New Paradoxes of Motion: Arguing Against Open-Bounded Material Objects

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Abstract
It is widely assumed that a geometric model of boundaries, which prescribes a tripartite topological characterisation of the boundaries for material objects – fully open, fully closed, or partially open/closed – can be unproblematically extended from regions to material objects. Drawing on a disanalogy between regions and material objects – that only the latter move – I demonstrate the incoherence of (fully or partially) open material objects through two arguments relating to the ability for such objects to freely move. The first is a dilemma considering separately open material objects occupying their location directly or indirectly (located in virtue of their proper parts occupying locations). It is argued that movement in the former case would involve a miraculous topological transformation; whilst in the latter case, would involve miraculous reorganising movements in the object's proper parts. The second argument reignites a problem regarding the moment of change specifically for the movement of such objects.

Material objects are intimately related to space. On the one hand, their structure and relations are limited by their occupancy. The extent of their existence (or presence) in reality is measured by the space they fill, and where they fill it restricts their potential for change and interaction with other material objects occupying space at varying distances. Yet, it also affords material objects these interactive opportunities, mediating their interrelations, and frames the dimensions through which they can express their being. So tightly bound are material objects by space, many able philosophers have doubted their distinctness (cf. Lewis, 1986; Schaffer, 2009; Sider, 2001). This *supersubstantivalism* treats material objects merely as special collections of properties had by substantival spatial regions, rather than distinct substances in their own right.

Space is distinctive in that its point-parts are essentially indiscernible in their intrinsic nature; they are distinguished, if at all, by the relations they bear to each other, and the accidents of material occupancy. On a supersubstantival conception, *any* region of space is potentially a material object, and (mereological) debates over whether those objects compose, or decompose into, other spatially

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coincident material objects should be given all or nothing answers on pain of arbitrariness. Conflation of space and its occupants thus has a material impact. Yet, even if we accept a dualism between space and its occupants, we might be similarly influenced in reading off the potentiality for objects from the structure of their container. I suspect such simplified understandings of the relationship between space and its occupants is too simplistic, ignoring important differences.

An important way the two differ is in their potential for movement: material objects can move, whilst spaces maintain relative positions. In developing new paradoxes of motion for material objects occupying certain kinds of region, I thus intend to upset the wedding, driving a wedge between space and its occupants. If material objects cannot sustain their distinctive potentiality for motion when having their structure moulded to fit certain kinds (peculiar subclasses) of regions, then this suggests there must be something distinctively different about the nature of material objects from the spaces they fill. Whatever relationship they bear needs to be more complicated than ordinarily imagined.

1. Boundary Settings.

A common geometric model holds that the boundary of a region,[1] R, is the set of points, $\{p_1, p_2, \ldots, p_n\}$, such that, all points within the limits of that set of points are part of R, whilst all points that are without those limits are not part of R.[2] Regions of space (or spacetime) are then classified topologically as *closed*, *open*, or some *partial* mixture of the two. Closed regions include all their boundary points, open regions include none of their boundary points, whilst

[1] I remain inconsequentially neutral about whether regions are sets, fusions, or pluralities of points.

[2] More technically, the boundary of R is the set of points, $\{p_1, p_2, \ldots, p_n\}$, such that every open area about each point in that set has a non-null intersection of R and its complement (the set of points excluded from R). Interestingly, this definition does not permit a boundary for an all-inclusive region, because there will be no non-null complement. So space itself necessarily lacks a boundary. And if space has an edge, things located there would to that extent be unbounded. Likewise, if there were no material objects, just fields, they too would be unbounded. The definition I use, however, is fairly standard (cf. Hudson, 2006, p.17). Note, however, that nothing that follows in this paper should be affected by whether one of the slightly different alternative characterisations or definitions, of which points are boundary points, is accepted.

