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Keep in touch

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Abstract. I introduce a puzzle about contact and de re temporal predication in relativistic spacetime. In particular, I describe an apparent counterexample to the following principle, roughly stated: if B is never in a position to say 'I was touching A, I am touching A, and I will be touching A', then (time travel aside) A is never in a position to say 'I was touching B, I am touching B, and I will be touching B'. In the case I present, the most that A is ever in a position to say is: 'I am now touching B, but this is the only instant at which this will ever be so'. B, on the other hand, can say: 'I was formerly touching A, I am currently touching A, and I will in the future be touching A'. (And neither object is a time traveler.)

0. Introduction

This paper introduces a puzzle about contact and de re temporal predication in relativistic spacetime. I consider a series of responses to the puzzle without endorsing any of them. The discussion is set within a stage theoretic[1] framework, not because I think that the puzzle poses a special problem for stage theory, but merely because the view is associated with a relatively explicit account of de re temporal predication. I strongly suspect that worm theory and endurantism confront more or less the same puzzle and have a parallel range of responses available to them, with similar costs and benefits, though I won't try to argue for that here.

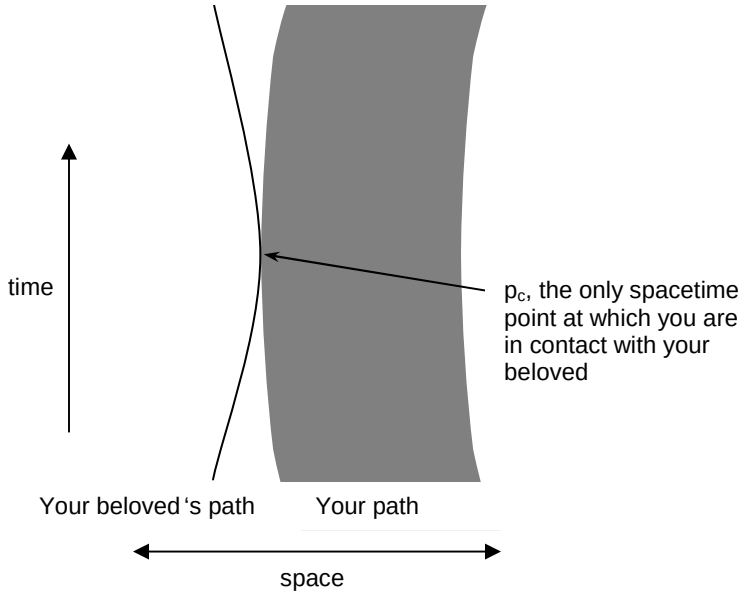
1. A Story

You, A, are a *Line* – a continuous, straight, spatially one-dimensional material object of finite length. Your beloved, B, is a *Point* – a spatially zero-dimensional material point particle. Your only desire is for some lasting contact with others (preferably your beloved). More specifically, you want to be able to say, 'I *was* touching someone, I *am* touching someone, and I *will be* touching someone.'[2] You want that sentence, as uttered by you at some moment of your life, to be true. More or less equivalently, you want there to be a time in your life when you are in a position to think (correctly) that you were formerly touching someone, that you are currently touching someone, and that you will in the future be touching someone. You ask the oracle whether you will ever get your wish. It answers thus:

> You and your beloved will one day move toward one another on a pathway. You will approach, touch, and recede. But this episode will be very brief. Indeed, you make contact at only a single spacetime point. And since the two of you are mutually impenetrable, you do not spatiotemporally overlap: no point belongs both to your spacetime path and to your beloved's spacetime path. Here is a spacetime diagram of your encounter:

[1] According to stage theory, ordinary objects are instantaneous stages each of which is located at just a single, temporally unextended spacetime region (Hawley 2001, Sider 2001). Ordinary objects persist, on this view, by having other stages (ones that are located at earlier or later spacetime regions) as temporal counterparts. Stage theory is typically contrasted with (i) *worm theory*, according to which ordinary objects are temporally extended 'worms' that have different temporal parts located at different times/spacetime regions and with (ii) *endurantism*, according to which ordinary objects are temporally unextended things that persist by being multilocated in spacetime – in particular, by exactly occupying each in a series of temporally unextended regions. See Balashov 2011, Hawley 2010, and Haslanger 2003 for surveys.

[2] The puzzle is most vivid when set up in such a way as to anthropomorphize the objects involved, but I take it to be straightforward to recast it in non-anthropomorphic terms.



> Each of you will live forever, but only on this occasion will the two of you be in contact, and you will never be in contact with anyone else. (And no one travels backward in time or traces out a closed timelike curve, etc.) The oracle has spoken.

Your sister, who has accompanied you on your visit to the oracle, offers consoling words. 'Ah well . . . you win some and you lose some . . . there's more to life than lasting contact . . . and anyway, an instant of contact is better than none at all. . .,' and so on. But you've never been happier. 'Don't you see?,' you say. 'I'm going to get the only thing I've ever wanted!'

2. The Argument for Optimism

2.1 A More Precise Description of the Case

You and your beloved inhabit Minkowski spacetime. Your beloved exists at all times and is spatially point-like throughout his career. His spacetime path,[3] R_B, is a timelike line.[4]

You, A, also exist at all times and are, throughout your career, spatially linelike and topologically open at both ends. To be more precise, let R_A be your path or 'worldsheet'. Then for any inertial reference frame F and for any hyperplane[5] H associated with F, there are distinct points p_{H1} and p_{H2} such that the intersection of H and R_A is the set whose members are those

[3] In the present context, we can say that the *path* of an ordinary object is the region that is exactly occupied by the sum of that object and its temporal counterparts. See Balashov (2010: 27).

[4] I assume that R_B is a timelike curve that is 'infinite in both directions': for any point p in R_B and any positive real number n, (i) there is a distinct point p+ in R_B, in the chronological future of p, such that proper time elapsed along R_B from p to p+ is n minutes, and (ii) there is another point p- in R_B (p-≠p+), in the chronological past of p, such that the proper time elapsed along R_B from p- to p is n minutes.

[5] A *region* is any non-empty set of spacetime points. A *hyperplane* is a region R such that for some inertial frame F and some point p: (i) p is in R, and (ii) a point p* is in R iff p* is simultaneous-in-F with p. Hyperplanes are spacelike, flat, and maximal. A hyperplane H is *associated* with an inertial frame F if and only if any two points in H are simultaneous-in-F.

points in H that are (with respect to F) spatially between p_{H1} and p_{H2}, where this set excludes those two points themselves. Informally, the idea is that your 'spatial locations' are line segments that do not include their endpoints.

To describe the encounter in a bit more detail, it will help to have some definitions in hand. First I want to make precise the notion of a *spatial endpoint* of the relevant sort of worldsheet, where a worldsheet may or may not include its spatial endpoints. (Yours doesn't.) I will say that p is a *spatial <H, F>-endpoint* of R if and only if: (i) F is an inertial reference frame, (ii) H is a hyperplane associated with F, (iii) p belongs to H, and (iv) there is a region R_H and a point p* such that: (a) p* belongs to H, (b) R_H includes every point in H that is (with respect to F) spatially between p and p*, (c) for any x, if $x \neq p$ and $x \neq p^*$ and x is not a point in H that is (with respect to F) spatially between p and p*, then x is not a member of R_H, and (d) R_H = the intersection of R and H. I will then say that p is a *spatial endpoint* of R if and only if: for some H and some F, p is a spatial <H, F>-endpoint of R.

Using this notion, we can specify the case further. In particular, if we let R_{EA} be the set of spatial endpoints of R_A (your path), we can add that R_{EA} is the union of two timelike lines, $L_{A'sLeftE}$ and $L_{YourRightE}$, whose intersection is null. We can also note that the intersection of R_A and R_{EA} is null. (Your path excludes its spatial endpoints.) Finally, we can say that $L_{A'sLeftE}$ and R_B have a non-null intersection: specifically, they have exactly one common member, p_c.

