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A Temporal Ontology for Reasoning about Actions

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GJCST Classification: K.4.4

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I. Introduction

The temporal reasoning consists to formalize the notion of time and to provide means to represent and reason on the temporal aspects of knowledge. To describe the properties of the good performance of applications, temporal logics are formalisms well adapted , in particular by their capacity to express the scheduling of actions/events in time.

Classic logics are unsuited to temporal reasoning. One of the weaknesses of these logics is that the material implication takes account neither of temporal scheduling between causes and effect, nor of monotony of causal reasoning.

The causal reasoning is a non monotonous temporal reasoning. Concept of cause is usually used in daily life, we frequently attribute to people and to objects a causal capacity compared to the events. The human use their knowledge on relations on causes/effect type to reason on current situations of the life and to make decisions which generally determine the choice of actions to carry out to reach desirable effects or to avoid undesirable effects.

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Temporal logics having retained researchers attention are Allen and Mc-Dermott's logics . They are the most important formalisms of temporal representation. The time representations can be characterized by the primitive objects which they consider. Allen developed a temporal motor specialized (time specialist) to manage relations between temporal aspects of knowledge and on this basis he conceived a temporal logic. The Allen temporal motor's role is the management of relations between the intervals. Its ontology is constitute of properties, events and process.

Mc-Dermott proposed a formalism of causality, action and planning. For causality, he mentioned the qualification problem of a cause and the persistence problem of a fact. He pointed out that a solution of these problems is in a good formalization of the non monotonous reasoning.

In Allen and Mc-Dermott formalism's, we notice that notions of past, present and future do not appear in the predicate Ecause. How can one know if Ecause $(p, e_1, e_2, r, d_1, d_2)$ means that the event e_1 is always followed event e_2 after a time included in the interval (d_1, d_2), occurred in the past, present or future? How to affirm that effects preceding step causes?

We are interested by an agentive design of causality, closely related to the concept of action whose modelling must include two fundamental aspects: - Temporal aspect at the representative level (the cause must precede the effect) and, - Non monotonous aspect on the functional level of the causal relations (an effect must have a cause). The design of adopted causality is from the formalization of the causal and temporal reasoning.

Our work is devoted to systematic study of actions theories by using a logical formalism based on a first order language increased by operators whose main aim is to facilitate the representation of causal and temporal relationships between actions and their effects as well as causal and temporal relationships between actions and events. Our formalism avoids an ambiguity like: effect precedes cause.

The originality of this work lies in proposal for a formalism based on equivalence classes. We also defined an operator who allows us to represent the universe evolutions for futures and passed varied. These operators allow to represent the types of reasoning which are prediction, the explanation and planning.

We propose a new ontology for causal and temporal representation of actions/events. The ontology used in our formalism consists of facts, events, process, causality, action and planning.

The paper is organized as follows: In the next section, we establish the formal background that will be used throughout this paper. In section 3, we propose a new ontology for causal and temporal representation of actions/events. The ontology used in our formalism consists of facts, events, process, causality, action and planning. In section 4, we define syntax and semantics of our temporal logic $\mathcal{L}_C$. We also define the valuation in the following cases:

– Case of the effects/events which require the realization of several actions at the same time. In this case, we represent the set of the actions occurred at the same time by the equivalence class of an action which is the representative of the class.
– Case of an action which is repeated in different time-element (process). We represent the set of the time-elements by the equivalence class of a time-element which is the representative of the class.
– Case of the competitive actions. We have two possibilities for the choice.

(i) Temporal choice
(ii) Economic choice

Section 5 is devoted to completude and in section 6 we conclude with a general idea of researches on actions theory.

II. Language, Notation and Terminology

a) Introduction

Within the framework of the formalization of an approach symbolic system for the temporal and causal reasoning, and inspired by work of [Allen, 84,][1], [McDermott, 82][3] and [Kayser and Mokhtari, 98][4], we propose a temporal causal formalism to reason on events and actions [Mamache, 2010][5].

The language is composed of two nival:

– To represent static information, the first level consists of a first order language with equality.
– the second level includes the predicates with temporal variables to represent dynamic information.

- Connectors: $\neg, \vee, \wedge, \supset$ and $\supset_c$ (causal implication)
- Two signs of quantification noted $\exists$ (existential quantifier) and $\forall$ (universal quantifier).
- A symbol of equality, which we will note $\equiv$ to distinguish it from the sign $=$.
- A countable infinite collection of propositional variable.
- A set of operational signs or symbols functional.
- Three unary temporal operators: P_k (past), F_k (future), and P_0 (present).
- The expressions are the symbol strings on this alphabet.
- The set of the formulas noted Φ is by definition the smallest set of expressions which checks the following conditions :
  - Φ contains the propositional variables.
  - A set of elements called symbols of individuals.
  - If A and B are elements of Φ it is the same for $\neg A$ and $A \supset_c B$.
  - If A is an element of Φ it is the same for $P_k A$, $F_k A$ and $P_0 A$.

