Electronic News Journal on Reasoning about Actions and Change 289
Vol. 2: *289-295*, 31.8.1998
http://www.etaij.org/rac/nj/9808-1/

## Protocol of the discussion during August, 1998 on

# Ontologies of Time

*Edited by: Erik Sandewall*
*Linköping University, Sweden*

## From: Erik Sandewall on 20.8.1998

Dear Jixin,

In ENRAC 27.7 (98059) I wrote and you answered:

> ... the timepoint domain will then be agent-specific. It will also be local to each scenario, ... In fact, it even becomes necessary to revise the timepoint domain each time a *query* is asked...

> *First of all, it is important to note that, by taking both intervals and points as primitive, the time domain is general enough for various scenarios, ... All these four cases are allowed by the same time theory, without the need to revise the time domain at all.*

One of the cases you mention is where two intervals Meet in direct succession; one is where the first interval Meets a point which in turn Meets a second interval; in the two remaining cases one or the other interval includes that point. - I am afraid there's a misunderstanding here, since I was referring to the domain used *in each of the interpretations*. For each particular interpretation, it must certainly be determined whether or not there is a point between the two intervals. Therefore, different scenarios will sometimes differ with respect to their domains for the type of "point" (and maybe also for the type "interval"?) if one insists on dealing with dividing instant situations by using domains where for certain clocktimes there is no corresponding (time)point. Sometimes, different models for the same scenario will also differ in that respect.

Now to the examples. I will take for granted that we talk about timepoints and intervals that are related along the lines of Pat's core theory, only with the adjustment that intervals are not entirely determined by their endpoints: there can be up to four intervals for each pair of endpoints, because you allow these intervals to be either open or closed at each end. (The interval will then be defined as closed if there exists a point beginning resp. ending it, otherwise it's open).