Now for four more definitions, which will help us pinpoint the sense in which you and your beloved *touch*.[6] First, say that R is an *open <H, F>-sphere* about p if and only if: (i) F is an inertial reference frame, (ii) H is a hyperplane associated with F, (iii) p is a point in H, and (iv) there is some spatial distance d such that R = {x: x∈H & with respect to F, the distance from x to p is less than d}, that is, R is the set of those points in H whose distance from p with respect to F is less than d. Second, say that p is an *<H, F>-boundary point* of R if and only if: (i) F is an inertial reference frame, (ii) H is a hyperplane associated with F, (iii) each open <H, F>-sphere about p has a non-null intersection both with R and with H – R.[7] Third, say that p is a *regional contact point* between R_1 and R_2 if and only if: (i) R_1 and R_2 are regions whose intersection is null, (ii) for some H and some F, p is an <H, F>-boundary point of R_1, (iii) for some H and some F, p is an <H, F>-boundary point of R_2, and (iv) p belongs either to R_1 or to R_2. Fourth, say that o_1 *is touching* o_2 if and only if there is an R_1, an R_2, and a p such that: (i) p is a regional contact point between R_1 and R_2, (ii) o_1 exactly occupies R_1 and (iii) o_2 exactly occupies R_2.

Now, given these definitions together with our previous claims about the case, I take it that p_c is the one and only regional contact point between R_A (your path) and R_B (your beloved's path), and that p_c belongs to R_B, not R_A.

2.2 An Optimistic Interpretation of the Case

On the basis of these facts, you reason as follows. Let a *slice*[8] of a region be a non-null intersection between that region and some hyperplane. Then there is a set S_A of slices of R_A that has the following property:

(i) it has continuum-many members,

(ii) each of its members is in regional contact with R_B at p_c,

[6] The first two definitions are straightforward relativistic analogues of definitions from Cartwright (1987: 171). The third and fourth definitions are based more loosely on Hudson (2005: 65).

[7] H – R = the set of points that are in H but not in R.

[8] I will sometimes shift from talking of slices of regions to slices of objects.

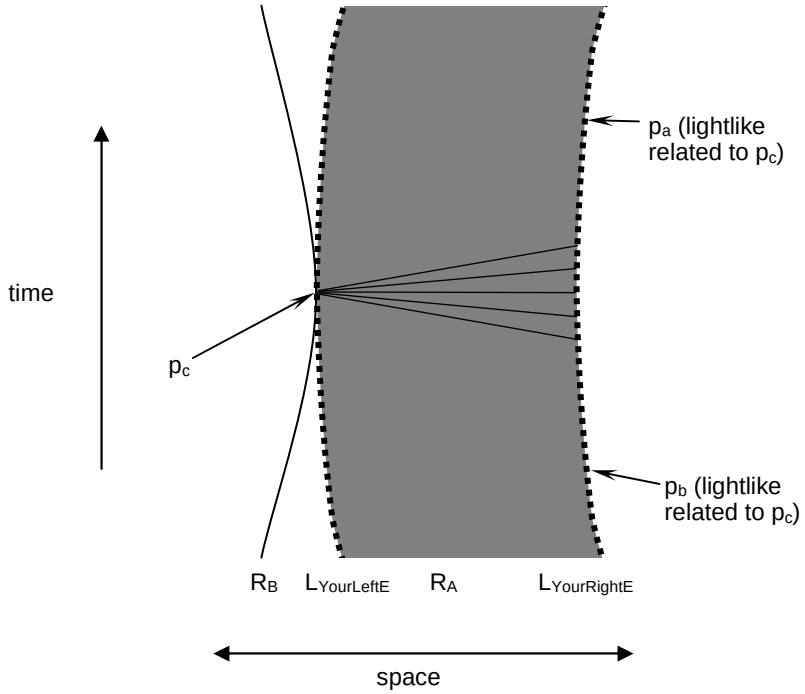
(iii) there is *strict total order* R_{Pr} on S_A,[9] where R_{Pr} is set of ordered pairs of members of S_A such that $\langle R_1, R_2 \rangle \in R_{Pr}$ iff:

(a) for each point p_1 in R_1, there is a point p_2 in R_2 such that p_1 is in the chronological past[10] of p_2,

(b) for each point p_2 in R_2, there is a point p_1 in R_1 such that p_1 is in the chronological past of p_2,

(c) no point in R_2 is identical to or in the causal past of any point in R_1.

We can think of R_{Pr} as corresponding to a relation of <u>being absolutely earlier than</u> that can hold between spatially extended spacelike regions in relativistic spacetimes.[11] In case one doubts the existence of such a set, consider the following diagram:



Put something in the set if and only if: (i) it is a line segment whose left endpoint is p_c and whose right endpoint lies on $L_{YourRightE}$ below p_a and above p_b (each of which is lightlike related to p_c), and (ii) it excludes both of its endpoints. (Notice that no two of these segments intersect. They all

[9] A strict total order on a set S is a transitive, asymmetric, and irreflexive relation R such that for any x and y in S, if $x \neq y$, then either $\langle x, y \rangle \in R$ or $\langle y, x \rangle \in R$.

[10] A point p* is in the *chronological* past of a point p if and only if there is a future-directed timelike curve running from p* to p – roughly, if and only if a slower-than-light signal emitted at p* could reach p. A point p* is in the *causal* past of a point p if and only if either there is a future directed timelike curve running from p* to p or there is a future-directed lightlike curve running from p* to p – roughly, if and only if a signal traveling at or below light speed emitted at p* could reach p. The chronological past of a point is a proper subset of its causal past.

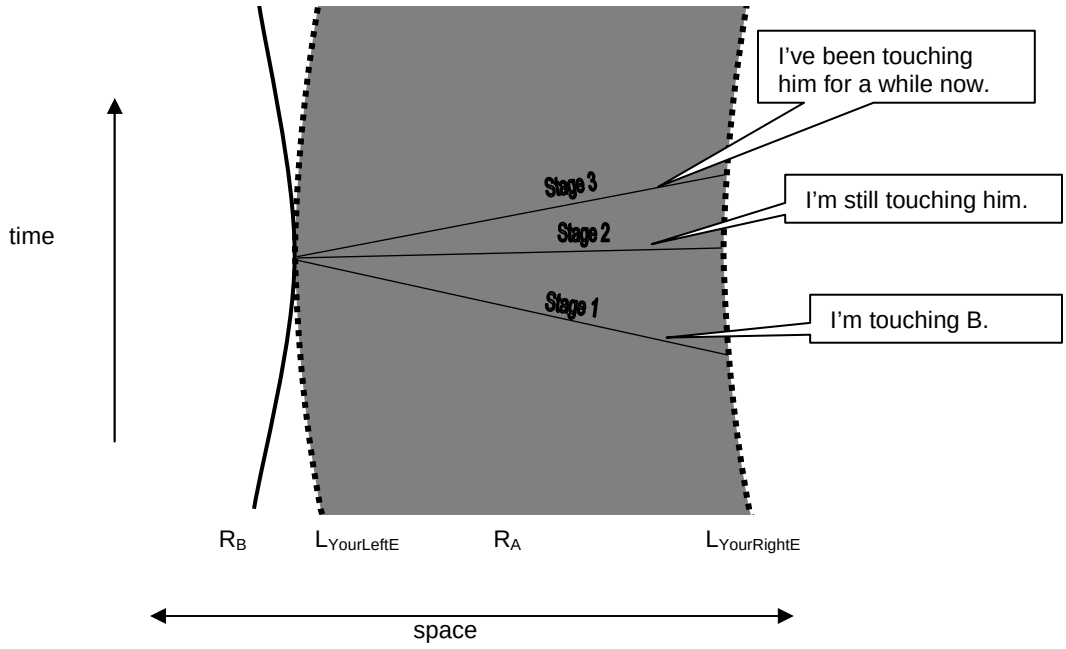
[11] At least, I find it natural to think of the relation associated with R_{Pr} as a very close analogue of <u>being absolutely earlier than</u>, especially given its formal properties. Admittedly, not everyone will agree, and indeed, some might ultimately see the puzzle as constituting a *reductio* of the claim that I find so natural here. (Thanks to Cord Friebe for pressing me on this.) But this result is interesting in its own right, I think.

have the same left endpoint, but they all exclude that point, and they obviously don't intersect anywhere else.) It should be easy to convince oneself that this set corresponds in a straightforward way to a set of slices of R_Y having the relevant features.

