Handout: Time, Change, and Grounding

Qichen Yan

1. Two accounts of motion (change):

1) *Reductionist "at-at" theory of motion*: Motion is grounded in position. An object is moving in virtue of the fact that it occupies different positions at nearby past/future times.

  • Orthodox view: Velocity is identical to the temporal derivative of position.

2) *Non-reductionism*: There are fundamental intrinsic properties—instantaneous velocities. Motion is not grounded in position. Instead, motion causally explains future positions. (If velocities are intrinsic properties, should motion be absolute?)

2. A puzzle about rates of change (An objection to the reductionist view)

If the reductionist view is true, then for it to be the case that [*a* has velocity *v* at *t*] just is for the following to be true:

(ε- δ) $\quad \forall \varepsilon > 0, \exists \delta > 0, \forall t' \; (| \; t' - t \; | < \delta \; \rightarrow \; | \; (p' - p)/(t' - t) - v \; | < \varepsilon)$

Then, given the following standard grounding principles:

($\forall$) For any ϕ, $[\phi(c)]$ is a partial ground for $[\forall x \; \phi(x)]$

($\exists$) For any ϕ, $[\phi(c)]$ is a partial ground for $[\exists x \; \phi(x)]$

every fact of the form [*a* has position at *p* at *t*] is a partial ground for [*a* has velocity *v* at *t*]. This is an unacceptable consequence (Facts about what is going on 10 years later are totally irrelevant to my movement *now*).

3. Reactions to the puzzle

1) Option I: deny the at-at theory

  • No rates of change are extrinsic

  • Justifications for this view:

a) Consider an object moving at constant velocity *v*, but which is destroyed immediately after t=1. Intuitively, at t=1, it still has velocity *v*, even though its temporal derivative is not well-defined.

b) Tooley's sci-fi case (1988): an extremely chancy world

2) Option II: the precise cut-off view

- There is some ε such that all facts of the form [*a* has position at *p* at *t*], where *t* is in (*t*-ε, *t*+ε), are partial grounds of [*a* has position at *p* at *t*]. The problem is, of course, that there is no non-arbitrary value for ε to have.

3) Option III: Holistic Grounds

- Dasgupta (2014) has argued that the relata of grounding can be irreducibly plural. One can say that these facts are grounded in those facts, with no further story about the grounds of particular facts being told.
    - Comparativists deny that there are fundamental intrinsic masses. They instead say that there are fundamental mass relations (e.g. "is twice as massive as"). On this view, the fundamental comparative mass facts *taken togethe*r ground the individual masses of things. Then the mass of my phone is partly grounded in the mass of some arbitrary electron light years away. This violates the relevance condition of grounding.
    - However, we do have independent motivation to think that the mass of any individual object is metaphysically interconnected with the mass facts of all other objects. But there's no reason to think that the velocity of an object now is metaphysically interconnected with its velocity centuries later.

4) Option IV: Indeterministic View

- Perhaps position facts "close enough" to t are determinately partial grounds, position facts far away enough are determinately not partial grounds, and there are some indeterminate facts that are indeterminate.
- This view faces the same problem of arbitrariness.

5) Option V: Ground Indeterminism

• Our notion of partial ground are metaphysically/semantically vague.

6) Option VI: Velocity Indeterminism

• Perhaps it is indeterminate what the partial grounds are for ordinary utterances such as "*a* has position at *p* at *t*" because it is indeterminate which precise mathematical notion of "acceleration" is being used.

7) Option VII: Time is discrete

4. The causal requirement for rates of change

Consider, for instance, an object *a* that experiences no forces. The Newtonian laws guarantee that the position $x_{t+\delta}$ of *a* at any time after *t* is given by:

$$x_{t+\delta} = x_t + v_t \cdot \delta$$

It is natural to think that [*a* has velocity v_t at *t*] partly causally determines [*a* has position $x_{t+\delta}$ at t+δ]. But if the at-at theory is true, then [*a* has velocity v_t at *t*] is partly grounded by [*a* has position $x_{t+\delta}$ at t+δ].

To solve this problem, one could argue that velocity is the *past derivative* of position so that an object is moving solely in virtue of the fact that it occupies different positions at nearby past times.

Past derivative: v_p^t is the past velocity of *a* at time *t* if and only if

$$\forall\varepsilon > 0, \exists\delta > 0, \forall t', t'' \left((t - \delta < t', t'' < t) \rightarrow \mid (x_{t'} - x_{t''})/(t' - t'') - v_p^t \mid < \varepsilon\right)$$

(We can see that past derivative is exactly the limit of the left-hand derivative)

However, according to the causal interpretation of classical Newtonian physics, the present acceleration of an object is causally determined by the present masses and locations of all objects. If acceleration is the past derivative of velocity, then there would be a sufficient set of grounds for it that are all temporally earlier than the present, which would thus violate existential forwards causation:

Existential forwards causation: If *A* partly causally determines *B*, then for any set S_A of sufficient grounds for *A* and any set S_B of sufficient grounds for

B, some member of S_A is not temporally later than some member of S_B.

If **Existential forwards causation** is true, then only past derivatives can be causes, and only future derivatives can be effects. (Really? It seems that we can reach the same conclusion without appealing to **Existential forwards causation.**)

5. Easwaran's proposal

Velocity is the past derivative of position; while acceleration is the future derivative of velocity. On this view, acceleration is in the end a future neighborhood property.

> **Future neighborhood property**: A future neighborhood property at t is a property of an object that is not grounded in the fundamental properties of the object at t, but, for every interval (t, $t+\delta$), the fundamental properties of the object across that interval are sufficient to ground it.

Consequently, present velocities could cause future movements, and present fundamental properties (e.g. forces, masses, etc.) could also cause accelerations.

However, since accelerations are future derivatives, they cannot cause velocities. Is this a vice? Easwaran doesn't think so. He argues that acceleration is only a cause in the indirect sense that the future velocities that constitute it can themselves cause things even farther in the future.

There is still something problematic here. Velocity is not a fundamental property (at least in classical physics), how could it play a role in causally determining future positions of objects? Easwaran thinks that the non-fundamental entity (whether a mind, a nation, an electorate, or a velocity) might be thought of as a notational device for abbreviating a causal power that is fundamentally a collective power of the fundamental entities that ground the non-fundamental one. Or perhaps there is some special way to understand higher-level entities as fundamentally playing a causal role despite not being fundamental entities themselves. (Note that locations are fundamental properties in classical physics.)

6. Why no third derivatives?

Whatever quantities play a role in causally determining the future positions of an object must be grounded entirely in the past and present. Thus, if a fundamental law causally determines the future by setting the *n*th derivative of some quantity, then the present value of that quantity, and its first *n*-1 derivatives, must be grounded entirely in the past and present. However, the *n*th derivative itself must be a future derivative in order to be causally determined by the present.

Given the Newtonian physics, acceleration must be a future derivative, so there cannot be a fundamental law which sets a third derivative of position. Otherwise, acceleration will be a past derivative.