To introduce causality J. Allen [1][2] uses the following formula:

Ecause (p_1,i_1,p_2,i_2). It expresses, thus, the fact that p_1 which occurs in i_1 caused the event p_2 which occurs in i_2.

Like Allen, we use the predicate Ecause to express that an action a is the cause of an event e.

b) Causality Atemporal Representation

In the following e designate an effect of the action a or an event caused by the action a.

To express that an action a is the cause of an event e or an effect of a, as Allen, we use the predicate Ecause$(a;e)$.

– If a is not the cause of e, we use $\neg$ Ecause $(a; e)$. In this case, the realization of e is due to another action.
– If a is the cause of the not realization of e, we use Ecause $(a; \neg e)$.
– If e is not realized because the action a is not executed, we use Ecause $(\neg a; \neg e)$. In this case a is a direct cause of e.

The actions seem first argument of the Ecause predicate.

The case where several actions $a_1,a_2,\ldots,a_m$ are the cause of the same effect or a single event is expressed by the formula:

Ecause $(a_1,a_2,\ldots,a_m; e)$ defined by

Ecause $(a_1,a_2,\ldots,a_m; e) \equiv$ Ecause$(a_1;e) \wedge \ldots \wedge$ Ecause $(a_m; e)$

where $a_1,a_2,\ldots,a_m$ are the atemporal expressions of actions type.

Definition 2.1 : Actions $a_1,a_2,\ldots,a_m$ are said to be direct cause of an event e if as soon as one of these actions is not carried out, the event is not executed.

This formula can be expressed as :

Ecause $(a_1,a_2,\ldots,a_m;e) \equiv ((\exists k)(\neg a_k \supset_c \neg e))$, if $a_1,a_2,\ldots,a_m$ are direct causes of e.

Example 2.2 : Ecause(prepare one's paper, travelling, ..., communicate) $\equiv$ ($\neg$ travelling) $\supset_c$ ($\neg$ communicate) $\vee$ ($\neg$ no prepare paper) $\supset_c$ ($\neg$ communicate)$\vee$...

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c) Causality Temporal Representation

If a is a temporal expression of action type we use the following formulas :

- $t \cdot a$ if a is produced in the past at the element of time t.
- $a \cdot t$ if a it happens in the future at the element of time t.

We will keep the same notations in the case of an event (or effect) e :

- $e \cdot t$ for the future.
- $t \cdot e$ for the past.

Example 2.3

a) *Colloquium · May, means:* the colloquium will be held in May.
b) *May · Colloquium, means:* the colloquium was held in May.

If a is an action carried out in t' then the predicate Ecause $(a.t'; e.t)$ expresses the fact that a carried out in t' is the cause of e true in t.

This notation avoids an ambiguity like:an action which will occur in the future in t' is the cause of the event e which occurred in the past in t (the effect precedes the cause). Thus the expression Ecause $(a.ta'; t.e)$ does not have a 'sense'.

An action can be instantaneous as it can be carried out during in a certain interval of time [Knight, 98][6],[Knight, 97] [7]. Consequently, the points and the intervals are necessary to express the execution time of an action.

We call time-element an interval or a point of time. Therefore, an action operates during a time-element [Knight, 98][6],[Knight, 97] [7].

Definition 2.4 : A point of time T is an instantaneous state of the universe defined by a subset of true proposals in a certain date and by this date.

This subset is the result of a causal relation. The set of points of time is noted P.

Definition 2.5 : A time-element is an interval or a point of time. An action thus operates during a time-element t. If a is an instantaneous action then t is a point of time. If a durative then t is an interval.

Definition 2.6 : Let T a nonempty set of time-elements, T is the union of two sets P and I, I is a set whose elements are intervals and P a set whose elements are points of time [Birstougeff, Ligozat, 89][9].

Definition 2.7 : Let T a nonempty set of time-elements and A a set of actions. $A.T$ is defined as being the set of elements $a.t$ where a is a temporal expression of action type which will be carried out in the future in the time-element t.

Definition 2.8 : Let T a non empty set of time- elements, A a set of actions, $A{\cdot}T$ the set of elements $a{\cdot}t$ and Dur_F; an application from $A{\cdot}T$ to IR_+ defined by [Knight, 98][6],[Knight, 97] [7].:

$$\begin{cases} Dur_F\,(a \cdot t) = 0 & \text{if } a \text{ is an instantaneous action, thus, } t \text{ is a point of time .} \\ Dur_F\,(a \cdot t) > 0 & \text{if } a \text{ is a durative action, thus, } t \text{ is an interval.} \end{cases}$$

Definition 2.9 : Let T a non empty set of time- elements, A a set of actions, $T{\cdot}A$ the set of elements $t{\cdot}a$ and Dur_P; an application from $T \cdot A$ to IR_+) defined by [Knight, 98][6],[Knight, 97] [7].:

$$\begin{cases} Dur_P\,(t \cdot a) = 0 & \text{if } a \text{ is an instantaneous action, thus, } t \text{ is a point of time .} \\ Dur_P\,(t \cdot a) > 0 & \text{if } a \text{ is a durative action, thus, } t \text{ is an interval.} \end{cases}$$

The primitive temporal entities are time-elements.