Now suppose that stage theory is true. (See note 1.) Ordinary objects such as you and your beloved are instantaneous stages. Such objects persist by having temporal counterparts (themselves instantaneous stages) existing at other times. Moreover, truth conditions for most de re temporal predications are given counterpart-theoretically. For example:

- the sentence type 'I *was* happy' is true as uttered by a stage s if and only if a past counterpart of s is$_{\text{tenseless}}$ happy,
- the sentence type 'I *am* happy' is true as uttered by a stage s if and only if s is$_{\text{tenseless}}$ happy, and
- the sentence type 'I *will be* happy' is true as uttered by a stage s if and only if a future counterpart of s is$_{\text{tenseless}}$ happy.

Given all this, it seems that you will get your wish. For it seems that there is a stage (e.g., Stage 2 in the diagram below) that is in a position to say, 'I was touching someone, I am touching someone, and I will be touching someone'.



After all, Stage 1, Stage 2, and Stage 3 are all touching someone (namely, B), and Stage 1 and Stage 3 would seem to be past and future counterparts, respectively, of Stage 2.[12]

[12] One should not interpret the diagram as suggesting that any of the stages *perceive* that they are touching B. (Presumably that would require, very roughly put, that some causal signal originating at p_c gets 'processed' by the stage in question, which would seem to be ruled out by the fact that each of the stage's parts is spacelike separated

Suppose that you are Stage 2. Why think that Stage 3 is one of your future counterparts? The main reason can be broken down into four claims. First, Stage 3 is an instantaneous temporal part[13] of the 'you-worm' – the sum of you and all your temporal counterparts. For future reference, call it *Worm A*. (Your path is the region that it exactly occupies.) Second, Stage 3 resembles you very closely. In particular, Stage 3 is the same kind of thing you are and it is not missing any spatial parts of you.[14] Third, Stage 3 lies 'wholly in your future' in the sense that the region that you exactly occupy bears the <u>being absolutely earlier than</u> relation (described above) to the region that Stage 3 exactly occupies.[15] Stage 3 does not spatiotemporally overlap you, no part of it is even in the causal (not to mention chronological) past of any part of you, every part of it is in the chronological future of some part of you, and every part of you is in the chronological past of some part of it. Fourth, and relatedly, you stand in the appropriate immanent causal relation to Stage 3: Stage 3 is the way it is in large part because you are the way you are.[16]

In light of these facts, it is highly plausible that Stage 3 is one of your future counterparts. To reinforce this verdict, consider a fanciful thought-experiment. Continue to suppose that you are Stage 2. But now suppose, further, that Stage 3 is in extreme pain, and that it is the *only* temporal part of Worm A that is in pain of any kind.[17] What sort of attitude should you have

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from p_c.) Instead, one should think of A as knowing in advance exactly how the encounter will play out, and setting up some sort of mechanism that guarantees that the appropriate stages will have the appropriate beliefs (which might then constitute *knowledge*, though not perceptual knowledge). A non-relativistic example: if I know that my grandmother will turn 100 at a certain instant t in 2012, I might – given sufficiently advanced technology – implant a timer in my brain that will cause me to have, at precisely t, the tensed belief that I would express with the sentence 'She is exactly 100 years old right now', and (though nothing turns on this) the belief might constitute knowledge.

[13] As defined by Gibson and Pooley:

> P is a[n] instantaneous temporal part of O just if (i) P is a part of O, (ii) P exactly occupies a region R_P that is spacelike, [and] (iii) R_P is a maximal spacelike subregion of the path R_O of O. (2006: 163)

[14] Contrast this with a 'corner slice' case (Gilmore 2006: 211-213): four particles, arranged in line, pop into existence simultaneously with respect to their common rest frame, the inertial frame F, remain at rest, then a few minutes later pop out of existence simultaneously with respect to F. They compose a persisting molecule. Consider the worm, W, associated with this molecule, and the worms W_1 – W_2 associated with the four particles. Note that there are 'corner slices' in this case: hyperplanes passing through W that intersect just one of W_1 – W_4. The regions of intersection correspond to instantaneous temporal parts of W, but these temporal parts are 'defective'. If you are the four-particle molecule, these defective temporal parts of W are not among your temporal counterparts. See Balashov (2010: 110-116; 2011: 33-35), Donnelly (2010: 229-230), Eagle (2011), and Sattig (MS) for further discussion of the corner slice case.

[15] Contrast this with a case of 'criss-crossing' stages, e.g., with diagonal lines in a flattened 'X': ><. Each diagonal might correspond to an instantaneous temporal part through the same worm (associated with different frames). But if you are one of these parts, the other one is not a future counterpart of you. Too much of it is in your past. (Nor is the other a past counterpart of you, for parallel reasons. Either it is not a counterpart of you at all, or it is what we might call a 'criss-cross counterpart' of you. In some ways it is related to you more as a 'fellow product of a fission', i.e., as a 'fission sister', than as a temporal counterpart.) See Gilmore (2006), Gilmore (2008), Gibson and Pooley (2006), and Balashov (2010) for more on criss-crossing slices.

[16] This is not an 'immaculate replacement' style-case in which a thing pops out of existence and is, by complete coincidence, immediately replaced with a duplicate that is causally unrelated to the original thing. See Swoyer (1984), Zimmerman (1997), Gibson and Pooley (2006), Gilmore (2006), and Balashov (2010: 116-129).

[17] For simplicity, suppose that spatially one-dimensional beings can feel pain. (The spatial one-dimensionality of the being in question is not essential to the paper. At the cost of some extra complexity, the paper could focus instead on a parallel case involving spatially three-dimensional things with the appropriate spatial topological properties.) Even so, it's not clear that a given instantaneous stage could feel extreme pain without having neighbors that feel some pain. Though nor is it clear that this case is impossible. Even if <u>being in extreme pain</u> is a highly relational property

toward this painful experience? The natural thing to say, it seems to me, is that it's appropriate for you to dread this pain. This suggests that Stage 3 is one of your future counterparts, since their pains are the only ones that it is appropriate for you to dread. (Analogous considerations support the verdict that Stage 1 is one of your past counterparts. I assume that these do not require separate discussion.)

Admittedly, Stages 1, 2, and 3 are associated with different inertial reference frames. But why should that matter? That fact by itself doesn't show that none of the given stages is a temporal counterpart of any of the others. Suppose that Obama is currently at rest with respect to the Oval Office, and call his current stage *O-stage-1*. All of O-stage-1's parts are simultaneous with respect to the inertial frame F_{ov} – the 'Oval Office frame'. Now suppose that later today, while flying aboard Air Force One, he will be at rest with respect to a *different* inertial frame, say, the frame F_{af1}. Pick one of those later stages and call it *O-stage-2*. All of its parts are simultaneous with respect to F_{af1}, but not with respect to F_{ov}. I take it to be just obvious that O-stage-2 is a temporal counterpart of O-stage-1 (and that any experiences that happen to O-stage-2 are ones that O-stage-1 is in position to anticipate). And yet those stages are associated with different inertial frames.