You refer to an example by Galton where a Green light and a Red light both switch On at the same time. This is somewhat counterintuitive - I would have thought that one goes Off when the other one goes On - but that doesn't matter. You propose the following scenario description for the case where we have decided to consider the Green light to be On at the dividing instant, and we have decided to keep that open for the Red light:

```
Holds(GreenOff, I2)
Holds(GreenOn, P)
Holds(GreenOn, J2)
Holds(RedOff, I1)
Holds(RedOn, J1)
Meets(I2,P)
Meets(P,J2)
Meets(I1,J1)
I1 + J1 = I2 + P + J2
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Actually, these axioms do not indicate that the two lights switch at the same time. Let's assume that such a statement has been added, otherwise the point with the example is lost. Now, in every model for these axioms it must be determined whether P is included in I1 or in J1. (Or, if you disagree, what would a model be like where P is neither included in I1 nor in J1?) Suppose P is included in I1. Then, as long as timepoints and intervals are related along the lines of Pat's core theory, you can't avoid the conclusion that the interval I1 ends with P, and hence that the Red light is Off at the dividing point. Similarly, if P is included in I2, it must be that I2 begins with P, and that the Red light is On at the dividing point. Therefore, *in each of the models* there is the kind of choice that you called "arbitrary" with respect to whether the Red light is to be considered On or Off.

My two examples come out in similar ways. For example A, you write:

> *Yeah, for the modelling of the throwing of a ball, it requires that there exists a point referring to the apex. However, the fact that Jim turned the switch does not necessarily imply that there must not be any such point, especially if one insists that "at a moment (point?) when it (the ball) reaches the top of its trajectory, he (Jim) turns the switch".*

But if (in a particular model) such a point exists for the clocktime where Jim turned the switch, then it must be determined (in that same model) whether the switch is on or off at that point, and you have your Dividing Instant Problem back again.

For example B, you write:

> *I don't agree with the claim that "a point both exists and does not exist at the clocktime whent he winner finishes his last cone and the bell rings". Again, I think this claim was reached by means of confusing two cases, that is, the case that an interval "Meets" a point, and the case that an interval was "Finished-by" a point.*

Not really. If you wish to avoid a dividing instant situation by using a punctuated time domain (for each of the models, so that there is no dividing instant problem in any of the models), then you *must exclude* models where that timepoint is present. It can't be present explicitly, and it can't be present implicitly by being the ending or beginning of an interval, because in all of those cases you end up assigning the truthvalue that you considered arbitrary. The only way of complying is to have two successive open intervals without any point between them. (That is, an interval not ending in a point, and a subsequent Meeting interval not beginning in a point). However, this in turn contradicts the assumption that the Bell rings, since it was assumed the Bell rings at (time)points. Therefore, the only possible models are those where the Bell rings without the cones having been finished, and you obtain the conclusion I indicated.

The bottom line is, therefore, that it is futile to try to impose noncommitment for dividing instants on the level of the models and by using non-standard time domains such as "punctuated time". In those cases where we wish to express that we don't know or don't care whether a certain proposition is true or false at a point of change, it's sufficient to use the multiple models approach while admitting "standard" time (integers or reals, by preference). Then we don't need any theory of time at all besides high-school or (at most) college math.

All of this presumes of course standard two-valued logic, where models can only assign the truth-value true or false. You may obtain another perspective by going to e.g. three-valued logic, where *everything* can be undetermined besides true or false. But, as H.C. Andersen once said, that is another story.

## From: Jixin Ma on 25.8.1998

In ENRAC 20.8 (98064), Erik wrote:

> *One of the cases you mention is where two intervals Meet in direct succession; one is where the first interval Meets a point which in turn Meets a second interval; in the two remaining cases one or the other interval includes that point. - I am afraid there's a misunderstanding here, since I was referring to the domain used* in each of the interpretations*. For each particular interpretation, it must certainly be determined whether or not there is a point between the two intervals. Therefore, different scenarios will sometimes differ with respect to their domains for the type of "point" (and maybe also for the type "interval"?) if one insists on dealing with dividing instant situations by using domains where for certain clocktimes there is no corresponding (time)point. Sometimes, different models for the same scenario will also differ in that respect.*
>
> *Now to the examples. I will take for granted that we talk about timepoints and intervals that are related along the lines of Pat's core theory, only with the adjustment that intervals are not entirely determined by their endpoints: there can be up to four intervals for each pair of endpoints, because you allow these intervals to be either open or closed at each end. (The interval will then be defined as closed if there exists a point beginning resp. ending it, otherwise it's open).*

Yeah, there's a misunderstanding about the time domain, and actually it was my fault since I didn't make it clear in my former message. In fact, the time domain (actually the time theory as a whole) which I was referring is that which takes both intervals and points as primitive on the same footing (neither intervals are constructed out of points, nor points are defined as the "meeting places" or other limiting structures of intervals), rather than the time lines of Pat's core theory. An interval can meet other intervals and/or points, but a point can only meet intervals (including moments) (see Ma and Knight, Comuter Journnal 94). Therefore, such a theory allows all the following cases:

1. interval I1 Meets interval J1 (without any information as whether there is a point, say P1, which Finishes I1, or Starts J1);
2. interval I2 Meets interval J2; and point P2 Meets J2 (or equivalently, point P2 Finishes I2);
3. interval I3 Meets interval J3; and interval I3 Meets point P3 (or equivalently, P3 Starts J3);
4. interval I4 Meets point P4, and point P4 Meets interval J4.

In it important to note that, in case (1), (2) and (3), there is not any time element, neither interval/moment nor point, that stands between the two successive intervals, while in case (4) there IS a time point which connects two intervals.

As I argued in my former message, all the above cases can be accommodated by the single time theory (model) – all these scenarios may (but not necessarily) appear somewhere over the time lines (even if the time itself is further characterised as linear) without the need of any futher specifications. They are not conflict with each other.