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partially open/closed regions include some, but not all, of their boundary points. It is then assumed, by at least many commentators (e.g. Hudson, 2006), that for any of these kinds of regions, there can be a material object that might occupy that region. So, objects exactly occupying a closed region are closed objects, those exactly occupying an open region are open objects, and those exactly occupying a partially open/closed region are partially open/closed objects. This topology of material objects has been an irresistible lure for those attracted to metaphysical obscurities, drawing increased attention these last few decades, especially regarding puzzles concerning *contact* (cf. Zimmerman 1996; Casati and Varzi 1999, Ch. 5; Sider 2000; Hudson 2006, Ch. 3; Weber and Cotnoir, 2015).[3] Yet, discussions have presupposed sense can be made of extending these topological distinctions from *regions* to *material objects*, such that, these peculiarly open or partially open shapes are not just space (or spacetime) oddities, but oddities of material objects too. This is unsurprising, since it would be strange to posit regions that could not be *exactly* occupied by material objects. Nevertheless, I am sceptical about the coherence of open and partially open/closed kinds of bounded material objects.

To understand why, consider *density*, a structural property of ordered sets such that, between any two distinct members, there is a third member distinct from them. Given the density of space, it may be said that a boundary forms the limit of the spatial region, R, occupied by a material object, such that, for any point, p, in the boundary set, $\{p_1, p_2, \ldots, p_n\}$, there is no closest point, or set of

[3] As far as I can tell, physics makes no presuppositions about the possibility of open boundaries; they would, after all, be undetectable. Moreover, modern physics, in so far as it accepts objects (or particles), has rejected the idea that objects (particles) literally come into contact like miniscule billiard balls bouncing off one another. Instead objects (particles) are made up of subatomic particles that often do not have a definite location (because of issues relating to the Heisenberg uncertainty principle), and interact via non-contact forces (such as the electromagnetic and strong nuclear forces). Indeed, some physicists think that there are not literally any objects at all, but are instead fields – which are often understood as assignments of values of some quantity to (at least some, if not all) spacetime points. Crucially, when physicists talk of subatomic "collisions" nowadays, they do not think that particles actually come into contact, though it may perhaps better be thought of as a collision or interaction of waves (given the wave-particle duality).

points, to those limits (either inside or outside of R).[4] That is because, by definition, spatial density ensures there is always a further point between any two points (within, without, or between, the boundary points, or indeed, any other points). This means that, for open objects, there is no last point before their boundary that falls within the region they exactly occupy; likewise, for partially open objects at their open bounds. It is this feature of fully and partially open material objects that baffles me. (From this point on, I will treat fully and partially open material objects as akin, referring to them inclusively as 'open objects'. For, what I have to say about the one, will apply equally to the other, lest otherwise stated.) Despite my best efforts, I can only glean the syntax, and not the semantics, of these modelled boundaries. I do not understand what it would mean for there to be no set of last point-locations up to which, and not beyond, a material object occupies, where this is not a matter of indeterminacy.[5] Of course, many philosophers claim they *do* understand this.

Is the failing my own? I think not, but such matters are notoriously hard to settle. Ideally, I need an argument to elaborate those features of open material objects impeding my comprehension. Moreover, since my complaint is restricted to material objects, and not regions, there must be some aspect (or aspects) of the former making them particularly difficult to reconcile with open topologies. One thing distinguishing regions from material objects (which will be my focus here) is that the latter can move, whilst the former cannot. Yet, as I now show, open material objects cannot move.[6]

4 If space were not dense (for instance, if it were discrete), all material objects (and regions) would be fully closed, since there would be a last set of points that a region includes whereby it occupies no points beyond those points; that last set of points would be the limit of the region and thus be the region's boundary points.