Of course, the two cases are different. O-stage-1 and O-stage 2 are both what we might think of, rather loosely, as 'rest frame stages' of Obama, whereas Stages 1 and 3 are not 'rest frame stages' of A. But the crucial point here is just this: the mere fact that Stages 1, 2, and 3 are associated with different inertial frames does not *by itself* guarantee that they are not temporal counterparts. We will return to these issues in section 3. (Eventually I argue, among other things, that we should not limit a thing's temporal counterparts to its 'rest frame stages'.)

To recap, then, the situation is this. You are Stage 2, and you are, in the tenseless sense defined earlier, touching someone (namely B). This, I submit, is sufficient for the result that:

(1) 'I am touching someone' is true as uttered by Stage 2.

Moreover, Stage 1 is your past counterpart and is also touching B in the tenseless sense. This suffices for

(2) 'I was touching someone' is true as uttered by Stage 2. [18]

(Sider 2001: 198), requiring the existence of past and future stages with appropriate intrinsic properties of their own, it doesn't follow that 'pains always build up gradually', so to speak.

[18] Gibson and Pooley (2006: 165-167) sketch a proposal about the truth conditions of tensed utterances that might block the case for (2) and (3):

> Here by 'moment' we mean a temporally extended but short-lived (i.e., momentary) interval, and the answer will depend upon its temporal extent. Let us first take it to be the duration of the specious present, the time it takes to have a single thought or enjoy a single experience. This, let us say, is about 0.2 of a second. Call the temporally extended spacetime region you occupy (partially or multiply) during this 'moment' *NOW*. To be something that can affect you in the NOW, an object must be located within the backward lightcone of the future boundary of the NOW. To be something that can be affected by you, as located in the NOW, the object must fall within the future light cone of the past boundary of NOW. Call the region bounded by these two lightcones the *Stein Present* of the NOW. The NOW's Stein Present is a four-dimensional discus-shaped region centered on the NOW. . . . Our tensed talk, which reports our spatiotemporal perspective on the world as at R, should be partially analyzed in terms of R's Stein Present. The present tense is correctly used at R to talk about objects and events as they are in the Stein present of R, the past tense is correctly used to talk about objects and events as they are in the absolute past of R [and so on for the future tense].

Finally, Stage 3 is your future counterpart and is touching B in that same sense. This yields

(3) 'I will be touching someone' is true as uttered by Stage 2.

I take it that if sentences S_1, S_2, and S_3 are each true as uttered by stage x, then the sentence ⌜S_1, S_2, and S_3⌝ is also true as uttered by stage x. This gives us

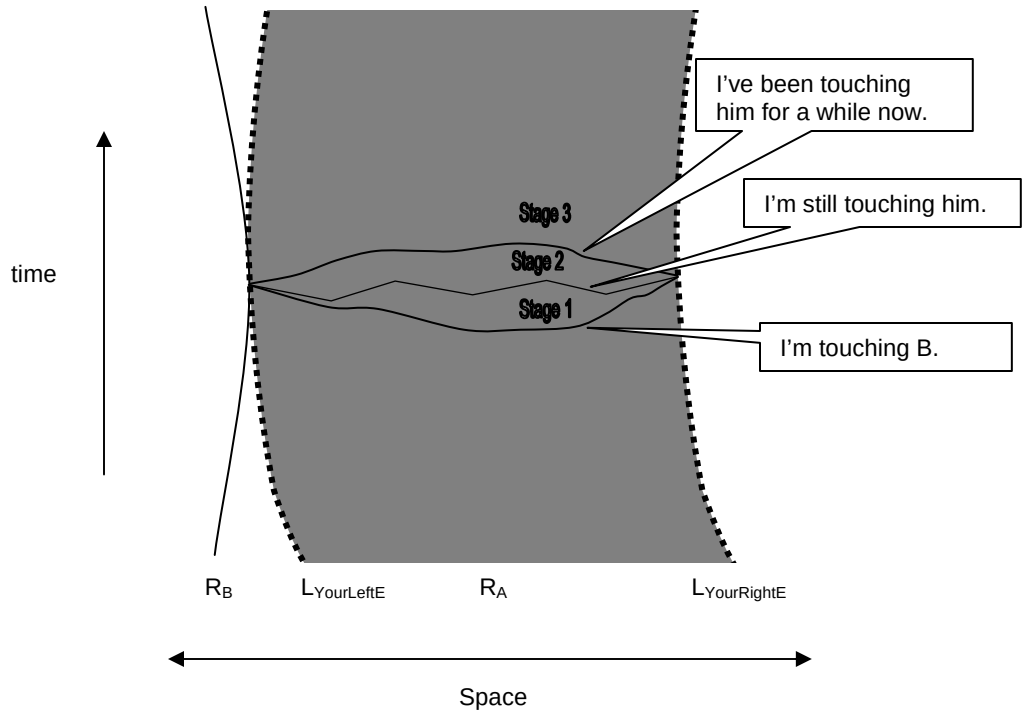
(4) 'I was touching someone, I am touching someone, and I will be touching someone' is true as uttered by Stage 2.

So you get your wish.

One small point before we move on. For simplicity, I've set up the case in such a way that the stages in question exactly occupy flat regions associated with different inertial frames. But that's in no way essential to the puzzle. At the cost of some additional complexity (e.g., in our definitions of 'contact' and 'touching'), we could focus instead on a different case in which the stages exactly occupied a series of non-flat (but still spacelike) regions, none of which has any special connection to any particular inertial frame.[19] (See the diagram below.)

Adapting this suggestion to a stage theoretic context, the idea would be that 'I was touching someone' is not true as uttered by Stage 2, since Stage 2's NOW, R, is temporally extended in such a way that Stage 2 does not have any temporal counterparts that are both: (i) in the absolute past of R and (ii) touching someone. I cannot do justice to this interesting proposal here.

[19] It has been suggested to me that if x is a non-flat spacelike stage in Minkowski spacetime, then it is somehow senseless (or at least incorrect) to say that x is *touching* something (presumably even after we modify our extant definitions in the relevant manner). The motivation for this claim, as I understand it, is that (i) touching is a spatial relation that holds only between things that exactly occupy only instantaneous spacetime regions, and (ii) the only spacetime regions that count as instantaneous in Minkowski spacetime are *subregions of hyperplanes* and hence *flat*. In response, I doubt both (i) and (ii). Against (i), I see no reason why two four-dimensional, temporally extended objects couldn't touch one another at a certain spacetime point. Presumably a worm theorist ought to say that A and B touch one another at point p_c despite they fact that they are both temporally extended things, neither of which exactly occupies an instantaneous region. Against (ii), it seems to me that 'spacelike' (or 'achronal') is a sufficiently close relativistic counterpart of 'instantaneous', even in Minkowski spacetime. But a full defense of this claim lies beyond the scope of the present paper. For further relevant discussion, see Gilmore (2006) and Gibson and Pooley (2006).



