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Protocol of the discussion during January-March, 1999 on

Ontologies of Time

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From: Johan van Benthem on 31.1.1999

Dear Erik,

Thanks for last year's questions. Here is a new year's reply. I will follow your points as I understand them. I hope this clarifies things, even without complete textual references.

> *What about versions of the Dividing Instant problem where the predicates apply to time points without particular problems, such as Galton's red and green lamps in a traffic light? (E.g., lightbulbs have their states at time points...)*

I am not sure what you mean here. I think of shining/glowing/ darkness for lightbulbs as exactly on a par with the burning/ extinguished states of the fire, which are discussed in my note. Mutatis mutandis, the same points apply. Of course, you could also describe a traffic light in terms of discrete 'states' in another sense (as in a 'finite state machine') - but I do not think the DI problem arises in the latter abstract perspective.

> *Engineers and scientists use Real Time in a carefree manner. So why should our kind of people be so uptight about it?*

I think that nothing can be deduced from engineering practice about conceptual foundational problems. But anyway, I do not think that the computational practice of engineeers or working scientists depends on 'the standard real numbers'. That practice consists in a set of computation rules (calculus, etcetera), and perhaps some proof principles - which underdetermine that number structure. (They also hold in other number structures sufficiently like IR.) If foundational problems come up (like truth or falsity of the Continuum Hypothesis: one of the two must hold for IR!), that practice gives us no clue. Moreover, some widespread practical working habits even seem at odds with the structure of IR, witness the usual 'infinitesimal calculus'.

An aside. Such a separation of concerns often makes eminent sense. Example: many different sets of set-theoretic axioms generate the same set of arithmetical truths, so that their vast theoretical differences have no impact on elementary arithmetic or computation. On the other hand, one never knows. What if the solution to P = NP turns out to depend essentially on abstract axioms about the mathe- matical universe? (Incidentally, it would be great to solve P = NP this year, so that the profession can announce at least *something* positive next January, amidst the dbris of the Millennium Problem.)

Does DI still arise when we fix standard IR as our structure?

Yes: see my ENRAC Note. You still have to decide what the relevant phenomenological predicates mean when lifted to those real numbers. (Incidentally, this means that in a sense I am advocating solving DI through engineering, too - be it 'conceptual engineeering'!)

'Axiomatic' versus 'intended model' approaches: an uncomfortable distinction? The former requires us to specify too much by way of reasoning principles, the latter by way of semantics, so that DI must have been solved before it can be properly stated.

I meant this as a methodological distinction to clarify conceptual discussions - but I agree it can be murky in practice. But this is like related useful distinctions. In any case, my distinction is reasonably clear in mathematics. If you start with some structure, and explore its true theory, you are in Intended Model mode. E.g., fix the natural numbers IN, and do number theory. Conversely, if you start with some bunch of geometrical axioms (say, those of non-Euclidean geometries) and play around with their deductive consequences, then you are in Axiomatic mode. In practice, mathe- maticians are no purists here. You can look at an intended model, extract some part of its theory, think of that as an axiomatic calculus, and then search for new models for that calculus, etc.

In the case of temporal reasoning, I think we mostly start with a bunch of working principles (by no means a complete theory) plus some intuitive mental 'picture' (by no means a totally defined model) sanctioning these principles. This leaves us precisely with the freedom to stipulate our way into convenient compromises.

Why not assume the real numbers in the background, and axiomatize only statements about events that take place over these, leaving indeterminacies of DI-points as variations in the space of complete 'chronicles'. (Each particular model settles the status of the intermediate point - but they need not all settle it in the same way.)

I am not totally sure that I understand this suggestion as intended. Anyway, I think it is compatible with what I proposed in my Note: 'either make up your mind uniformly about point-interpretation of the phenomenological predicates involved, or leave a slack'. The slack could show up in the form of different models making their full specifications one way or another. (But please note my discussion of the dangers of unreflected 'two-valuedness' for predicates lifted from temporal intervals to temporal points...)

But there is another interesting aspect to what you say. If the language refers to events, then I think its predicates do not apply to temporal points at all, and we rather have a case of translations and correspondences between genuinely different languages. The latter is in line with how I would prefer to view the situation anyway. There are different kinds of object in our temporal ontology: events, times, etc. - and many logical systems assume too much linguistic uniformity across these. Just as in science, language should change when we jump orders of magnitude.

Johan

From: Pat Hayes on 17.3.1999

Before getting too involved with the details of these examples and arguments concerning timeintervals and points (which will take some time because I think there are some mutual misunderstandings still between the protagonists) let me ask Erik to first come clean, as it were, and tell us what his formal theory of time is. Until we can compare axioms, we are all just arguing in a vacuum.

I know Erik would prefer to first get agreement on intended models and only then move to an axiomatisation, but my point (Im not sure Jixin agrees here) is that this might well be impossible. Many apparently intuitive classes of models - all finite domains, for one notable example - just dont have any axiomatisation. Sorry about that, but since its a fact, its best to learn to live with it. So I'd like to first see what our axioms are, and then ask what models they might have.

Moreover, one needs to realise that an apparently simple model-theoretic specification may carry an enormous axiomatic burden. It is easy to say: I will assume that time is the real line. But to specify the real line axiomatically requires w-order logic, or quite a bit of set theory (enough to be able to characterise continuity.) A first-order approximation to all this high-powered mathematics will just *have* nonstandard models, and no amount of declaring that such models are unintended, or attempts to exorcise them by invoking the Gods of methodology, will make them go away. Note, I'm not arguing that one should *choose* to base ones temporal thinking on 'nonstandard' domains, punctuated continua, etc. etc.. But these structures may well be models of your temporal axioms, whether or not you had them in mind when you composed the axioms.

Pat Hayes