> *You refer to an example by Galton where a Green light and a Red light both switch On at the same time. This is somewhat counterintuitive - I would have thought that one goes Off when the other one goes On - but that doesn't matter.*

Yeah, this doesn't really matter. Actually, the facts that one light, e.g., Green light, is On before P and then switched Off at P, and the other, the Red light, is Off before P and then switch On at P can be just expressed as: Holds(GreenOn, I) and Holds(RedOff, P), leaving the real question still as how to express the state of the two lights at the switching point P. If both lights are asserted as "On" at P, the corresponding axioms will be:

$$Holds(GreenOn, I)$$
$$Holds(GreenOn, P)$$
$$Holds(GreenOff, J)$$
$$Holds(RedOff, I)$$
$$Holds(RedOn, P)$$
$$Holds(RedOn, J)$$
$$Meets(I, P)$$
$$Meets(P, J)$$

Similar treatments apply to the case where both the lights are asserted as "Off" at P.

As for the case where no information about the Switching point is given at all, i.e., none of the two lights is asserted as On or Off at the switching point P, the axioms wil be as simple as:

$$Holds(GreenOn, I)$$
$$Holds(GreenOff, J)$$
$$Holds(RedOff, I)$$
$$Holds(RedOn, J)$$
$$Meets(I, J)$$

Therefore, the only remaining case is that at the switching point P, one light is known as On (or similarly, Off), while there is no assersion as to the state of the other light at P. This is actually similar to Galton's example, and can be treated by the same approach (see below).

> *You propose the following scenario description for the case where we have decided to consider the Green light to be On at the dividing instant, and we have decided to keep that open for the Red light:*
>
> $Holds(GreenOff, I2)$
> $Holds(GreenOn, P)$
> $Holds(GreenOn, J2)$
> $Holds(RedOff, I1)$
> $Holds(RedOn, J1)$
> $Meets(I2, P)$
> $Meets(P, J2)$
> $Meets(I1, J1)$
> $I1 + J1 = I2 + P + J2$
>
> *Actually, these axioms do not indicate that the two lights switch at the same time. Let's assume that such a statement has been added, otherwise the point with the example is lost. Now, in every model for these axioms it must be determined whether P is included in I1 or in J1. (Or, if you disagree, what would a model be like where P is neither included in I1 nor in J1?) Suppose P is included in I1. Then, as long as timepoints and intervals are related along the lines of Pat's core theory, you can't avoid the conclusion that the interval I1 ends with P, and hence that the Red light is Off at the dividing point. Similarly, if P is included in I2, it must be that I2 begins with P, and that the Red light is On at the dividing point. Therefore,* in each of the models *there is the kind of choice that you called "arbitrary" with respect to whether the Red light is to be considered On or Off.*

After I had sent my former message containing the above solutions, I found I should include an additional "axiom", that is:

$$Duration(I1) = Duration(I2)$$

which implies that Duration(J1) = Duration(J2). Remember that

$$Duration(P + J2) = Duration(J2)$$

therefore the following axioms:

$Holds(GreenOff, I2)$
$Holds(GreenOn, P)$
$Holds(GreenOn, J2)$
$Holds(RedOff, I1)$
$Holds(RedOn, J1)$
$Meets(I2, P)$
$Meets(P, J2)$
$Meets(I1, J1)$

$I1 + J1 = I2 + P + J2$

$Duration(I1) = Duration(I2)$

together express the specified example, showing that:

(a) "GreenOff" Meets "GreenOn", i.e., $Meets(I2, P + J2)$, "RedOff" Meets "Red"On, i.e., $Meets(I1, J1)$;

(b) Since, together with the rest axioms, axiom $I1 + J1 = I2 + P + J2$ and axiom $Duration(I1) = Duration(I2)$ indicate that the Green light and the Red light are both Off before the switching point P, and are both On after P. Therefore, both the Green light and the Red light are switched at the same time point P

(c) The switching point P satisfies the "GreenOn" property which is specified as P Starts the GreenOn interval (i.e., $P + J2$), where there is nothing specified as whether the switching point P Finishes the RedOff interval (i.e., I1) or Starts the RedOn interval (i.e., J1).

*My two examples come out in similar ways. For example A, you write:*

> Yeah, for the modelling of the throwing of a ball, it requires that there exists a point referring to the apex. However, the fact that Jim turned the switch does not necessarily imply that there must not be any such point, especially if one insists that "at a moment (point?) when it (the ball) reaches the top of its trajectory, he (Jim) turns the switch".

*But if (in a particular model) such a point exists for the clocktime where Jim turned the switch, then it must be determined (in that same model) whether the switch is on or off at that point, and you have your Dividing Instant Problem back again.*

*For example B, you write:*

> I don't agree with the claim that "a point both exists and does not exist at the clocktime whent he winner finishes his last cone and the bell rings". Again, I think this claim was reached by means of confusing two cases, that is, the case that an interval "Meets" a point, and the case that an interval was "Finished-by" a point.

*Not really. If you wish to avoid a dividing instant situation by using a punctuated time domain (for each of the models, so that there is no dividing instant problem in any of the models), then you* must exclude *models where that timepoint is present. It can't be present explicitly, and it can't be present implicitly by being the ending or beginning of an interval, because in all of those cases you end up assigning the truthvalue that you considered arbitrary. The only way of complying is to have two successive open intervals without any point between them. (That is, an interval not ending in a point, and a subsequent Meeting interval not beginning in a point). However, this in turn contradicts the assumption that the Bell rings, since it was assumed the Bell rings at (time)points. Therefore, the only possible models are those where the Bell rings without the cones having been finished, and you obtain the conclusion I indicated.*

*The bottom line is, therefore, that it is futile to try to impose noncommitment for dividing instants on the level of the models and by using*

> *nonstandard time domains such as "punctuated time". In those cases where we wish to express that we don't know or don't care whether a certain proposition is true or false at a point of change, it's sufficient to use the multiple models approach while admitting "standard" time (integers or reals, by preference). Then we don't need any theory of time at all besides high-school or (at most) college math.*
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> *All of this presumes of course standard two-valued logic, where models can only assign the truth-value true or false. You may obtain another perspective by going to e.g. three-valued logic, where* everything *can be undetermined besides true or false. But, as H.C. Andersen once said, that is another story.*

I feel my explanations/arguments about the time theroy (model) in the first part of this message and the above revised demostration of the two-lights exmple also apply to Erik's questions/arguments and his examples A and B, since as Erik observed, they come out in similar ways.

Jixin