3. Pessimism

3.1 Motivating Pessimism

Isn't it obvious that something has gone wrong here? For there seems to be a compelling argument for an opposing conclusion:

The First Pessimistic Argument

P1 If a persisting point-particle makes contact with a persisting line-segment at just a single spacetime point, if nothing else ever makes contact with the persisting line-segment, and if nothing travels backward in time (etc.),[20] then the persisting line

[20] To see why the qualification about time travel is needed, suppose that A undergoes the encounter described by the oracle and shortly thereafter disappears, reappearing shortly prior to the collision, this time on the left side of B. The time traveling A races to catch up with B (who is moving to the right) and eventually does so, just managing to make contact with B at p_c. The time traveling A then jumps into the future and appears there just where and when she had originally disappeared, thus leaving no gap in her path. (There are other more physically realistic ways of telling the story as well.) In this modified case, A and B make contact at just a single spacetime point, but intuitively A does seem to be in a position to say 'I am touching someone and I will be touching someone' at one moment of A's career and 'I am touching someone and I was touching someone' at another moment. A further revision, involving an additional trip back in time, would give us a case in which it plausible that A is in a position to utter the sentence considered in the main text. (These cases suggest that truth conditions for de re temporal predications should be given in terms of personal time rather than external time.)

segment is never in a position to say (correctly), 'I was touching someone, I am touching someone, and I will be touching someone'.

P2 You are a persisting line segment, a persisting point-particle makes contact with you at just a single spacetime point, nothing else ever makes contact with you, and nothing travels backward in time (etc.).

C1 So, you are never in a position to say (correctly), 'I was touching someone, I am touching someone, and I will be touching someone'.

P3 If you are never in a position to say that, then you don't get your wish.

C2 So, you don't get your wish.

I have some sympathy with this argument and with P1 in particular. It can be reinforced by considering a somewhat different line of thought – one that involves your beloved's perspective and the apparent symmetry of touching:

The Second Pessimistic Argument

P4 If touching is a symmetric relation, then (time travel aside) if B is never in a position to say 'I was touching A, I am touching A, and I will be touching A', A is never in a position to say, 'I was touching B, I am touching B, and I will be touching B'.

P5 Touching is a symmetric relation.

P6 B is never in a position to say 'I was touching A, I am touching A, and I will be touching A'.

C3 So, A is never in a position to say 'I was touching B, I am touching B, and I will be touching B'.

P7 If A is never in a position to say 'I was touching B, I am touching B, and I will be touching B', and if A never touches anyone other than B, then A is never in a position to say 'I was touching someone, I am touching someone, and I will be touching someone'.

P8 A never touches anyone other than B.

C4 So, A is never in a position to say 'I was touching someone, I am touching someone, and I will be touching someone'.

This leads, as before, to the conclusion that you don't get your wish. One key premise in this argument, and the only one that I take to require comment, is P6. To see why it's plausible, note that there is only one 'B-stage' that touches Worm A or any 'A-stage'. The B-stage in question is

the one that exactly occupies the region, call it R_c, whose sole member is p_c. Call the given stage *Stage 4*. Stage 4 is in a position to say 'I am touching A', but no other B-stage is in a position to say that. And since no past or future counterpart of Stage 4 touches any part of Worm A, Stage 4 is not in a position to say 'I was touching A' or 'I will be touching A'. So no B-stage whatever is in a position to say 'I was touching A, I am touching A, and I will be touching A'. In other words, B is never in a position to utter the given sentence.

This leaves us with a puzzle. We have an apparently convincing case for the conclusion that you do get your wish and a perhaps equally convincing case for the conclusion that you don't get your wish.

3.2 Some Objections to the Case for Optimism

Objection One: Relativize to inertial frames. The Case for Optimism saddles the stage theorist with the assumption that he must provide an account of the notion of a *sentence type's being true as uttered by a stage*. This is a *dyadic* notion of truth, with a slot for a sentence type and a slot for a stage. But the stage theorist is under no burden to accept this assumption. An alternative and perhaps more appropriate target is a notion of truth that is at least triadic, with a slot for a sentence type, a slot for a (presumably *inertial*) reference frame, a slot for an instant of time in (or hyperplane associated with) that frame, and perhaps additional slots – e.g., for the speaker. Here is how Sider puts it:

> The stage theorist should provide an account of a somewhat theoretical notion, that of *a sentence type's being true as uttered at a time t, understood relative to frame of reference F*. The stage theorist should claim, for example, that the sentence type 'Ted will be bald', as uttered at t, interpreted relative to F, is true iff the Ted-stage at t, relative to F, has a temporal counterpart in the future, relative to F, that is bald. (Sider 2001: 199).

How does this help? Put very crudely, the idea is this. Relative to any inertial frame F, there is only a single instant at which A is touching B (or anyone). So, relative to any inertial frame F and instant t in F, the sentence 'I was touching someone, I am touching someone, and I will be touching someone', as uttered by the A-stage corresponding to <t, F>, is not true.

To spell this out fully, recall that A's wish is to be in a position to say 'I was touching someone, I am touching someone, and I will be touching someone'. Now, if

(i) the only notion of truth for sentence types that can be made sense of in a relativistic context is the one Sider focuses on,

then presumably

(ii) A's wish is satisfied if and only if there is an inertial frame F and an instant t in F such that the relevant sentence is *true as uttered (by some A-stage) at t understood relative to F*.

Moreover, it's clear that

(iii) there is no such <instant t, inertial frame F> pair.

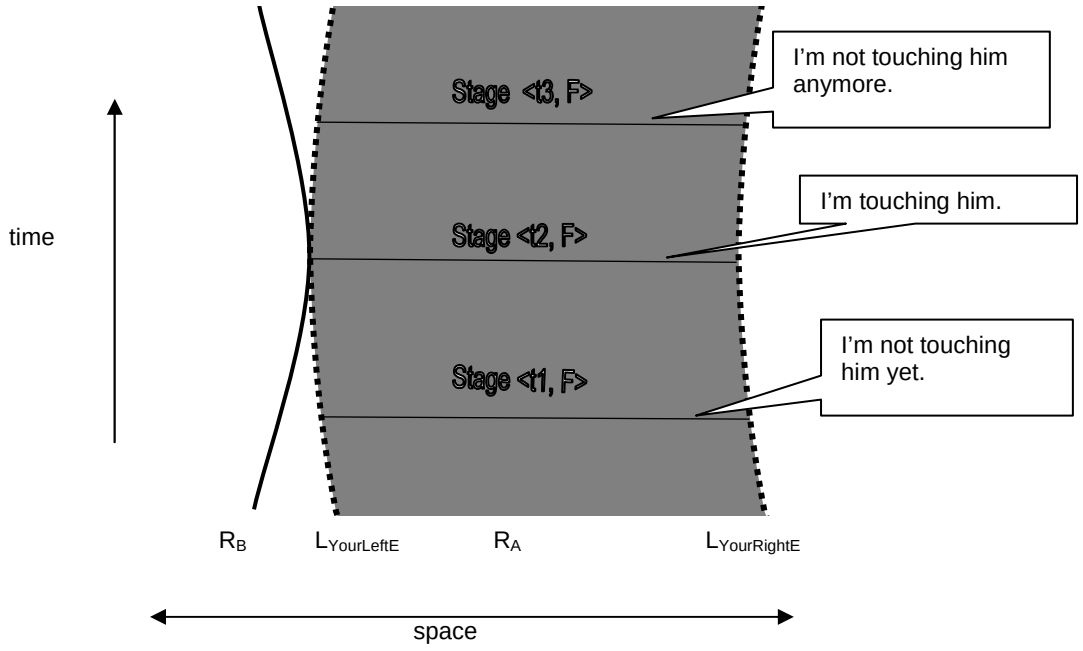
For

(iv) the sentence type 'I was touching someone, I am touching someone, and I will be touching someone' is true as uttered by an A-stage x at an instant t relative to an inertial frame F if and only if there are hyperplanes H_P, H_t, and H_F of 'simultaneity-with-respect-to-F' such that:

(a) H_t is the hyperplane corresponding to <t, F>
(b) H_P is earlier-with-respect-to-F than H_t,
(c) H_F is later-with-respect-to-F than H_t
(d) x is the A-stage that exactly occupies the intersection of R_A and H_t and x is touching someone
(e) x has a (past) temporal counterpart that exactly occupies the intersection of R_A and H_P and that is touching someone, and
(f) x has a (future) temporal counterpart that exactly occupies the intersection of R_A and H_F and that is touching someone.

