ELECTRONIC NEWSLETTER ON
REASONING ABOUT ACTIONS AND CHANGE

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Today

Sergio Brandano's contribution earlier this week received rapid replies by both Jixin Ma and Pat Hayes.

Debates

Ontologies for time

From: Jixin Ma

To Pat

As an addition to my response (ENRAC 15.4 (98035)) to Pat's suggestion of "simply map Allen and Hayes' moments to Ma and Knight's points":

The constraint that "moments cannot meet other" will lead to the conclusion that we can have neither a completely discrete nor a completely dense system which contains both moments and decomposable intervals. However, if we revise Allen and Hayes' system to include both points and intervals (including moments), and impose the "not-meet-each-other" constraint on points only, rather than on moments, this objection does not apply.

To Sergio

> *In fact, in this discussion I have not yet seen any explanation why an alternative notion of continuous structure is needed at all? I am not asking you to argue about your own notion, I just ask you to give a convincing argument on the need of a notion which is an alternative to the classical one, such as: "the problem P of temporal reasoning about actions and change can not be solved adopting the axiom of completeness", or "the axiom of completeness is too strong an assumption for our purposes; axiom A is better suited, because...".*

First of all, what do you mean "the classical one"? (the classical continuous time structure)? Does it refer to the classical physical model of time, where the structure is a set of points which is isomorphic to the real line?

> *in Pisa, we write "continuity" and we read "axiom of completeness", which is what everyone commonly means when speaking' about (the founding notion of) continuity.*

At the ontological level, the notion of continuous time vs. discrete time is closely related to questions "Is the set of time elements dense or not?", and "Are there really time atoms?". For a point-based model, the continuity is usually characterised as "Between any two points, there is a third"; while for an interval-based model (like that of Allen), it is characterised as "Every interval can be decomposed into two adjacent sub-intervals". In addition, as for a model which takes both intervals and points as primitive, one may characterise two levels of density. At the weak level, it is only required that each interval can be divided into two adjacent sub-intervals. At the strong level, it is required that there is always a point within any interval. It is easy to infer that the latter can imply the former.

As for general treatments, the Basic Time Structure **does not** have to impose the axiom of density or discreteness (Similar arguments apply to issues such as linear/non-linear, bounded/un-bounded). Therefore, the time structure as a whole may be continuous or discrete, or neither continuous nor discrete.

Now, "why an alternative notion of continuous structure is needed at all"? It has been noted that temporal knowledge in the domain of artifical intelligence, including "temporal reasoning about actions and change", is usually imcomplete, and using time intervals in many cases is more convenient and more in-keeping with common sense of temporal concepts than to use the classical abstraction of points. In fact, the notion of time intervals (or periods) has been introduced for a long time in the literature. In addition, in order to overcome/bypass the annoying question of whether various intervals are open or closed, various approaches have been proposed. An example is Allen's interval-based time theory. As for these time theories, the old (classical?) notion of continuity no longer simply applies.

Jixin

From: Pat Hayes

Sergio Brandano wrote:

> *Here in Pisa, we write "continuity" and we read "axiom of completeness", which is what everyone commonly means when speaking about (the founding notion of) continuity. I really find it difficult to believe that you like to make an exception in this sense, also because the hat here is "formal (temporal) reasoning". It also seems to me that any temporal structure must necessarily fail to be persuasive if on one hand it includes the*

notion of continuity and on the other it refuses it; how can time be continuous ... with some exception? Either it is continuous, or it is not! That is, either the Basic Time Structure assumes the axiom of completeness, or it does not!!

Why cannot time be continuous in some places but discontinuous at others? There is no mathematical objection to such a structure, and it has been argued that a continuum punctuated by a sparse collection of points of discontinuity might be a plausible mathematical picture of time which seems to 'flow smoothly' except when things happen suddenly. (Similar arguments can be made for describing spatial boundaries, by the way; and elementary physics makes similar assumptions, where velocity is supposed to change smoothly except when 'impact' occurs.)

You talk about a 'founding notion' of continuity as being that captured by the axiom of completeness. Here, in my view, you commit a philosophical error (especially in Pisa!) There are *intuitions* about continuity which one can try to capture in various formal ways, but there is no 'founding notion' of continuity other than those intuitions. In the late 19th century, famous mathematicians objected strongly to the view of the continuum as consisting of a set of points, for example. This modern perspective, now taught in high schools, is a modern invention, not a 'founding' notion. It is more recent than the gasoline engine, yet people have had intuitions about smoothness, instantaneity and continuity for eons. (Whether or not one agrees with me on this admittedly controversial point, it seems unwise to *identify* a mathematical property such as continuity with any kind of axiom until one has verified that no other axiom will do as well; and as I am sure Sergio knows, there are many alternative ways to axiomatize continuity.)

In my view, axioms are tools which we can manipulate at will; they are not set in stone or somehow inevitable. Different formal accounts of time might be appropriate for different purposes or to capture different intuitions. (I agree with Jixin that it is useful to seek a common 'core' theory which can be extended in various ways to describe various possible more complex temporal structures; and that this theory will have to be rather weak.)

In fact, in this discussion I have not yet seen any explanation why an alternative notion of continuous structure is needed at all? I am not asking you to argue about your own notion, I just ask you to give a convincing argument on the need of a notion which is an alternative to the classical one, such as: "the problem P of temporal reasoning about actions and change can not be solved adopting the axiom of completeness", or "the axiom of completeness is too strong an assumption for our purposes; axiom A is better suited, because...".

The 'dividing point' problem which gave rise to this discussion would do. According to the modern account of the continuum, this point must exist, and since all intervals consist of points, the light is therefore either on or off at it. But it seems more natural, as well as formally simpler, to just say that the question is meaningless; perhaps (though this is no longer my own preference) because that point doesnt exist.

A more mundane example is given by temporal databases, which usually assume in their basic ontology that time is discrete: for example, they routinely describe times as integers representing the number of milliseconds since the birth of Christ. (Of course, one can always insist that these are to be understood as being embedded in a continuum, but then what use is an axiom whose sole purpose is to insist that times exist which have no name and about which nothing can be asserted, other than that they exist?)

Pat Hayes