Case where several actions $a_1,a_2,...,a_m$ are the cause of the same effect or a single event.

If $a_1,a_2,...,a_m$ are the temporal expressions of actions type carried out respectively in $t_1,t_2,..,t_m$, we use the formula :

Ecause $(a_1.t_1,a_2.t_2,...,a_m.t_m; e.t) \equiv$ Ecause $(a_1.t_1; e.t) \wedge ... \wedge$ Ecause $(am.t_m; e.t)$.

Example 2.10 : Ecause (January. prepare one's paper, send paper. April, ..., travelling. 15May; Communicate.18 June) ≡ Ecause (January. prepare one's paper; communicate.18 June) ∧...∧ Ecause (travelling.15 May;communicate.18 June).

Example 2.11 : The fact of travelling on Monday to communicate on Wednesday can be expressed as follows :

a) Ecause(travelling. Monday; communicate .Wednesday) expresses: the agent will travel on Monday in order to communicate on Wednesday.
b) Ecause(Monday. traveling; communicate. Wednesday) expresses: the agent travelled on Monday in order to communicate on Wednesday.
c) Ecause(Monday. travelling; Wednesday. communicate) expresses: the agent travelled on Monday and communicated on Wednesday.

The action of travelling has the effect communication on Wednesday, as effects do not precede action so we cannot have:

Ecause (travelling. Monday; Thursday .communicate)

An action a can be primitive as it can be complex. In the case of a complex action, to express that the actions $a_{i1},...,a_{is}$ carried out in $t_{i1},...,t_{is}$ (precondition) are the cause of a_i realized in t_i and this one will cause the effect (or event) e carried out in t we define:

Definition 2.12

$$\text{Ecause}\ (a_i.t_i;t.e).\ \equiv \text{Ecause}\ (a_{i\ 1}.t_{i1},a_{i2}.t_{i2},\ldots,a_{is}.t_{is};e.t)$$
$$\equiv\ \text{Ecause}\ (a_{i1}.t_{i1}) \wedge \text{Ecause}\ (a_{i2}.t_{i2}) \wedge \ldots \wedge \text{Ecause}\ (a_{is}.t_{is};e.t)$$
$$\equiv \bigwedge_{j=1}^{j=s} \text{Ecause}\ (a_{ij}.t_{ij};e.t).$$

The basic sets are:

a) A a set of the actions,
b) E a set of the events/effects, and
c) T a set of the time-elements.

To represent the connection which links a_n to its effect/events, we define the following application :

Definition 2.13

$$\zeta_{ev} : A \to E$$
$$a \mapsto \zeta_{ev}(a) \equiv e.$$

If event/effect requires several actions $a_1,a_2,\ldots,a_m$, we define:

Definition 2.14

$$\zeta_{ev} : A \times A \times \ldots \times A \to E$$
$$a_1,a_2,\ldots,a_m \mapsto (a_1 \wedge a_1 \wedge \ldots \wedge a_m) \equiv e.$$

The function which associates to an action a the time-element t_a in which it is carried out is defined as follows:

Definition 2.15

$$f_a : A \to T$$
$$a \mapsto f_a(a) \equiv t_a.$$

We defines the function which associates to an event e the time-element t_e of which it is carried out by:

Definition 2.16

$$f_e : E \to T$$
$$e \mapsto f_a(e) \equiv t_e.$$

An action causes an event/effects after a time allowed Δt. $t_e = t_a + \Delta t$. If $\Delta t = 0$ the action a and the event e occur at the same time.

Definition 2.17 : The set of the time-elements is projected on the axis of reals by a function date which associates to any element t of T its date noted d_t.

$$f_e : E \to T$$
$$e \mapsto f_a(e) \equiv t_e.$$

If $\Delta t = 0$ then $d_t\ \ a\ =d_{te}$.

Definition 2.18 : An Annal of time has [line of time for Kayser and Mokhtari, 98] [4] is a succession of time-elements Tt representing an evolution of the universe.

A point of time of the succession answers the rule 'there are no effects without cause', it is the result of a relation 'cause to effect'.

An annal of time is a convex unit, completely ordered in bijection with the axis of reals.