5 Some might be tempted to complain, after reading the forthcoming, that I really do understand what it means to be an open material object, and resultantly am in a position to show that such objects cannot be satisfied. In honesty, I waver between this way of looking at things and my own. For, as far as I *do* understand such open material objects, it is in a way that they are absurd entities. And it is debatable whether grasping the absurdity of such entities constitutes understanding such entities, rather than an understanding of the impediments to a cogent understanding of such entities. However, nothing in the forthcoming arguments should depend on which of these ways of interpreting their consequences is preferred.

6 For those tempted to respond to the forthcoming arguments by simply noting that it is possible that some material objects be immovable, note that my arguments suggest that *all* open material objects *cannot*

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2. The Argument from Miraculous Transformation

Suppose there are two ways objects can occupy regions: i) *directly*, by being *simply* located at that region (i.e. not occupying that occupied region *in virtue of* having proper parts located there), or ii) *indirectly*, by occupying that occupied region *in virtue of* having proper parts located there.[7] When open material objects occupy a region in either way, we are presented with insurmountable difficulties with respect to their motion. On the first horn of this dilemma, suppose an arbitrary open material object were to occupy directly whatever region it occupies. If that open material object were to move towards its open boundaries, it must first occupy those *initial* boundary points before occupying any region beyond them. This follows from the continuity of motion: that an object's motion necessarily traces a continuous (without gaps) path through space from its origin to its destination (lest it not have moved, but rather teleported).[8]

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move, for *no other reason* than that their openness does not permit a coherent account of motion. And it is the suspiciousness of this inexplicable modal quality of open material objects which I am using to encourage further scepticism about their coherence. Moreover, it is indeed dubious whether material objects that cannot, even in principle, move, do possess a genuine distinctness from the locations they occupy; such 'material objects' are threatened by supersubstantival identification with the locations they purportedly occupy.

[7] Note, the 'in virtue of' here is important, since it is arguable that a composite object *directly* occupies a region in which it has proper parts located.

[8] To be clear, understand a trajectory roughly as follows: an ordered-set of such point-sets, $<\{x^0, x^0_1,\ldots, x^0_n\},\{x^1, x^1_1,\ldots, x^1_n\},\ldots \{x^m, x^m_1,\ldots, x^m_n\}>$, such that material object, O, can exactly occupy each point-set within that ordered-set, given its actual size and shape, and $<\{x^0, x^0_1,\ldots, x^0_n\},\{x^1, x^1_1,\ldots, x^1_n\},\ldots \{x^m, x^m_1,\ldots, x^m_n\}>$ traces a path from journey start (first point-set) to finish (last point-set) including interceding point-sets O might occupy, whereby point-sets later in the ordered-set include new points (not occurring in some of the earlier point-sets), only if those points had earlier in the ordered-set been included in a point-set at the represented region's extremities (such that no point beyond that point were included then in that point-set). Here, m must be a real number. I am claiming, then, that *continuous* motion demands that, for any two point-sets, $\{x, x_1,\ldots, x_n\}$ and $\{y, y_1,\ldots, y_n\}$, that a material object, O, can exactly occupy, in a trajectory, T, that a material object can pass to reach its destination, then:

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Indeed, despite space's density, a material object's open boundary points are immediately adjacent to it. Accordingly, those initial open boundary points towards which the object moves would be the first new positions occupied by the material object via an uncharacteristically discrete movement.[9] But then, in its first movement, the open material object must undergo a topological transformation from being open to closed at those boundary points.[10] (Otherwise, the

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Continuity: If $\{x, x_1, \ldots, x_n\}$ is earlier than $\{y, y_1, \ldots, y_n\}$ in T, then O must exactly occupy $\{x, x_1, \ldots, x_n\}$ before it exactly occupies $\{y, y_1, \ldots, y_n\}$.

(Note that, in space, there are usually multiple potential trajectories that objects can take to reach their destination, but that does not weaken our point.) Some may try to pass off a weaker condition for continuity in an attempt to avoid my argument. For instance:

Pseudo-Continuity: If $\{x, x_1, \ldots, x_n\}$ is earlier than $\{y, y_1, \ldots, y_n\}$ in T, then O must not exactly occupy $\{y, y_1, \ldots, y_n\}$ before it exactly occupies $\{x, x_1, \ldots, x_n\}$.

