not allow us to separate clearly the state before change from the state after it. It is impossible to determine the last moment of a prior state and the first moment of a posterior state. The predicates of natural language do not possess the values at the moments of time (Hamblin 1969, p. 414; Needham 1980, p. 49). The beginnings and the ends of many states and processes are placed somewhere in the intervals of time and not at fixed points. So far as there exists a vagueness of the boundaries between different states of being, either propositions describing the states before and after change are both true or their truth-value is not determined.

C.L. Hamblin (1969) proposed the first axiomatic theory of the time-intervals. An irreflexive, antisymmetric and transitive "later-then" relation was taken as a primitive notion. An attempt to argue that Hamblin's "later-then" relation is more than simple ordering relation has brought to another version of the interval theories. P. Needham (1980) aimed to built a theory of linear order in such a manner that the direction and the distinctions of future and past would be inexpressible:

> Such a theory of linear order expresses no more than that certain times lie between others, the fundamental order concept being that of three-place betweeness rela-

tion. The procedure adopted in the theory presented here is to define a betweeness relation in term of which the linear ordering of time is expressed. A dyadic order relation can than be defined on the basis of the betweeness relation (Needham 1980, p. 51).

E. Lemmon (1967) introduced a notion of truthfulness relative to the intervals side by side with the notion of truthfulness relative to the moments. The basic relation of this logic of space-time zones is a four-dimensional relation "part-whole". Next step in creation of the logic of space-time zones is a temporal interval logic.

A special sort of inconsistent propositions, the propositions about transition states, is the proper subject of temporal logic. Most of the temporal logic calculi presuppose a concept of time moment as a starting abstraction. An evaluation of the formulae is carried out relative to the moments that are ordered by an "earlier-later" relation. Change of a truth-value of a formula testifies the change in a state of affairs. The change of truth-value is considered here as an instant one.

G. von Wright (1963) proposed an interesting formalism to explicate the concept of change in the above mentioned style. According to this formalism the values of formulae are determined relative to the temporal structures with discrete order of moments. An event is considered a pair of the states of affairs, i.e., a transition state. It is represented by the formula *A*T*B*. *A* and *B* designates the propositions about states and T is a binary copula "*and next.*" In von Wright's semantics the formula *A*T*B* is true only when the formula *A* is true. In virtue of discreteness of temporal structure there is no intermediary moment between the last moment of *A*'s truth and the first moment of *B*'s truth. Thus, in this approach the moment of transition coincides with the last moment of *A*'s truth, or with the first moment of *B*'s truth. On the other hand, if the order of moments is dense, there is always a moment between *A*'s and *B*'s truth. However, in this case the formula *A*T*B* is true at the moment in which formulae A and B are false (Humberstone 1979, pp. 190-192).

The first step in the construction of tense interval logic was to involve *two* operators of negation:

> The strong negation of a formula would be true with respect to an interval if the formula itself was false through all subintervals of the interval, while the weak negation would be true merely if it was not the case that the formula negated was true with respect to the interval in question (even if it was true for some subintervals) (Humberstone 1979, p. 172).

The interval model I is a triple $< T, \subseteq, |\ | >$, where T is a class of time intervals: $t, u, v, \ldots t', u', v' \ldots$; $\subseteq$ is a mereological subinterval relation; $|\ |$ is an interpretation function: $|\ |: F \times T \rightarrow \{0,1\}$, where F is a set of formulae, 0 and 1 are the values "false" and "true" respectively. A propositional variable a is true relative to an element of the model $< T, \subseteq, |\ | >$ if and only if $|a|_t = 1$. A peculiarity of the interpretation of the propositional variables is an assumption of the steadiness of a truth-value: $|a|_t = 1$ entails $|a|_{t'} = 1$ for any t', $t' \subseteq t$. This assumption is introduced to exclude the intervals when a propositional variable is true and false simultaneously.

The second stage of this construction consists in introducing the tense operators into the formal language. The insertion of the "earlier-later" relation R into the model I turns it into a tense interval model TI: $<T, \subseteq, R, |\ |>$. The minimal conditions on the relations between $\subseteq$ and R are:

(a) for all $t, u, u' \in T$, if uRt and $u' \subseteq u$, then $u'Rt$,
(b) for all $t, t', u \in T$, if uRt and $t' \subseteq t$, then uRt',
(c) for all $w, t, u \in T$, if $u \subseteq$ t and uRw, then either tRw, or for some $v \in T$, $v \subseteq w$ and $v \subseteq t$.