In short, the given sentence is true as uttered by an A-stage x at t with respect to inertial frame F if and only if x is the <t, F>-slice of Worm A, x is touching someone, x has, as temporal counterparts, earlier and later 'F-slices' of the A-worm that are themselves touching someone.

And the right-hand side of the biconditional in (iv) is false. Pick any inertial frame F. There will be exactly one instant t associated with F such that the <t, F>-slice of the A-worm is touching someone. Hence, for any inertial frame F and instant t in F, if the <t, F> slice of the A-worm is touching someone, then that slice does *not* have, as temporal counterparts, earlier or later F-slices of the A-worm that are themselves touching someone. (See the diagram below.)



There is no <t, F> pair with respect to which the given sentence is true. And since the only sense in which the given sentence could be true is relative to some <t, F> pair, there is no sense in which the sentence is true.

Reply. Ian Gibson and Oliver Pooley (2006: 160-163) have argued that there is a tendency in the literature on persistence and relativity to rely too heavily on the notion of an *inertial reference frame* and the associated notion of a *hyperplane* – i.e., a maximal spacelike hypersurface that is *flat*. In connection with Sider's definition of the notion of an instantaneous temporal part (a definition that makes heavy use of the notion of an inertial reference frame), they write:

> While flat regions of spacetime are in some sense geometrically privileged, there is no reason to suppose that this gives them any special metaphysical status, in the context of questions about persistence or otherwise. More significantly, one surely wants a definition applicable the context of our best theory of space and time, general relativity. While this theory allows spacetimes containing flat spacelike regions, generic matter-filled worldtubes will have no flat maximal spacelike subregions (2006: 163).

I agree[21] and would only add that one also surely wants an *account of the truth conditions of de re temporal predications* applicable in general relativity. Inertial frames are not, in general,[22] available there.

Let me be explicit about the problem this causes for Sider's account, if that account were applied in a general relativistic spacetime that contains no inertial frames. (In fairness to Sider, his account is intended for Minkowski spacetime only.) Suppose that we inhabit such a spacetime, and consider the sentence 'I was a boy'. Sider's account delivers the result that this sentence is not true as uttered by me now (by my present stage), since there is no inertial frame F such that I have, as a temporal counterpart, an F-slice of the Cody-worm that is: (i) earlier-with-respect-to-F than my present stage and (ii) a boy. But that sentence is true as uttered by me now. So Sider's account is incorrect.

The stage-theoretic account of de re temporal predication implicit in the Case for Optimism does not suffer from the above problem. It does not employ the notion of an inertial frame. Instead, it uses only frame invariant notions that apply equally in both special relativistic and typical general relativistic spacetimes. This makes it preferable to Sider's account.

Objection Two: Relativize to foliations of spacetime. A *foliation* F of a set R of spacetime points is a set of *subsets* of R (the *leaves* of the foliation) such that: (i) each point in R belongs to exactly one member of F and (ii) each member R* of F is a maximal spacelike subregion of R – i.e., a subset of R that is spacelike (any two distinct points in it are spacelike separated) and maximal (it is not a proper subset of some other spacelike subset of R). Informally, a foliation of

[21] Though for dissent, see Balashov (2010: 94-102). I suspect that many of the authors who make use of inertial frames and hyperplanes do so only as a matter of convenience and would, if pressed, agree that more general (but more complex) accounts are preferable. Often the more general accounts are not especially difficult to formulate and do not differ in any interesting or significant way from the simpler accounts, in which case there is little reason to bother with them. The present case, in my view, is an exception to the rule.

[22] Some general relativistic spacetimes do contain inertial frames. Minkowski spacetime is a general relativistic spacetime (corresponding to one possible way in which the universe could be empty) and it contains inertial frames.

a region is a way of exhaustively slicing that region into a series of non-intersecting, temporally unextended (but not necessarily flat) *leaves*.

Typical general relativistic spacetimes do not contain inertial reference frames but do admit of foliations. This suggests an emended version of Sider's account that offers truth conditions in terms of the notion of *a sentence type's being true as uttered at a leaf l in a foliation f of spacetime.* Specifically, the emended account says that

(iv*) the sentence type 'I was touching someone, I am touching someone, and I will be touching someone' is true as uttered by an A-stage x at a leaf l in a foliation f of spacetime if and only if there are leaves l_P and l_F of f such that:

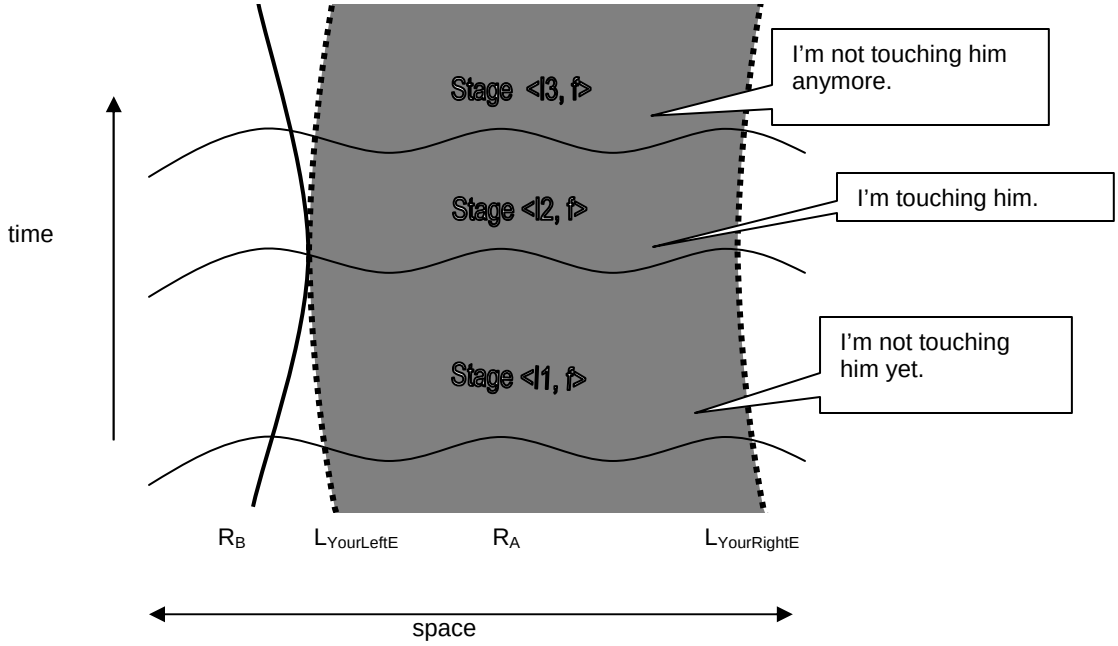
- (a) l_P is earlier-with-respect-to-f than l
- (b) l_F is later-with-respect-to-f than l
- (c) x is the A-stage that exactly occupies the intersection of R_A and l, and x is touching[23] someone
- (d) x has a (past) temporal counterpart that exactly occupies the intersection of R_A and l_P and that is touching someone, and
- (e) x has a (future) temporal counterpart that exactly occupies the intersection of R_A and l_F and that is touching someone.

In short, the given sentence is true as uttered by a given A-stage x at an f-leaf l if and only if x is the l-slice of Worm A, x is touching someone, and x has, as temporal counterparts, earlier and later 'f-slices' of Worm A that are themselves touching someone. (An f-slice of a worm is a temporal part of that worm that exactly occupies the intersection of the worm's path and some leaf in the foliation f.)