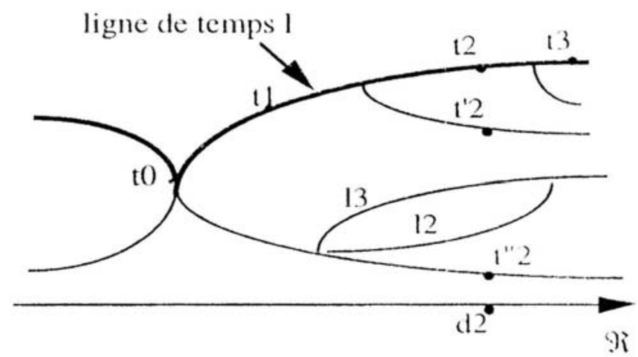

Figure 1: An Annal of time

III. A New Ontology to Represent Causal and Temporal Relationships Between Actions and Events/Effects

The ontology used in our language consists of effects, events and process.

a) Fact

A fact p is true in a point of time or interval. The notation True (p,t) expresses that the fact p is true in the time-element t.

b) Event

An event is carried out in a time-element. In the case of an interval, the events are true in the intervals where they are defined. They are not defined in the subintervals.

c) Processus

The processes are defined on intervals. If a process is true on an interval, it is true also on all subintervals of this interval.

d) Causality

An event causes another event.

If $e_1, e_2, \ldots, e_m$ are a temporal expressions of events type carried out respectively in $t_1,t_2,\ldots,t_m$, the formula:

a) Ecause $(e_1.t_1,e_2.t_2,\ldots,e_m.t_m;\ e.t) \equiv$ Ecause $(e_1.t_1;\ e.t) \wedge\ldots\wedge$ Ecause $(e_m.t_m;\ e.t);\ e.t)$ expresses that the events $e_1,e_2,\ldots,e_m$ which will be realized respectively in $t_1,t_2,\ldots,t_m$ will cause the event e which will take place in the time-element t.

b) Ecause $(t_1.e_1,t_2.e_2,\ldots,t_m.e_m;\ e.t) \equiv$ Ecause $(t_1.e_1;\ e.t) \wedge\ldots\wedge$Ecause $(t_m.e_m,e.t)$ expresses that the events $e_{11},e_2,\ldots,e_m$ which are realized respectively in $t_1,t_2,\ldots,t_m$

will cause the event e which will take place in the time-element t.

c) Ecause $(t_1.e_1,t_2.e_2,\ldots,t_m.e_m;\ t.e) \equiv$ Ecause $(t_1.e_1;\ t.e) \wedge\ldots\wedge$Ecause$(t_m.e_m,t.e)$ expresses that the events $e_{11},e_2,\ldots,e_m$ which are realized respectively in $t_1,t_2,\ldots,t_m$ will cause the event e which will take place in the time-element t.

e) Action and Planning

We are still inspired by Allen's work, an action is carried out by an agent and it produces an event/effect. Planning consists to defining a sequence of actions to be carried out by an agent to solve a general or specific problem. In addition to the construction of a sequence of obligatory or optional actions, J.Allen uses the concept of belief and intentionality. He proposes the following principles:

a) An agent S carries out an intentionally action a if and only if: - the agent carries out the action in a given interval;
b) The action belongs a plan that the agent had been committed carrying out during a given time interval.

J.Allen [1] is limited to the intervals.To use concept of temporality in planning and without limiting themselves with the intervals, we enrich our language by an operator noted $\oplus$. Our operator is defined on time-elements.

Definition 3.1: $t_1 \oplus t_2$ is defined if there are two actions a_1 and a_2 taking place in t_1 and t_2 respectively and which are the cause of an event (or effect) e carried out in a point of time t.

This operator has the following characteristics:

- ⋆ The operator $\oplus$ is internal if $t \in T$ (the agent must act so that the event or effect takes place in time-element t belonging to T).
- ⋆ The operator is commutative if the order of the actions does not intervene (the agent is free to start with any action). We denote: $t_1 \oplus t_2 \equiv t_2 \oplus t_1$.

J. A. Pinto [Pinto, 94] [8] established in his thesis a relation between events, actions and situations but he finds it more convenient to establish a relation between events, actions which occur for the realization of these events and the time when they are carried out. In our approach, we establish a relation between events, actions who occur for the realization of these events and time when they are carried out.

To express the fact that the actions $(a_1,a_2,\ldots,a_m)$ $\in A \times\ldots\times A$ which take place respectively, $t_1, t_2,\ldots, t_m$ are the cause of an event e carried out in $t \in T$, we define the following diagram:

Definition 3.2 :

$$\begin{array}{ccc} A \times A \times \ldots \times A & \xrightarrow{\zeta_{ev}} & E \\ \varphi \downarrow & & \uparrow \phi \\ T \times T \times \ldots \times T & \longrightarrow & T \end{array}$$

where $\varphi(a_1,a_2,\ldots,a_m) = (f_1(a_1), f_2(a_2),\ldots,f_m(a_m)), f_i(a_i) =t_i\ \forall\ i \in 1,2,\ldots,m$ and h a function defined as follows:

$$h : T \times T \times\ldots\times T \rightarrow T$$

$$h(t_1,t_2,\bullet,\bullet,\bullet,t_m) = t_1 \oplus t_2 \oplus \bullet\bullet\bullet \oplus t_m \equiv t.$$

h is defined if there exist actions $a_1,a_2,\cdot,\cdot,\cdot,a_m$ carried out respectively in $t_1,t_2,\cdot,\cdot,\cdot,t_m$ which gave place to e realized in t.