The assumptions (a) and (b) reveal a sense of uRt, (c) expresses the uninterruptedness (continuity) of intervals (Humberstone 1979, p. 184). An additional condition for an interpretation of the formulae of such calculi is an infinite divisibility of the intervals. This concept was introduced to express the continuity of time (cf. Aristotle 1950, 218 a, 263 a 10-15).

The infinite divisibility gives us intervals that combine the features of dense and discrete structures. In interval structures infinite divisibility is equivalent to the density of momentary structures. The discreteness of intervals consists in an absence of an interval between two given intervals.

This peculiarity of the interval structures may be used in modeling of dynamic systems if the arising and disappearing of the objects are momentary events, while their coexistence is a process which lasts in time. Such systems belong to a class of continuous-discrete systems. They are characterized by discrete and continuous types of changes. Namely, these systems behave as the continuous ones in the periods which are laid between the discrete events.

The impossibility of an exact fixation of a moment when an object arises or disappears demands an alternative approach to analysis of changing systems: the arising and disappearing should be considered *uninterrupted processes.*

This argument shows clearly the use of the tense paraconsistent calculi with interval semantics. The sphere of application of existing tense interval logic is the propositions about states and processes only. Semantics of such logic is standard in the sense that the propositions which are interpreted relative to the time intervals submitted to the law of non-contradiction. Contradiction is distributed among the distinct time periods. A proposition about a state before change is true relative to one period and a proposition about a state after change is true relative to another period. The transition itself is excluded from a logical consideration. The problem of explicating the origin and the end of a state remains unresolved.

The attempts to demarcate the states clearly express an intention to eliminate inconsistency. Unlike that, tense paraconsistent logic allows us to express not only a succession of states, but also a tie between them. There is a peculiarity of the "paraconsistent analysis" of the propositions about transition states. Namely, it is assumed that any change occupies some period of time. The propositions are valued with respect to its subperiods. They are ascribed to a degree of truthfulness from the interval [0,1]. Such an approach is in close agreement with the fact that a changing object both, in certain degree, the features of its previous state and acquires the new ones, passing a number of the states or phases.

I will discuss later a description of change in the framework of one branch of temporal logic, namely, tense interval logic. My goal is to present an approach to the construction of tense paraconsistent logic in line with the proposals of N.C.A. da Costa and S. French (1989). In accordance with Hamblin's intention, I consider change occupying an interval of time that has fuzzy boundaries. The description of change consists in conjunction of the descriptions of those states overlapping the interval of change.[2] As a result, such a description contains inconsistent statements.

In order to give a formal representation of such description, I offer to consider a formula to be true relative to an interval if and only if its negation is false over some subinterval. And if a negation of a formula is true over an interval, then the formula without negation must be false over some subinterval. Conjunction of two formulae is true over an interval if and only if there is some subinterval, and these formulae are true over all subintervals of that subinterval. The reference to all subintervals is stipulated by the above intuition about truth of a formula at an interval. Without this restriction the connected formulae considered as connected ones may be true over different subintervals of the evaluation interval.

These intuitions are embodied in semantics of interval paraconsistent logic. It is defined relative to model I. The function $|\ |$ is extended inductively to supply values to all the formulae of the language of interval paraconsistent logic.

*Definition 1.*The truth conditions for the formulae of the language of interval paraconsistent logic are:

T1. $|{\sim}A|_t = 1$ iff $\exists t'(t' \subseteq t$ and $|A|_{t'} = 0)$;
T2. $|A \wedge B|_t = 1$ iff $\exists t'(t' \subseteq t$ and $\forall t''($if $t'' \subseteq t'$, then $|A|_{t''} = 1$ and $|B|_{t''} = 1))$;
T3. $|A \vee B|_t = 1$ iff $\exists t'(t' \subseteq t$ and $\forall t''($if $t'' \subseteq t'$, then $|A|_{t''} = 1$ or $|B|_{t''} = 1))$;
T4. $|A \supset B|_t = 1$ iff $\exists t' (t' \subseteq t$ and $\forall t''($if $t'' \subseteq t'$, then $|{\sim}A|_{t''} = 1$ or $|B|_{t''} = 1))$;
F1. $|{\sim}A|_t = 0$ iff $\forall t'$ (if $t' \subseteq t$, then $|A|_{t'} = 1)$;
F2. $|A \wedge B|_t = 0$ iff $\forall t'($if $t' \subseteq t$, then $\exists t''(t'' \subseteq t'$ and $|A|_{t''} = 0$ or $|B|_{t''} = 0)$;
F3. $|A \vee B|_t = 0$ iff $\forall t'$ (if $t' \subseteq t$, then $\exists t''(t'' \subseteq t'$ and $|A|_{t''} = 0$ and $|B|_{t''} = 0))$;
F4. $|A \supset B|_t = 0$ iff $\forall t'($if $t' \subseteq t$, then $\exists t''(t'' \subseteq t'$ and $|{\sim}A|_{t''} = 0$ and $|B|_{t''} = 0))$.