Of course, none of my arguments dispute that open material objects can undergo pseudo-continuous motion. But pseudo-continuous motion is not continuous motion! Pseudo-continuous motion, because of its negative characterisation (i.e. it states what an object *cannot* do, rather than what it *must* do) allows objects to skip positions in their trajectory. And that is what is problematic.

[9] It is unclear how the rest of the object's boundaries change with this discrete step. Would the object's closed boundary (if only partially open) proceed beyond its initial bounds? And if so, by how far? After all, there is no first location after the closed boundary. Likewise, how does the open boundary, which the object moves away from, rather than towards, develop over that discrete step? There again seems to be no definite amount which it can shrink from its initial bounds.

[10] Interestingly, those initial boundary points, which the object first occupies after movement, would remain amongst its post-movement boundary points. So, the movement of the object at those boundaries does not necessarily alter its boundary points. This itself is quite bizarre. However, some might also note that where there is continuous movement in the boundary of an open material object, the actual material object would move pseudo-continuously, skipping the *exact* occupation of regions on its trajectory that encompass up to the boundary points that it advances towards, but no further region further. Some will use this feature to suggest that what is important for motion is that there is continuous movement in the boundary of an open material object. But this simply misses the point of my arguments. The boundary is *not* part of the open material object, and it is the *object* that

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object, in its first movement, will have moved beyond (further than) those initial boundary points, and thus failed to move continuously through space; it would, in some sense, have jumped over those initial boundary points so that those boundary points were infinitely many points deep within the region that the object now occupies.) Moreover, having closed those boundaries, it is difficult to envisage how they might ever be reopened in the material object. It is simply incredible that such slight of movement (a relational change) could affect the structure of the material object (an intrinsic change, for it is the object itself, not the region it occupies, that undergoes these changes) so dramatically. To help illuminate the kind of change that the object undergoes in this simple movement, it will be fruitful to distinguish two kinds of *parthood*: what John Heil calls *substantial* and *non-substantial* parthood. The former parts are independent from the composites they help compose, or should at least be treated as entities in their own right.[11] And the latter parts merely describe the spatial or temporal region of a thing fully occupying it regardless of whether that region of the thing corresponds to any substantial part of it. In Heil's words:

> A simple substance cannot have parts that are themselves substances – substantial parts. A simple substance might, however, have non-substantial spatial or temporal parts. Suppose a simple substance is square, for instance. Then it has a top half and a bottom half. If the square is four inches on a side, then its surface comprises sixteen distinct regions, each of which is

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has or lacks motion. If the object can jump past regions in its trajectory without exactly occupying them, however small the jump might be, then it is not moving, but teleporting, to its new locations; indeed, after permitting teleportation across small gaps, there seems little in principle to stop things from teleporting greater distances.

It has been suggested to me that what matters for continuous motion is a continuous *metrical* change from one position to another. Since a point's difference is not a metrical difference, skipping over them is fine – no metrical distance is skipped over. (Similarly, for puzzles of contact, it might be thought that metrical distance is key; where a point's gap between objects has no metrical gap, there is contact between the objects.) This cannot be right. Both motion and contact seem possible in worlds that lack a metrical structure. Accordingly, metrical structure seems inessential for the presence or absence of motion and contact.

[11] The second disjunct is in case there are genuine instances of *hological essentialism*, the view that wholes are necessary for the existence of their parts (cf. Dainton, 2000, p. 185).