The intervening order of the actions in some events plays a significant role; like carrying out an action before another, reproduction of an action (process) or to carry out several actions at the same time. This led us to introduce operators on the actions. These operators define constraints over time.

Definition 3.3 : We define on T a relation of precedence noted R_c as follow: $t_1\ Rc\ t_2$ or rather t_1 precedes t_2 if the action a_1 must occur before the action a_2 (a_1 and a_2 being the actions which are the cause of e).

Proposition 3.4 : (T, R_c) is a strict order temporal framework. (T, R_c) has the discretion property , than (T, R_c) is a discrete temporal framework provided with a strict order.

f) Temporal Relationships between Events

An event can be the cause of one or more events in the future as it is often due to one or more events which proceeded in the past.

To represent this, we define the following operator which can be used to represent the effects, post and pre conditions for an action. Concept time present, past and future is represented by a relative entirety k such as:

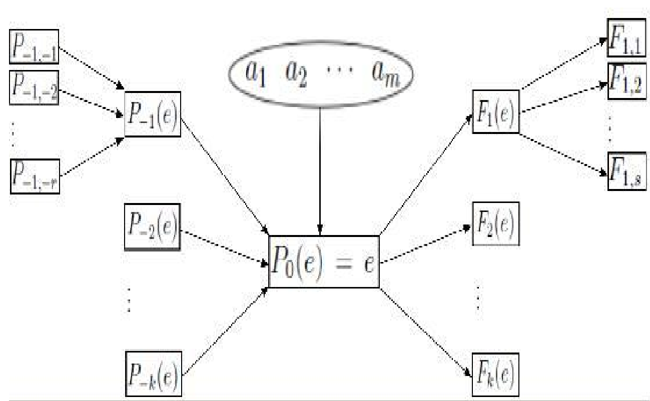

Figure 2 : Representation relationships between actions and effects/events

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a) $k = 0$ represents present,
b) $k > 0$ represents the future,
c) $k < 0$ represents the past.

Definition 3.5 :

$$\otimes : \mathbb{Z}\times \mathrm{T} \rightarrow \mathrm{T}$$
$$(\mathrm{k}, \mathrm{t}) \mapsto \otimes(\mathrm{k}, \mathrm{t}) \equiv \mathrm{k} \otimes \mathrm{t}$$

- If $k = 0$, then $k \otimes t = {}_0t$ where ${}_0t = t_1 \oplus t_2 \oplus \cdots \oplus t_m$ is time-element where **e** occurs at the present and where m is the number of actions which are the cause of e true in ${}_0t$. We denote $e = P_0e$.
- If $k > 0$ then $k \otimes t = {}_kt$ where ${}_kt$ is time-element where the event F_ke will occur in the future and which is due to e carried in ${}_0t = t_1 \oplus t_2 \oplus \cdots \oplus t_m$
- If $k < 0$ then $k \oplus t = {}^kt$ where ${}^kt$ is time-element where the event denoted P_ke which occurred in the past and gave place to e in ${}_0t = t_1 \oplus t_2 \oplus \cdots \oplus t_m$. Here, m is the number of intervening actions so that e is true in ${}_0t$, consequently, F_ke (respectively P_ke) is true in ${}_kt$ (respectively in ${}^kt$). $|k|$ is the number of events F_ke (respectively P_ke).

The operator F_k will allow us to enumerate all effects/events that proceed in the future whereby e is the cause (ramification) and the operator P_ke will allow us to enumerate all precondition/ events which proceeded in the past and which gave place to e. The operator $\otimes$ may give us the possibility of representing the continuous evolutions of the universe for varied futures (prediction) or past (diagnostic). It may allow the representation of the actions and their effects as well as the types of reasoning which are the prediction, the explanation and planning.