Definition 2. A formula A of the language of interval paraconsistent logic is valid if and only if for any model I, for every $t \in T$, $|A|_t = 1$.

Under some restrictions it is possible to express the truth conditions for the system C_1 (Da Costa & Alves 1977) in the given interval semantics. Let A^o and B^o be abbreviations for ${\sim}(A \wedge {\sim}A)$ and ${\sim}(B \wedge {\sim}B)$ respectively. In the accepted notation the truth conditions for the system C_1 can be written down as follows:

(1) $|A| = 0 \Rightarrow |{\sim}A| = 1$;
(2) $|{\sim}{\sim}A| = 1 \Rightarrow |A| = 1$;
(3) $|B^o| = 1$ and $|A \supset B| = 1$ and $|A \supset {\sim}B| = 1 \Rightarrow |A| = 0$;
(4) $|A \supset B| = 1 \Leftrightarrow |A| = 0$ or $|B| = 1$;

(5) $|A \wedge B| = 1 \Leftrightarrow |A| = |B| = 1$;
(6) $|A \vee B| = 1 \Leftrightarrow |A| = 1$ or $|B| = 1$;
(7) $|A^{o}| = |B^{o}| = 1 \Rightarrow |(A \vee B)^{o}| = |(A \wedge B)^{o}| = |(A \supset B)^{o}| = 1$.

As was told above, if we take an "earlier-later" relation R, the model I is turned into a tense interval model TI. The conditions T1- F4 are supplemented by the conditions for the formulae with tense operators "it will always be the case, that..." (G), "it has always been the case, that..." (H), "it will be the case, that..." (F) and "it has been the case, that..." (P):

T5. $|GA|_t = 1$ iff $\forall t' \in T$ (if tRt', then $|A|_{t'} = 1$);
T6. $|HA|_t = 1$ iff $\forall t' \in T$ (if $t'Rt$, then $|A|_{t'} = 1$);
T7. $|FA|_t = 1$ iff $\exists t' \in T$ (tRt' and $|A|_{t'} = 1$);
T8. $|PA|_t = 1$ iff $\exists t' \in T$ ($t'Rt$ and $|A|_{t'} = 1$);
F5. $|GA|_t = 0$ iff $\exists t' \in T$ (tRt' and $|A|_{t'} = 0$);
F6. $|HA|_t = 0$ iff $\exists t' \in T$ ($t'Rt$ and $|A|_{t'} = 0$);
F7. $|FA|_t = 0$ iff $\forall t' \in T$ (if tRt', then $|A|_{t'} = 0$);
F8. $|PA|_t = 0$ iff $\forall t' \in T$ (if $t'Rt$, then $|A|_{t'} = 0$);

and by the special conditions for the operators "it always be the case, that..." (L), "it sometimes be the case, that..." (M):

T9. $|LA|_t = 1$ iff $\forall t'$ (if $t' \subseteq t$, then $|A|_{t'} = 1$);
T10. $|MA|_t = 1$ iff $\exists t'$ ($t' \subseteq t$ and $|A|_{t'} = 1$);
F9. $|LA|_t = 0$ iff $\exists t'$ ($t' \subseteq t$ and $|A|_{t'} = 0$);
F10. $|MA|_t = 0$ iff $\forall t'$ (if $t' \subseteq t$, then $|\neg A|_{t'} = 1$).[3]

The axiom set from (Da Costa & Alves 1977) may be extended by the standard tense axioms:

$G(A \supset B) \supset (GA \supset GB)$;
$H(A \supset B) \supset (HA \supset HB)$;
$A \supset GPA$; $A \supset HFA$;
$L(A \supset B) \supset (LA \supset LB)$

and by the special axiom $A \supset M(A \wedge A^{o})$.

We can use this semantics to study the many-valued logic. D. Bochvar has offered calculus with internal and external connectives. The truth matrices for some of them are:

I.

