Temporal Relation Primitives

based on fuzzy boundaries

Martin Doerr, Manos Papadakis

Information Systems Lab

Institute of Computer Science

Foundation for Research and Technology - Hellas

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# Introduction

It is characteristic for archaeologists and historians to derive from stratigraphic and other observations and considerations of causality between events temporal topological relations. Therefore the CIDOC CRM introduced version 3.3 the whole set of temporal relationships of Allen’s temporal logic (properties P114 to P120). It was regarded at that time as a well-justified, exhaustive and sufficient theory to deal with topological relationships on the time scale of spatiotemporal phenomena relevant to the cultural historical discourse. It is based on the assumption of known, exact endpoints of time intervals (time-spans), and splits them into a set of mutually exclusive relationships.

Since many temporal relations can be inferred from facts causal to them, e.g., a birth necessarily occurring before any intensional interaction of a person with other individuals or are the result of observation of phenomena, without knowing the absolute time, the relationships are applied in the CIDOC CRM to E2 Temporal Entities, and not to their Time-Spans, which require absolute knowledge of time. If absolute times are known, deduction of Allen’s relation is a simple question of calculus and not primary knowledge. However, their application turned out to be problematic for two reasons:

**Firstly,** facts causal to temporal relationships result in expressions often require a disjunction (logical OR condition) of Allen’s relationships. For instance, a child may be stillborn. Ignoring states at pregnancy as usual in older historical sources, birth may be *equal to* death, *meet* with death or be *before* death. The knowledge representation formalism chosen for the CRM however does **not allow** for specifying **disjunctions**, only in queries. Consequently, simple properties of the CRM that imply a temporal order, such as *P134 continued*, cannot be declared subproperty of the temporal relationship they necessarily imply.

**Secondly,** nature does not allow us to observe equality of points in time. Any observable phenomenon that can be dated has a **natural extent** and **fuzzy boundaries**. Assuming a lowest granularity in time is a trick which doesn’t help, because the relevant extent of fuzziness varies at a huge scale even in cultural reasoning, depending on the type of phenomena considered. The only exact match can be between declared time intervals, such as end of a year / beginning of the next year, or that “Early Minoan” ends exactly when “Middle Minoan” starts, whenever that might have been.

Consequently, we introduce here a new set of “temporal relation primitives” with the following properties:

* It is a minimal set of properties that allows for specifying all possible relations between two time-spans given by their start and end points, either directly, or by conjunction (AND condition) of the latter.
* Start and end points are interpreted as “thick” fuzzy boundaries, and conditions of equality of end points are relaxed by conditions of overlap of boundaries.
* All of Allen’s relationships can be implied directly or by conjunctions of these properties.
* For time-spans without or with negligible fuzzy boundaries, adequate conjunctions of these properties become identical with Allen’s.
* No relationship is equal to the inverse of another.

## Notation

We use the following notation:

Comparing two instances of E2 Temporal Entity, we denote one with capital letter A, and its (fuzzy) starting time with Astart and its (fuzzy) ending time with Aend, such that A = [As,Ae]; we denote the other with capital letter B, and its (fuzzy) starting time with Bs and its (fuzzy) ending time with Be, such that B = [Bs,Be].

We define a temporal relation by a name and one or more (in)equality expressions between its end points, such as:

A *starts before the end of* B if and only if (≡) **As < Be**

We visualize a temporal relation symbolizing the temporal extents of each instance of E2 Temporal Entity as a horizontal bar on an assumed horizontal time-line proceeding from left to right:



Should ensure gradient in fuzzy area in order to indicate the movement away from

On second graphic with the arrow, it could be changed to a number of continuing smaller boxes that move towards lines. (like a cigarette)

Carlo: comment on the ‘hard line’ : Make a distinction between what is precise and observable and precise but not observable (in relation to the hard line in the graphic which seems to indicate a precise point. It is indeed precise, but not observable.) [4 combinations between precise and observable, should make different graphs to represent this]

In defintino of ‘interior’ above chage wording to ‘definite’ from ‘precisely’

## Overview of Temporal Relation Primitives

The final set of temporal relation primitives can be separated into two groups: Those based on improper inequalities, such as As ≤ Be (odd number items in table 1) and those based on proper inequalities, such as As < Be (even number items in table 1). Improper inequalities with fuzzy boundaries are understood as extending into situations in which the fuzzy boundaries of the respective endpoints may overlap. In other words, they include situations in which it cannot be decided if these endpoints are equal or not, but there is no knowledge of a definite gap between these endpoints. In a proper inequality with fuzzy boundaries, the fuzzy boundaries of the respective endpoints must not overlap, i.e., there is knowledge of a definite gap between these endpoints, for instance, a discontinuity between settlement phases based observation of archaeological layers. Further, there is a set of relations based on one inequality (item 1 -8 in table 1), and another based on the conjunction of one of the latter with the inverse properties of another of the latter (item 9-12). Finally, item 1-4, 9,10 describe conditions on the start time of the property domain, whereas 5-8, 11, 12 describe conditions on the end time of the property domain. (perhaps delete

Two relationships stand out against the others, item 1: As ≤ Be, because it allows the possibility that temporal entity A has had an influence on temporal entity B. The proper inequality item 2: **As < Be** on the other side is a necessary condition if A is known as having had an influence on B. The relations are organized such that any end-point based temporal relation can be described by at most two primitive relations including the above “influence conditions” item 1 and 2.