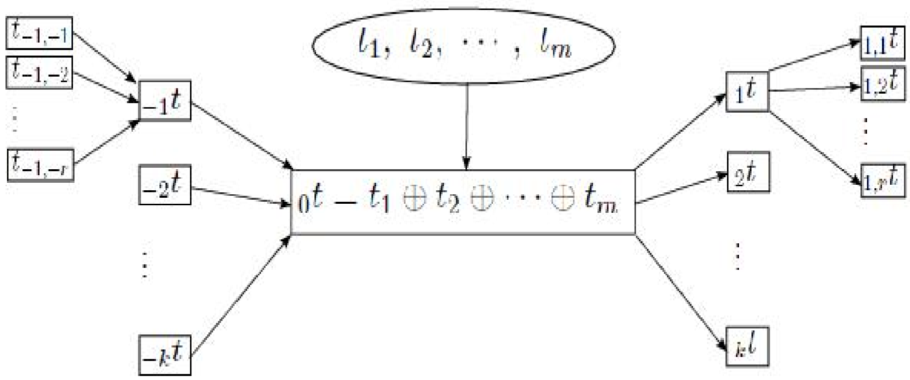

Figure 3 : Representation of temporal relationships between actions and effects/events

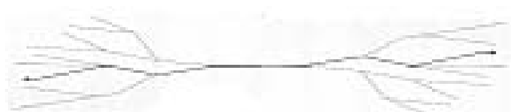

Figure 4: Ramified time: several past, several futures

IV. Temporal Logic L_C for Reasoning Causal between Actions and Events/Effects

In this chapter, we propose a temporal logic to reason on the actions and events. We give its axioms and semantic.

a) Deductive System

i. *Temporal Logic L_c'axioms*

(i) Axioms of propositional logic [Bourbaki, 71][11].
(ii) (a) $F_k(A \supset_c B) = (F_kA) \supset_c (F_kB)$ where $F_k(A \supset_c B)$ is the effect/event which will occur in the future and which will take place only if $A \supset_c B$ takes place ($A \supset_c B$ is due to m actions $a_1, a_2, \cdots, a_m$)

(b) $P_k(A \supset_c B) = (P_kA) \supset_c (P_kB)$ where P_kA is an event/precondition which occurred in the past and which gave place to ($A \supset_c B$)

(c) $P_0(A \supset_c B) = (P_0A) \supset_c (P_0B)$.

The axioms (ii) : (a), (b) and (c) express the distributivity of the operators F_k, P_k and P_0 with regard to the causal implication.

ii. *Temporal Logic L_c'deduction rules*

The rules of deductions are :
(i) The modus ponens [Bourbaki, 71][11].
(ii) Temporal generalization: If A is a theorem, F_kA, P_kA and P_0A are equally theorems.

The theorems of L_c are by definition all the formulas deductible from the axioms by using the rules of deductions. In particular all the theorems of propositional calculus are theorems.

b) Semantic of L_c

In the semantic of propositional calculus, an assignment of values of truth V is an application, that each propositional variable associates a value of truth.

An assignment of value of truth describes a state of the world.

Definition 4.1: A valuation V on a temporal framework (T,R) is a function of set of the propositional variables in the set of the parts of T.

Definition 4.2 : A model of temporal logic is the data of a temporal framework (T,R) and a valuation V defined on this temporal framework. We note $M = (T,R,V)$.

In the case of L_c, we choose as variable propositional the actions whose effect occurs in a time-element t or actions which are the cause so that an event e is true in a time-element t.

Definition 4.3 : Let V_c the valuation defined on the framework temporal (T,Rc) :

$$V_c \ : \ A \ \rightarrow P\,(T)$$

$$ai \ \mapsto V_c\,(ai) = T_i = \{t_i / a_i trueint_i\}$$

t_i is the time-element when the action a_i occurs so that the event e is true in ${}_0t = t_1 \oplus t_2 \oplus \cdots \oplus t_m$ or the effect e occurs in ${}_0t$.
The action a_i thus, occurs only once in T then $T^i = \{t_i\}$.

If T^i is empty then, a_i is not true in t_i or a was not carried out consequently e will not take place in ${}_0t$.

Definition 4.4 :

1. $V_c P_0 e = V_c(e) = V_c(a_1 \wedge \cdots \wedge a_m) =_{def} V_c(a_1) \oplus \cdots \oplus V_c(a_m) \equiv \{t_1\} \oplus \{t2\} \oplus \cdots \oplus \{t_m\} \equiv \{{}_0t\}$
2. $V_c\{\neg a_i\} = T - V_c\{a_i\} = T - T_i$
3. As e is due to the actions $a_1, a_2, \cdots, a_m,$ thus, if there is k such as an action a_k does not take place, this would inevitably involve non-achievement of e (or that e will not be true in $\{{}_0t\}$ accordingly :

$V_c\{e\} = V_c\{a_1 \wedge \cdots \wedge \neg a_k \wedge \cdots \wedge a_m\} = V_c\{a_1\} \oplus \cdots \oplus V_c\{\neg a_k\} \oplus \cdots \oplus V_c\{a_m\} = T_1 \oplus \cdots \oplus \{T_k\} \oplus \cdots \oplus T_m \equiv T - V_c(e)$.