As with (iv), the right-hand side of the biconditional in (iv*) is false. Pick any foliation f of spacetime as a whole. Exactly one leaf, l_c, of f, will intersect B's path, R_B, at the 'contact point' p_c. This leaf will also intersect A's path, R_A, at a certain region, $R_A \cap l_c$. The temporal part of Worm A that exactly occupies $R_A \cap l_c$ will touch (in a suitably generalized sense) Worm B at the contact point. But, I assume, no other 'f-slice' of Worm A will touch Worm B.

(Intuitively, such an f-slice – call it *slice** – would need to have parts that are spacelike separated from p_c and 'arbitrarily spatially close' to p_c. Now, since slice* would belong to a different leaf, l*, in the original foliation (f), l* would need to intersect R_B at some point p* that is timelike separated from p_c. But if slice* contains parts that are spacelike separated from p_c and arbitrarily spatially close to it, and if p_c is timelike separated from p*, then presumably some of slice*'s parts are also timelike separated from p*. And slice*'s parts, along with p*, are all supposed to be associated with the same leaf, l*. This gives us the result that l* contains timelike related entities, contrary to our assumption that l* is a leaf in a foliation and hence spacelike.)

[23] Given a suitably generalized (and still tenseless) notion of touching. The notion defined earlier depends upon the existence of hyperplanes. Henceforth I leave this qualification implicit.



If all of this is correct, then there is no leaf in any foliation of spacetime with respect to which the given sentence (as uttered by some A-stage) is true.

Reply. There are general relativistic spacetimes (e.g., the Gödel spacetime) that do not admit of global foliations.[24] Presumably our account of the truth conditions of de re temporal predications ought not entail that the given sentence can never be uttered truly in such spacetimes, regardless of what goes on in them. But the account sketched above entails just that.

Let me elaborate. There are large, four-dimensional 'chunks' of the Gödel spacetime that are intrinsically very similar to chunks of 'ordinary' foliable spacetimes that lack closed timelike curves (CTCs).[25] These chunks, even when embedded in the Gödel spacetime, admit of 'local' foliations – foliations into 'locally' spacelike leaves.[26]

Now, to see why this is relevant, suppose that the Gödel spacetime contains language users much like ourselves but that they (and indeed all living things in the Gödel spacetime) are confined to a four-dimensional chunk that is intrinsically very similar to some chunk from an ordinary foliable spacetime devoid of CTCs. Suppose that the life-containing chunk is spatially very large – say, the size of a supercluster of galaxies – and temporally quite long – say, 7 billion years long. Further, suppose that the living things in it are confined to a single planet and to a time span of just one billion years. Suppose that the language-users speak English (or something qualitatively just like it), and that two of them come into perfect contact for several hours (locally speaking). Midway through this period of contact, one of them assertively utters the sentence 'I was touching someone, I am touching someone, and I will be touching someone'. Surely the sentence is true in the relevant context.

[24] Gödel (1949). See Lockwood (2003: e.g., 128-130) for helpful discussion.
[25] Though some foliable spacetimes do contain CTCS, e.g., a Minkowski spacetime that is 'rolled up' in the appropriate way.
[26] See Earman (1995: 171) and Gilmore (2006: 229, note 19) for details.

But the foliation-based account given above does not allow for this. Since the relevant spacetime is non-foliable, it contains no 'leaves'. Hence the given sentence is not true in the 'leaf-relative' sense: it is not true relative to any leaf in any foliation. What this shows is that we need a notion of truth that is not relativized only to leaves in foliations.

Objection Three. As we just noted, non-foliable spacetimes may contain regions that can be foliated into a series of 'locally' spacelike leaves. Presumably the path of any ordinary persisting object can be so foliated. We might then offer a second emendation of Sider's account in terms of the notion of *a sentence type's being true as uttered at a leaf l in 'local foliation' f*, where f need not be a foliation of spacetime as whole. This emended account might be expected to yield the following analogue of (iv) and (iv*):

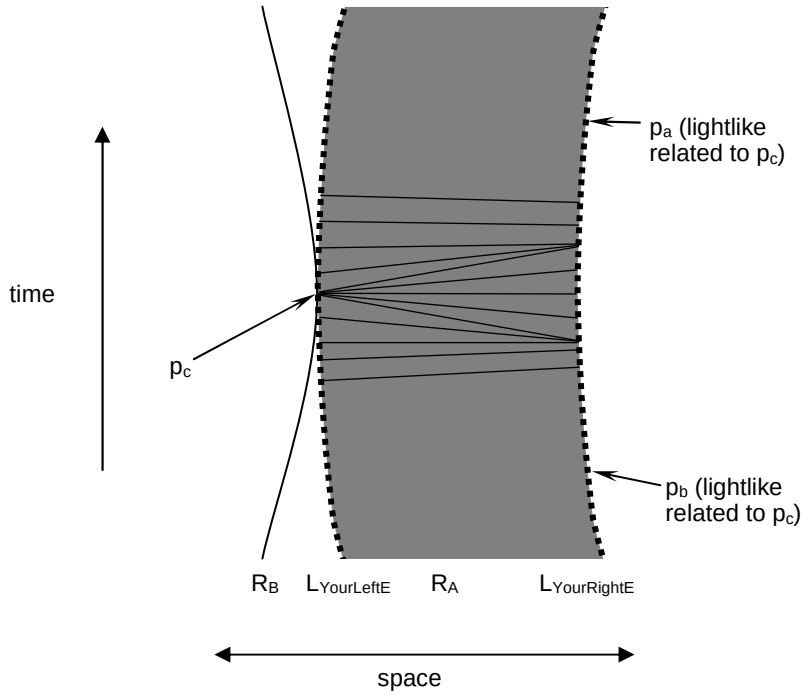
(iv**) the sentence type 'I was touching someone, I am touching someone, and I will be touching someone' is true as uttered by an A-stage x at a leaf l in a local foliation f of a region R if and only if there are leaves l_P and l_F of f such that:

- (a) l_P is earlier-with-respect-to-f than l,
- (b) l_F is later-with-respect-to-f than l,
- (c) x is the A-stage that exactly occupies the intersection of R_A and l, and x is touching[27] someone,
- (d) x has a (past) temporal counterpart that exactly occupies the intersection of R_A and l_P and that is touching someone, and
- (e) x has a (future) temporal counterpart that exactly occupies the intersection of R_A and l_F and that is touching someone.

Unlike (iv) or (iv*), this account allows that the given sentence can be uttered truly even in nonfoliable spacetimes.

Reply. Yes, but (iv**) also differs from its predecessors in another way: it fails to block the Case for Optimism. For there are leaves in local foliations with respect to which the given sentence, as uttered by an A-stage, is true. In particular, A's path, R_A, *can* be foliated into (non-intersecting) locally spacelike slices many of which are in contact with R_B at p_c. A glance at the following diagram should make this clear:

[27] Given a suitably generalized (and still tenseless) notion of touching. The notion defined earlier depends upon the existence of hyperplanes. Henceforth I leave this qualification implicit.



Call the relevant foliation f*. Now pick the 'horizontal' leaf l_2 that is in contact with R_c at p_c. This leaf is exactly occupied by an entity, call it *Stage 2*, that is a temporal part of Worm A and an 'A-stage'. Now consider the not-quite-horizontal lines that are, respectively, directly above and below the line corresponding to leaf l_h. These lines correspond, respectively, to leaves l_3 and l_1, each of which is also in contact with R_c at p_c. Leaf l_1 is exactly occupied by Stage 1, and l_3 is exactly occupied by Stage 3, where each of these stages is also: (i) a temporal part of Worm A, (ii) a temporal counterpart of Stage 2, and (iii) touching a certain B-stage, hence touching someone. According to (iv**), then, the given sentence is *true* as uttered by Stage 2 at leaf l_2 in the local foliation f*. So once again, you get your wish.