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one inch square. (1998, p. 41; cf. Heil, 2003, pp. 100–101, 134–36, 173–75; similarly, see E. J. Lowe, 1998, p. 116)

We can then say that, before moving, open material objects have no last non-substantial punctiform parts at their open boundaries. But after moving towards one of its initial open boundary points, it miraculously gains a last non-substantial punctiform part at that initial boundary point. Likewise, for every other initial open boundary point it approaches. For clarity, the argument on this horn of the dilemma can be neatly summarised, thus:

P1. If open objects move towards their open boundaries, then they must occupy some of their *initial* boundary points before any region beyond those points.

P2. If an object occupies an initial boundary point, and no region beyond it, then (in its first movement) it has closed boundaries at those points.[12]

From **P1** and **P2** via *conditional proof*:

C1. If open objects move towards their open boundaries, then (in their first movement) they become closed at those boundary points.

P3. Non-intrinsic mere relational changes (such as, an open object's movement towards its open boundaries) cannot transform an object's topology (intrinsic change) from open to closed (i.e. not-**C1**).

From **C1** and **P3** via *reductio ad absurdum*:

C2. It is not the case that open objects can move towards their open boundaries.

Call this the *Argument from Miraculous Transformation*. My suspicion is that the main criticism of this argument will be made against **P1**. Some might think that obviously an open object cannot come to

[12] This characterisation is not very precise, but should nonetheless be good enough to convey the main point. It is imprecise because the open boundaries of some material objects may well occupy regions beyond those points. For instance, a partially open material object, that otherwise has closed boundaries, except for open boundaries surrounding a single unoccupied point missing from its centre (perhaps a torus-shaped entity, with a maximally small centre hole), after its first movement, could occupy its initial boundary points whilst *continuing* to occupying regions beyond those initial boundary points.

occupy its initial boundary points and no region beyond it, since qua open object, it cannot be that there are points it occupies such that it does not occupy any points beyond them; by definition, open objects have no last points they occupy. I agree that this is obvious, and in a sense trivial. But I am not being uncharitable; this is simply what is required for continuous motion, since, otherwise, those spatial points corresponding to the object's boundaries will be surreptitiously skipped over by the object as it traverses them.

To see that this is so, consider a one-dimensional partially-open material object, LINE. LINE occupies the region [1, 10).[13] For all regions that LINE can occupy in the direction of its open boundary, whilst maintaining its topology, namely any region [1 + m, 10 + n),[14] LINE has already passed 10 at that region – for any value of 'n', LINE occupies a region in excess of point 10. And it is not just the one point that LINE will have had to skip passing over on its journeys; for any journey it will have to have jumped over infinitely many other points between 10 and 10 + n. Since, all numbers between 10 and 10 + n will at some time in that journey have been LINE's open boundary point. So, though the argument is in some sense rather trivial, that should not make its conclusion any less compelling. Indeed, given the nature of my task – which as I earlier explained was simply to draw out the incoherencies (impeding my comprehension) already present in the concept of open-bounded objects – the triviality of the arguments that I need to employ is almost an inevitability; this should not dissuade some of the successfulness of the arguments, but rather of the coherence and grasp they may have thought they had of the concept of open-bounded objects.[15]

[13] I am following the convention here, whereby the square brackets '[' and ']' indicate that the region is closed at that end, and thus occupies the point represented by the number at that end. In contrast, the round brackets '(' and ')' indicate that the region is open at that end, and thus does not occupy the point represented by the number at that end. For instance, region '[1, 5]' includes all points between '1' and '5' including those end points. However, region '(1, 5)' includes all points between '1' and '5' excluding those end points.

[14] Where 'm' and 'n' are any positive real numbers and it is not the case that m – 9 > n (lest its first boundary overtake its second). Some might want to further stipulate that the size of the occupied region remain constant, such that m = n, but that will not affect the point that I am making, so I will ignore it here.

[15] Interestingly, assuming there can be closed point-sized material objects, the argument from miraculous transformation might pose a challenge to unrestricted composition, the thesis that any collection of

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3. The Argument from Miraculous Transportation.