4. The effect/event e can give place to several effect/events in the future (ramification) noted $F_k e$, $k \geq 1$, and each effect/event will occur in a time-element ${}_k t$ with the following condition:

$t_i\, R_c\, {}_0t\, R_c\, k_t$ and ${}_0t = t_1 \oplus t_2 \oplus \cdots \oplus t_m$ then $V_c(F_k e) = \{{}_k t \,/ t_i\, R_c\, {}_0t\, R_c\, k_t,\, {}_0t = t_1 \oplus t_2 \oplus \cdots \oplus t_m\}$.

5. the event e can be due to several events $P_k e$ which occurred in the past and each event $P_k e$ occurred in a time-element ${}_k t$ with the following condition:

$t_i\, R_c\, {}_0t\, R_c\, {}_k t\; {}_0t = t_1 \oplus t_2 \oplus \cdots \oplus t_m$ and therefore : $V_c(P_k e) = \{{}^k t \,/ t_i\, R_c\, {}_0t\, R_c\, {}_k t,\, {}_0t = t_1 \oplus t_2 \oplus \cdots \oplus t_m\}$.

6. $V_c(A \supset_c B) = \{t / t_A\, R_c\, t_B\, R_c\, t,\, {}_0t = t_1 \oplus t_2 \oplus \cdots \oplus tm\}$, indeed $(A \supset_c B)$ is true in a certain time-element t pertaining to T only if A is true in one time-element t_A of T; but A true in t_A is the cause of B true in t_B, thus, to have B in t_B it is enough to have A in t_A and this will give $A \supset_c B$ true in t.

We also define the valuation in the following cases :

- Case of the effects/events require the realization of several actions at the same time. For that we define on A a relation defined as follows :

Definition 4.5 :

$$a_1 R_c a_2 \Leftrightarrow V_c(a_1) = V_c(a_2) \Leftrightarrow t_1 = t_2.$$

It will ,thus, be said that a_1 and a_2 are in relation if they occur in even time.

Proposition 4.6 : R_c is a relation of equivalence.

Proposition 4.7 : We have the following diagram [Mamache, 2010]:

$$\begin{array}{ccc} A & \xrightarrow{V_c} & P(T) \\ s\downarrow & & \uparrow i \\ A/R_c & \xrightarrow{\overline{V_c}} & ImV_c \end{array}$$

$\overline{V}_c(a) = V_c(a)$, $i(t_1) = \{t_1\}$ and $s(a) = a = \{a' \in A / a' R_c a\}$ is the class of equivalence of a, it contains all the actions which occur at the same time as a, $ImV_c = \{s(a),\, a \in A\}$ is a subset of $P(T)$ and A/R_c is the set of the classes of equivalence of the elements of A, it contains the' packages' of actions or the subset of actions which are carried out at the same time in other words, the actions which occur at the same time is gathered in subsets of A in the form of classes called equivalence classes and each class is represented by an action, the time-element when this action is carried out is the time-elements of all the other actions of the class.

We can, thus, represent the set of the actions occurred at the same time by the equivalence classes of an action that is the representative of the class. We associate to this class only one time-element. This simplifies the temporal representation of actions/events.

- Case of an action which is repeated in different time-element (process). Let

Definition 4.8 :

$$\begin{array}{ccc} f: T & \rightarrow & A \\ t_i & \mapsto & a_i \end{array}$$

We define on T a relation :

$$t_1 R_c t_2 \Leftrightarrow a_1 = a_2$$

it will ,thus, be said that t_1 and t_2 are in relation if the same action a occurs in t_1 and t_2.

Proposition 4.9 : R_c is a relation of equivalence.

Proposition 4.10 : We have the following diagram [Mamache, 2010][5]:

$T/R_c = \{\overline{t} \,/\, t \in T\}$, is the set of the classes of equivalence, Imf is the set of images of the elements of T, $\overline{t} = \{t_i \in T \,/\, tR_c t_i\}$ is the class of equivalence of t, it contains all the time-elements t_i where an action a produced in t and is reproduced in other time-element t_i (process).

Therefore, we represent the set of the time-elements when an action is repeated by the class of equivalence of a time-element that is the representative of the class. For this case one defines a valuation.

Definition 4.11 :

$$V_c : A \rightarrow P(T)$$
$$a \mapsto V_c(a) = \{t_i / a \text{ true in } t_i\}$$

- Case of competitive actions. Let a and a' two actions concurrent for the realization of an effet/event e. We have two possibilities for the choice of the actions.

Temporal choice

(i) Case where actions do not start at the same time but the agent is interested by the first achieved action,

(ii) Case where actions start at the same time but the the agent selects the action which spends less time (the least durative action),

(iii) Emergency case: the agent must choose the most urgent action.

Economic choice

(i) The agent is interested by the least expensive action in carried out independently of time,

(ii) The agent is interested by the simplest action in carried out independently of time.

Definition 4.12 : Let S a set of actions which can carry out an event e, S is a part of A. We define a relation on S:

$\forall\, a \in S, a\, R\, a' \Leftrightarrow a$ is better than a'.