A	$\neg A$	$+A$
0	1	0
1	0	1
*	*	0

II. $A \cap B$:

$A \cap B$	0	1	*
0	0	0	*
1	0	1	*
*	*	*	*

where $\neg A$ is an intrinsic negation of A, $+A$ is an extrinsic assertion of A ("A is true"), $\cap$ is an intrinsic conjunction and * is the value "meaningless". The connectives $\neg$, + and $\cap$ constitute a functionally complete system of connectives (cf. Finn 1974).

Theorem. Bochvar's matrices are recoverable by the truth conditions of interval paraconsistent semantics

Proof. The matrix I is represented by conditions:

1. $|A|_t = 1$ iff $\forall t'$ (if $t' \subseteq t$, then $|\neg A|_{t'} = 0$);
2. $|\neg A|_t = 1$ iff $\forall t'$ (if $t' \subseteq t$, then $|A|_{t'} = 0$);
3. $|A|_t = 0$ iff $\forall t'$ (if $t' \subseteq t$, then $|\neg A|_{t'} = 1$);
4. $|\neg A|_t = 0$ iff $\forall t'$ (if $t' \subseteq t$, then $|A|_{t'} = 1$);
5. $|A|_t = *$ iff $\forall t'$ (if $t' \subseteq t$, then $|\neg A|_{t'} = 1$ and $|A|_{t'} = 1$);
6. $|\neg A|_t = *$ iff $\forall t'$ (if $t' \subseteq t$, then $|\neg A|_{t'} = 1$ and $|A|_{t'} = 1$);
7. $|+A|_t = 1$ iff $\forall t'$ (if $t' \subseteq t$, then $|A|_{t'} = 1$);
8. $|+A|_t = 0$ iff $\forall t'$ (if $t' \subseteq t$, then $|\neg A|_{t'} = 1$) or $\forall t'$ (if $t' \subseteq t$, then $|\neg A| t' = 1$ and $|A|_{t'} = 1$).

The matrix II is represented by the conditions

9. $|A \cap B|_t = 1$ iff $|A|_t = 1$ and $|B|_t = 1$;
10. $|A \cap B|_t = 0$ iff $|A|_t = 0$ or $|A|_t = 0$;
11. $|A \cap B|_t = *$ iff $\forall t'$ (if $t' \subseteq t$, then $|\neg A|_{t'} = 1$ and $|A|_{t'} = 1$) or $\forall t'$ (if $t' \subseteq t$, then $|\neg B|_{t'} = 1$ and $|B|_{t'} = 1$).

Thus, we obtain the interval interpretation of Bochvar's calculus.

Notes

1 In his lecture 'The Theory of Continuity' Bertrand Russell considered philosophical aspect of the problem of continuity: "Space and time are treated by mathematician as consisting of points and instants, but they also have a property, easier to feel than to define which is called continuity, and thought by many philosophers to be destroyed when they are resolved into points and instants" (Russell 1995, p. 135).

2 G. Priest (1982) uses the conjunction of the descriptions of the states before and after the change in order to represent the instant of change.

3 Then $\neg A$ = L-A, where "$\neg$" is Humberstone's strict interval negation (see Humberstone 1979).

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LOGICAL MODELLING OF CONFLICT PHENOMENON

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ABSTRACT: The paper seeks to schematize some fundamental characteristics of the conflict situations by means of modal (intensional) logic. Conflict is considered a deviant interaction as well as an intersubjective process of delegitimizing an activity on realization of interests. Interpreting a normal interaction as a symmetry of certain type, the author constructs a special model of a symmetric situation and applies it to the analysis of a conflict. The paper examines theoretic schemes for legitimization of deviations as well as for legitimization of social asymmetry, and ascertains a general relationship between symmetrization and deduction (deductive legitimization) by means of the operation *C* of "deductive closure" (consequences addition).[1]

Keywords: conflict, interest, symmetrization, deviation, legitimization.

CONTENTS

The idea of the logical modeling of conflicts dates back to J. von Neumann and I. Morgenstern (1953), who elaborated the set-theoretic (axiomatic) approach to the analysis of games as models of "economic behavior". Since that time the *Theory of Games* has been developing in the matrix, functional and numerical directions, but not in the logical axiomatic one. In our opinion, the prospects of the logical modeling of conflicts are associated with methodological works in social phenomenology (Grathoff), cognitive approach (Filley) and discourse modeling (Apostel, Allen, Cohen, Levesque).

In this article we clarify the principal ideas of our approach to the intersubjective modeling of a conflict discourse which have been developed in detail in a number of works (see Ishmuratov 1987, 1987a, 1988, 1989, 1994, 1995, 1997).