This leads to the second horn of the dilemma, where it is alternatively supposed that an arbitrary open material object were to occupy *in*directly whatever region it occupies. Now, if the substantial proper parts in virtue of which the arbitrary open material object occupies its region are themselves open objects, then we can go back to the first horn of the dilemma, where the same problem arises for those substantial proper parts (and infectiously for their composite). However, it could be that, whilst the composite is an open object, its substantial proper parts (upon which its location supervenes) are each closed. In that case, the composite would have an infinite number of closed proper parts approximating its open boundaries, with no nearest closed substantial proper part to those open boundaries (lest they themselves be open). This possibility may perhaps (though I am somewhat sceptical here) reasonably be presented as a challenge to premise **P3** of the argument from miraculous transformation above by deflating the extent to which the changes in an object's topology are substantial intrinsic changes of a distinctive kind from the non-intrinsic mere relational changes of the object's movement itself. After all, the kind of open composite object currently under consideration would indeed only undergo mere relational changes (in the arrangement of its substantial proper parts) when it

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substantial objects are parts of a composite substantial object (cf. Varzi, 2016, §4.4). Since, it might seem to follow that unrestricted composition would entail that a region saturated with closed point-sized material objects (in a dense space) would – and even if we put some restriction that they be *appropriately* arranged, there is little reason to think they could not be so arranged – provide the resources for composing both fully and partially open material objects. This move might be blocked, however, if composition relations could only hold between finite many entities.

Yet, there is a more obvious challenge to unrestricted *de*composition: that for all non-substantial parts of an object, there is a corresponding substantial object that exactly occupies that same region (cf. Simons, 2004, p.372, especially the *Geometric Correspondence Principle*). If my contention in this paper is correct, then there can be no *substantial* parts of objects that are open, lest they be halted by their topology. In which case, a closed object would be halted by having open objects as parts. Clearly, the arguments presented in this paper pose a serious challenge to unrestricted decomposition. They might therefore be used as a means towards supporting either or both of extended simples (cf. Simons, 2004) and mereological nihilism (cf. Sider, 2013).

transforms its topology, from open to closed, as a result of its moving towards its initial open boundary points (as envisaged in the first horn of the dilemma). Some may even claim that what really matters is what goes on at the level of simples (entities lacking proper parts), since only they, and not their composites, are fundamentally real and feature in the ultimate story of reality.

Accordingly, **P3**, and likewise the conclusion **C2**, ought to be restricted to a certain subclass of open objects: namely, those directly occupying the region they occupy. This can be done fairly straightforwardly, thus:

> **P3***. Non-intrinsic mere relational changes (such as, an open object's movement towards its open boundaries) cannot transform an object *O*'s topology (intrinsic change) from open to closed, if *O* directly occupies the region it occupies.
>
> **C2***. It is not the case that open objects, directly occupying the regions they occupy, can move towards their open boundaries.

It is because of this possibility of composite open objects with closed substantial proper parts, in virtue of which they indirectly occupy the region they occupy, that the argument from miraculous transformation needs to be restricted accordingly. And with this restriction the need for a second horn to our dilemma to rule out those composite open objects not challenged by the now restricted argument from the first horn. Though, it should be noted that the restricted argument does indeed *in itself* pose severe limitations on the possibility of open objects, not to be unduly dismissed.

Nevertheless, composite open objects, with closed substantial proper parts, face an equally recalcitrant problem. In particular, if composite open material objects were to move towards their initial open boundaries, in virtue of the movements of their closed substantial proper parts, then they must still first occupy those initial boundary points before occupying any points beyond them. But then we are compelled to answer which of its closed substantial simple parts reaches those initial boundary points first. The problem is, given that there is no closest substantial proper part to those initial boundary points – indeed, for each substantial proper part, there will be infinitely many other substantial proper parts that are closer to the initial boundary points – there would seem to be no plausible candidate substantial proper part of the composite open object to first occupy those initial open boundary points at the moment when the composite open object first reaches those initial open boundary points and no further. And to this my fictional accused must surely

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feel some compunction, for it is clear that no serious answer is forthcoming. Or, if there is a good answer, we need to hear it. In short, if there is no nearest part, there ought to be no first arriver!