An action a is the best element of S if a is better than all other actions for the realization of an event e.

Temporal choice

(i) $\forall\, a \in S, a\, \Re\, a'$ expresses that a is the first achieved action. So, it is the action chosen by the agent,

(ii) $\forall a \in S, a\, \Re\, a'$ expresses that a is the least durative action)

(iii) $\forall\, a \in S, a\, \Re\, a'$ expresses a is the most urgent action.

Economic choice

(i) $\forall a \in S, a\, \mathcal{R}\, a'$ expresses that a the least expensive action in carried out independently of time,

(ii) $\forall\, a \in S, a\, \mathcal{R}\, a'$ expresses that a is the simplest action in carried out independently of time.

The corresponding valuation is defined as follows:

$$Vc : A \rightarrow P(T)$$
$$a \mapsto Vc(a) = \{ta/a \text{ true inta}\}$$

$V_c(a) = \{ta\}$ if a' is negligible in front of a if not $V_c(a) = \emptyset$.

We can generalize this with several actions a_1, $a_2, \cdots, a_m$.

$V_c(a_i) = \{t_{ai}\}$ if a_j is negligible in front of a_i for any $j \neq i$ if not $V_c(a_i) = set$.

V. Completude

: Is Axiomatic L_c complete for the class K of the temporal framework? For that, we must show the validity : Are the theorems valid formulas ?

Theorem 5.1 (Mamache,2011) [12] Any theorem of L_c is a valid formula in the class K of the temporal framework. It should be checked that:

1) The axioms of L_c are valid formulas in K.
2) The rules of deductions preserve the validity of the formulas : if their arguments are valid, their result is true.

VI. Conclusion and Open Problem

Some basic concepts emerge in the existing actions formalisms, as causality and time. They are difficult to express in a first order language. We propose a logical formalism based on a first order language to which we add operators to represent multiples futures and multiples pasts. Furthermore, these operators allow to describe pre-conditions and effects of an action. They allow the representation of the prediction, explanation and planning.

The principal contribution of this work is the simplification of the representation of causal and temporal relationships between actions and their effects as well as the causal and temporal relationships between actions and events. We used the classes of equivalence to represent the execution time of a process and the execution time of competitive actions. We propose a new ontology for causal and temporal representation of actions/events. The ontology used in our formalism consists of facts, events, process, causality, action and planning.

Although this work is located in axis of theoretical study of knowledge reasoning, we can hope that this study will be used as a basis on which theories of action can be established. It can be prolonged in several directions.

- A track which appears very important consists in representing temporal relationships of the causes of events if these causes are complex actions/events. We plan a matrix representation to enrich our formalism.
- Inspired of action modeling formalisms, more precisely of action theory and Allen's time [Allen, 84][1], Galton [Galton, 2009][15]has combined a space theory with a temporal theory. The primitive entities of Galton are moments and intervals but he does not consider the cases where the regions are separate in the future and the past.

Inspired by our ontology, we envisage a new ontology to represent space-time relationships between objects and regions where the events will be the changes caused by the various positions of the objects. Our formalism could be used to facilitate space-time representation of objects positions. This logic allows to study the evolution of the relative positions between entities during time.

- F.Baader and al [Baader, 2005][16]propose an action formalism based on description logics (Dls). H.Strass and M.Thielscher [11] study the integration of two prominent fields of logic- based AI: action formalisms and non-monotonic reasoning.
- H. Liu[Liu, 2010][18] have investigated updates of ABoxes in DLs and analyzed their computational behavior. The main motivation for this en-deavor is to establish the theoretical foundations of progression in action theory based on DLs and to provide support for reasoning about action in DLs. Within the framework of integration description logics in action formalism, we envisage to integrating description logics in our temporal formalism.
- The information extraction (IE) is an important subject of research in Natural Languages Automatic Processing . The analysis of named entities (EN)[Ehrmann, 2008][14] is generally focused on the traditional concepts of place, organization, person or dates. The events are rarely considered, but they have a great importance for the usual applications as information search. Our formalism can be used to develop information extraction system of extraction of event type.
- Another study way would be the exploitation of temporality in biographical information extraction . The temporal reference marks of biographical information allow to replace a fact in its context and to order it compared with other events by using our operators F_K and P_K. A good exploitation of our approach will certainly make it possible to obtain a functional and satisfactory solution with the problems encountered within the framework of the extraction and the information management.
- In medical applications, our formalism can to be used to describe states of the world, such as data of patients. In this context, the actions can be used to represent diagnostic and therapeutic of the processing of patient treatment.
- Several experimental works will certainly make it possible to enrich this work in particular, like implementing an interface to represent expressions of temporal actions type and events temporal type based on our formalism. This work would allow to describe several applications and to compare them with other formalisms.

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