Decision: to be looked over and made simpler both conceptually and linguistically

1. **starts before or at the end of**
	* As ≤ Be
2. **starts before the end of**
	* As < Be
3. **starts before or with**
	* As ≤ Bs
4. **starts before**
	* As < Bs
5. **ends before or at the start of**
	* Ae ≤ Bs
6. **ends before**
	* Ae < Bs
7. **ends with or after**
	* Ae ≥ Be
8. **ends after**
	* Ae > Be
9. **starts with or within or at the end of**
	* As ≥ Bs & As ≤ Be
10. **starts within**
	* As > Bs & As < Be
11. **ends with or within or at the end of**
	* Ae ≤ Be & Ae ≥ Bs
12. **ends within**
	* Ae < Be & Ae > Bs

Table 1, temporal relation primitives

Discussion: introduce first 8, 9-12 would be conveniences, not necessary to start

Wolfgang could analyze against some use cases

Steve: 10 and 12 look like usual examples. 9 and 11 seem less so.

Decision: keep 12, and we will see. MD

# Scope notes

## P ΧΧ1 starts before or at the end of (ends after or with the start of)

Domain: E2 Temporal Entity

Range: E2 Temporal Entity

Superproperty of: E2 Temporal Entity. PXX2 starts before the end of (ends after the start of) E2 Temporal Entity

Quantification: many to many (0,n:0,n)

Scope note:

This property specifies that the temporal extent of an instance, A (domain), of E2 Temporal Entity starts definitely before the end of the temporal extent of another instance, B (range), of E2 Temporal Entity.

In other words, if A = [As,Ae] and B = [Bs,Be], we mean As ≤ Be is true.

This property is part of the set of temporal primitives Pxx – Pxn.

This property corresponds to the disjunction (logical OR) of the following Allen temporal relations [ Allen, 1983]: {before, meets, overlaps, starts, started-by, includes, finished-by, equals, is included by, is overlapped by, is started by}

Note: there should be a reference in the scope note to the introductory text that explains the overall use of these properties

Decision: we are close to an agreement on the scope note, however, there is still an open question of whether the ‘domain’ and ‘range’ elements in the definition to differentiate A from B are accurate.

Overall decision: on-going. Texts need improvement. Lida will check super and sub properties. Goal would be to be able to close by next meeting.

## P ΧΧ2 starts before the end of (ends after the start of)

Domain: E2 Temporal Entity

Range: E2 Temporal Entity

Subproperty of: E2 Temporal Entity. PXX1 starts before or at the end of (ends after or with the start of) E2 Temporal Entity

Superproperty of: E7 Activity. P134 continued by (was continued by): E7 Activity

E2 Temporal Entity. PXX3 starts before or with (ends after or with the start of) E2 Temporal Entity

Quantification: many to many (0,n:0,n)

Scope note:

This property specifies that the temporal extent of an instance A of E2 Temporal Entity starts definitely before the end of the temporal extent of another instance B of E2 Temporal Entity. I.e., if A = [As,Ae] and B = [Bs,Be], then As < Be holds.

Typically, this property is a consequence of a known influence of some event on another event of activity, such as a novel written by someone is continued by someone else, or the knowledge of a defeat on a distant battlefield causes people end their ongoing activities.

This property corresponds to a disjunction (logical OR) of the following Allen temporal relations [ Allen, 1983] : {before, meets, overlaps, starts, started-by, includes, finished-by, equals, is included by, is overlapped by}



## P ΧΧ3 starts before or with (starts after or with the start of)

Domain: E2 Temporal Entity

Range: E2 Temporal Entity

Subproperty of: E2 Temporal Entity. PXX2 starts before or at the end of (ends after or with the start of) E2 Temporal Entity

Superproperty of: E2 Temporal Entity. PXX3 starts before the end of (ends after the start of) E2 Temporal Entity

Quantification: many to many (0,n:0,n)

Scope note:

This property specifies that the temporal extent of an instance A of E2 Temporal Entity starts before or simultaneously with the start of the temporal extent of another instance B of E2 Temporal Entity. I.e., if A = [As,Ae] and B = [Bs,Be], then As ≤ Bs holds.

This property corresponds to a disjunction (logical OR) of the following Allen temporal relations [ Allen, 1983] : {before, meets, overlaps, starts, started-by, includes, finished-by, equals}



## P ΧX4 starts before (starts after the start of)

Domain: E2 Temporal Entity

Range: E2 Temporal Entity

Subproperty of: E2 Temporal Entity. PXX3 starts before the end of (ends after the start of) E2 Temporal Entity Quantification: many to many (0,n:0,n)

Scope note:

This property specifies that the temporal extent of an instance A of E2 Temporal Entity starts definitely before the start of the temporal extent of another instance B of E2 Temporal Entity. I.e., if A = [As,Ae] and B = [Bs,Be], then As < Bs holds.

This property corresponds to a disjunction (logical OR) of the following Allen temporal relations [ Allen, 1983] : {before, meets, overlaps, includes, finished-by}