That presentation of the argument may have been a bit quick for some. So, let us outline the argument a little more formally as follows:

A1. Composite open material objects can move towards their initial open boundaries.

P4. If composite open material objects were to move towards their initial open boundaries, in virtue of the movements of their closed substantial proper parts, then they must occupy those *initial* boundary points before occupying any region beyond those points.

P5. If a substantial composite object, composed by closed substantial proper parts, occupies some of its *initial* boundary points without occupying any region beyond those points, then it must have closed substantial proper parts occupying those points without having any closed substantial proper parts occupying any region beyond them.

From **P4** and **P5** via *conditional proof*:

C3. If substantial composite open material objects move towards their open boundaries, in virtue of the movements of their closed substantial proper parts, then (after their first movement) they have closed substantial proper parts occupying those boundary points without having any closed substantial proper parts occupying any region beyond them.

P6. Substantial composite open material objects, composed by closed substantial proper parts, initially have no nearest closed substantial proper parts to their initial open boundaries.

P7. If a substantial composite open material object, composed by closed substantial proper parts, moves such that it has a closed substantial proper part occupying a point without having any closed substantial proper parts occupying any region beyond it, then, prior to the movement, it must have a nearest (or some joint nearest) closed substantial simple parts to its initial open boundaries.

From **A1**, **C3**, **P6**, and **P7**, via *reductio ad absurdum*:

C4. It is not the case that **A1**.

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Call this the *Argument from Miraculous Transportation*. **P4** follows from the same reasoning for **P1** of the dilemma's first horn. **P5** follows from the definitions of closed objects and boundaries together with the indirect occupation contention that the open composite object's location supervenes on the location of its proper parts. **P6** is just an *ex hypothesi* description of the starting condition of the considered scenario. And **P7** rests on a presumption of what I take to be a plausible mechanics, wherein movement of composites does not *require* substantial proper parts jumping past an infinite number of closer substantial proper parts.

Together, I think the arguments from miraculous transformation and miraculous transportation make a compelling case against the possibility that fully open objects can move and that partially open objects can move towards their open boundaries. And I take the denial of this possibility to leave our understanding of open objects in a plainly absurd position. At the very least, I think answers need to be provided here, and it would help all of us understand open-bounded objects much better if some response to these challenges were made.

4. A Boundary to Movement.

This dilemma also highlights how the movements of open material objects aggravate a well known puzzle regarding the moment of change. Richard Sorabji nicely summarises the puzzle thus:

> 'The train leaves at noon', says the announcer. But can it? If so, when is the last instant of rest, and the first instant of motion? If these are the same instant, or if the first instant of motion precedes the last instant of rest, the train seems to be both in motion and at rest at the same time, and is not this a contradiction? On the other hand, if the last instant of rest precedes the first instant of motion, the train seems to be in neither state during the intervening period, and how can this be? Finally, to say that there is a last instant of rest but not a first instant of motion, or vice versa, appears arbitrary. What are we to do? This puzzle has a long history. It is found in Plato's *Parmenides* (156C-157A), and is thoroughly treated by Aristotle. (1983, p. 403)

The moment of change is when something stops being true of a thing, whilst something else starts being true of it. Pertinent to our present case is the change from *rest* to *motion*. I shall take for granted that

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things cannot be simultaneously at rest *and* in motion – contrary to a proposal by Graham Priest (2006, Chs. 11–12). So, if there is a last-moment-of-rest and a first-moment-of-motion, they must be distinct instants. However, assuming time's density, between any two instants there is a third. What then should we say of instants between the last-moment-of-rest and first-moment-of-motion? If they are genuinely what they are claimed to be, the thing cannot there be either in rest or in motion, and this too is deemed unacceptable. So, seemingly there cannot be both a last-moment-of-rest *and* a first-moment-of-motion. Yet, there must at least be either a last-moment-of-rest *or* first-moment-of-motion, since otherwise, there would be no moment of change, and consequently, no change at all. But which moment must we exclude? As Sorabji notes, the choice *seems* arbitrary.