Objection Four. Ordinary objects are stages. The sum of an ordinary object and all of its temporal counterparts is an 'o-worm'. Time travel cases aside, all ordinary objects and temporal counterparts thereof are instantaneous temporal parts of o-worms. More specifically, for any ordinary object o1 and any temporal counterpart o2 of o1, o1 and o2 are each instantaneous temporal parts of the 'o1-worm' – the sum of o1 and all of o1's temporal counterparts.

But not all instantaneous temporal parts of o-worms are ordinary objects or temporal counterparts thereof. We already knew this on the basis of the 'corner slice' example from Gilmore (2006: 212). (See note 13 for further discussion.) But now we can see that an even more extreme position is required. Indeed, it turns out that *relatively few* instantaneous temporal parts of an o-worm are ordinary objects or temporal counterparts thereof. In particular:

RF For any x, any y, and any z, if x is an ordinary object, if y is a temporal counterpart of x, and if z is the sum of x and all of x's temporal counterparts, then there is a region R and a set f such that:

(i) R is the region that z exactly occupies,
(ii) f is a local foliation of R,
(iii) f is the 'z rest frame foliation' of R: i.e., of all the local foliations of R, f is the one that, roughly put, does the best job of slicing R into leaves whose points are simultaneous-with-respect-to-z's rest frame at the relevant moment of z's career,
(iv) x exactly occupies some leaf in f, and
(v) y exactly occupies some leaf in f.

According to RF, an entity is an ordinary object or a temporal counterpart of one only if that entity is a 'rest-frame-slice' of the corresponding worm.[28] Admittedly, there are serious doubts as to whether the notion of a rest-frame-foliation of a region can be made sense of.[29] But suppose for the sake of argument that it can. Presumably Worm A has only one rest-frame-slice that touches Worm B,[30] in which case, given RF together with plausible assumptions about the truth conditions of the sentence in question, there is no A-stage with respect to which that sentence is true. And in that case, you don't get your wish.

Reply. Concerns about the notion of a 'rest frame foliation' aside, the above strategy succeeds in blocking the Case for Optimism. But it faces a very serious problem of its own – essentially just stage-theoretic version of the problem for endurantism described in Gilmore (2006: 220-222) and (2008). I am an ordinary object, and so is each of my red blood cells. Pick one of them, and call it *BC*. BC is currently in motion relative to me. I've been sedentary throughout the last second or two and I will continue to be sedentary for the next few seconds. BC, meanwhile, has been moving rapidly upward, from my left foot toward my heart, and will continue to do so for the next few seconds. As a result, the relevant section of BC's path (the one stretching from 2 seconds ago to two seconds from now) is not parallel to the relevant section of my path. Accordingly, the rest-frame-slices of BC's path (in the relevant section) are not subregions of the rest-frame-slices of my path. But, given RF, this entails, absurdly, that the sentence 'BC is a part of Cody' is not true as uttered by me now.

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[28] An analogous but less specific thought is expressed by Michael Rea:

> A perdurantist who believes in persisting persons will, I take it, think that there is some 'right' way to carve up a person into thought-bearing person-stages. (1998: 232–3)

In stage theoretic terms, the idea is that not just any way of slicing up the path of a given o-worm yields regions that are exactly occupied by temporal counterparts of an ordinary object: rather, only *one* such slicing does this. Likewise, an endurantist might say that not just any way of slicing up the path of a given ordinary object yields regions that are exactly occupied by the object; rather, only one foliation of the given path yields regions that are so occupied. Rea thinks that we may be unable to formulate a general principle that tells us, as applied to the case of a given object, which slicing is the privileged one.

[29] See Gibson and Pooley (2006: 194-195, note 29), Balashov (2010: 191-195), and Balashov (this volume) for more on this. It is worth noting, however, that even if there are problem cases involving regions to which the notion of a rest frame foliation cannot be sensibly applied, this is not obviously fatal to RF. For it is always open to the stage theorist to hold that the problematic regions in question are ipso facto not exactly occupied by o-worms. The idea would be to adopt a relatively 'sparse' theory of ordinary objects, and to say that an object o1 counts as *ordinary* only if, among other things, the region that is exactly occupied by the o1-worm admits of a unique rest frame foliation. If the only regions that do not admit of rest frame foliations are relatively 'exotic' ones, then the present strategy would not be especially costly.

[30] Unless A is accelerating *very* rapidly at the relevant moment of its career. If its acceleration is such as to make some of its rest frame slices 'converge' on a single point in the relevant way, then presumably there's nothing objectionable (only surprising) about the given sentence's being true as uttered by the given stage.

To see why, note first that given stage theory and RF, the name 'BC' will refer to some rest-frame-slice S_{BC} of the BC-worm, where this slice is confined to the section of that worm in question. Likewise, the name 'Cody' will refer to some rest-frame-slice S_{Cody} of the Cody-worm, where this slice is also confined to the section of *that* worm in question. Now let R_{BC} be the region that S_{BC} exactly occupies, and let R_{Cody} be the region that S_{Cody} exactly occupies. Since the relevant slices are *rest*-frame-slices of the relevant paths, and since the relevant paths fail to be parallel throughout the relevant period, we get the result that R_{BC} fails to be a subregion of R_{Cody}. (To be sure, R_{BC} is a subregion of the region occupied by the Cody-worm, and R_{BC} intersects a great many rest-frame-slices of that region, but it isn't a subregion of any of them.) But for any x and any y, if the region that x exactly occupies is not a subregion of the region that y exactly occupies, then x is not a part of y.[31] So S_{BC} is not a part of S_{Cody}. So the referent of 'BC', as uttered by me now, is not a part (*simpliciter* and in the tenseless sense) of the referent of 'Cody', as uttered by me now. So the sentence 'BC is a part of Cody' is not true as uttered by me now.

Making truth relative to a frame or a foliation won't help, since according RF, ordinary objects and their temporal counterparts are 'sparse': they exactly occupy only certain select slices of the relevant paths. No BC-temporal counterpart (located in the relevant region) is a part of any Cody-temporal counterpart.

4. Conclusion

There are, of course, responses that I haven't considered. One might reject relativity. One might insist that any possible spacetime has a unique privileged foliation. One might deny the possibility of the relevant sorts of material objects.[32] My goal here has been not been to settle on any particular solution, but only to raise the puzzle and to argue that the most tempting responses to it are more problematic than they initially appear to be.[33]

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[31] Here I am ignoring complications involving things that are multi-located or things that are located somewhere without exactly occupying any region. See Parsons (2007), Gilmore (2006), and Gilmore (2009).

[32] This is less promising than it may sound, given the plausibility of abundant, supersubstantivalist views about material objects. According to supersubtantivalism, material objects are identical to (or mereologically coincide with) spacetime regions of certain sorts. 'Abundant' versions of supersubstantivalism say that every spacetime region is (or mereologically coincides with) a material object. (See Hawthorne (2006: viii, 118) and Schaffer (2009) for discussion.) According to such a view, if some spatially zero-dimensional timelike region is in contact with some spatially one-dimensional temporally extended region (that doesn't include its spatial endpoints) at just a single point (in the manner specified in the paper), then there are corresponding material objects that behave in the corresponding way. In the context of such a view, the most plausible way to deny the possibility of the relevant sorts of material objects is to take spacetime to be *gunky* (in the manner of Arntzenius 2009).

[33] Special thanks to Yuri Balashov, Florian Fischer, Cord Friebe, Thomas Müller, and Oliver Pooley for helpful comments.

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