Thankfully, as Sorabji explains, the choice is not as arbitrary as it first appears. For, given the continuity of motion, there would be a decisive asymmetry settling the matter:

> There will be an asymmetry between the series of positions away from the position of rest and the position of rest itself. For, in such a motion, there can be no first *position* occupied away from the starting point, or last *position* occupied away from the finishing point, since positions are not next to each other. Hence there can equally be no first *instant* of being away from the starting point or last *instant* of being away from the finishing point. No such considerations apply to being at the position of rest. This already supplies a solution to the paradox in some of its applications. For if someone were to ask, 'When is the last instant of being at the position of rest, and when the first instant of being away from it?', we could safely reply that the latter instant does not exist. (*Ibid*., p. 405)

According to Sorabji's solution – a solution he argues is shared by Aristotle – there is no first-moment-of-motion, only a last-moment-of-rest. We pick out the moment of change via the instant which is either the initial or terminal stage of the change. If the former, it is a change *from* how things are at that instant. If the latter, it is a change *to* how things are at that instant. But given time's density, there is no first change *from* or last change *to* how things are at any instant. In short: '…in a continuous transition, there is no first or last instant of being *away* from the initial or terminal stage. But there is a first instant of being *at* the terminal stage.' (*Ibid*., p. 413).

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This implies that, when objects change from rest to motion, there is a last-moment-of-rest, but no first-moment-of-motion. However, at this point, material objects with open boundaries do not conform. Since, despite time's assumed density, their initial motion is discrete, not continuous. For, upon moving, they must first occupy their initial boundary points before exceeding them (lest it not be motion, but teleportation) – this following from the same reasoning given for premises **P1** and **P4** in the arguments from miraculous transformation and miraculous transportation above. And, *ex hypothesi*, there are no intervening points between the open object and its initial boundary points. So, upon its moving, there must be a first position – which includes those initial boundary points, but not points beyond them – occupied away from its starting position. Moreover, given this initial discrete change in position, unless the open object rests at its initial boundary points for some period, there must be a first moment when it reaches its *initial* boundary points but no further. More specifically, to avoid there being a first moment when it reaches its *initial* boundary points but no further, it must have moved a point's length, only to have immediately, and inexplicably, ceased moving. And if it were then to start moving again, unprovoked, *when* that movement begins would be completely arbitrary and inexplicable. Consequently, this suggestion simply defies plausibility. So, there must indeed be a first-moment-of-motion.

Accordingly, we are again saddled with both a first-moment-of-motion *and* a last-moment-of-rest. Yet, given time's density, this is impossible, since time's density entails there must be a third instant between the first-moment-of-motion and last-moment-of-rest. And either the object is in motion or at rest then. If the former, what was said to be the first-moment-of-motion would not be that, since there is a preceding moment-of-motion after the rest. If the latter, what was said to be the last-moment-of-rest would not be that, since there is a succeeding moment-of-rest before the motion. Therefore, once again, open material objects are rendered strangely immovable.

5. Conclusion

We have seen how open material objects resist the simplest movements. What moral should we draw from this? The mistake is that, not all that can be said of regions can be said of their occupants. Just because the shoes fit, does not mean you should wear them;

especially when they belong to someone else! I have shown that a certain geometric model of boundaries, perhaps apt for regions, is not suitable for material objects. Consequently, we should resist accepting, on the basis of those models, the coherence of open material objects, and by extension, the problems they deliver. The relationship between material objects and the spaces they occupy is more complicated than ordinarily assumed.[16]

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