The Paradoxes of Time Travel

Atriya Sen

AHR?

Nov 3 2016
Let \( R = \{ x \mid x \not\in x \} \), then \( R \in R \iff R \not\in R \)

**LP:** A perfectly rational person can believe P and \( \neg P \) at the same time!

Is time travel impossible?
Axiomatization: The General Theory of Relativity

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Gödelian Time Travel

\[ R_{\mu\nu} - \frac{1}{2} R g_{\mu\nu} + \Lambda g_{\mu\nu} = \frac{8\pi G}{c^4} T_{\mu\nu} \]

- Inner cylinder: vertical time axis
- Outer cylinder: circular time axis; wraps around the inner cylinder
- In Gödel’s best-known actual solution, the transition between the two cylinders is gradual.
- At every instant, the world-line of the particle (red star) is oriented toward the future (remains within local light-cones).
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Paradox 1:
By the definition of time travel

To travel in time is to traverse some temporal interval in a time that differs from the duration of that interval.

Contradiction?
Paradox 2: 
Time Travel + Leibniz’ Law

Leibniz’ Law: Identical objects have all the same properties.

Leibniz’ Law (explicated): Identical objects have all the same properties at the same time.
Paradox 3:
‘Grandfather’
“This state of affairs seems to imply an absurdity. For it enables one e.g., to travel into the near past of those places where he has himself lived. There he would find a person who would be himself at some earlier period of his life. Now he could do something to this person which, by his memory, he knows has not happened to him.”

–Kurt Gödel
Free Will + Classical Physics
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Am I free to punch my earlier self in the face?
Free Will + Classical Physics

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Seemingly, yes.
Free Will + Classical Physics

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If I do, my memory of not being punched in faulty. If I don’t, my memory is truthful.
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But no.
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No contradiction.

**But no.**

My action was determined from the creation of the universe!
(Underlying graphic extracted from (Deutsch & Lockwood, 1994), modified & animated by S Bringsjord.)
TIME TRAVELER GREET GRANDFATHER

DISASTROUS DINNER

NO WEDDING

NO CHILDREN

NO GRANDCHILDREN

TIME MACHINE AND TIME TRAVELER

GRANDFATHER MEETS CHARMING LADY

GRANDFATHER DRESSES FOR DINNER

DELIGHTFUL DINNER

WEDDING

BIRTH OF DAUGHTER

BIRTH OF GRANDDAUGHTER (TIME TRAVELER)

NO TIME TRAVELER

(Underlying graphic extracted from (Deutsch & Lockwood, 1994), modified & animated by S Bringsjord.)
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Autonomy & Consistency

**Autonomy principle:** It is possible to create in our immediate environment any configuration of matter that physics permits locally without worrying about the rest of the universe.

**Consistency principle:** Only configurations of matter that are self-consistent globally can occur locally.

**Consistency requires the autonomy principle to fail in the presence of CTCs!**

(According to classical physics)
Paradox 4: ‘Looping Painter’
The year is 2056. The novels of Arthur are venerated, making him the greatest novelist of the current and previous century, at least.
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‘Looping Painter’ / The Paradox of Proust

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The Quantum Multiverse
Quantum Reality

If you set up identical experiments on identical particles that have been set up identically, you will generally not get identical results!

Instead regularity is found in the statistical distribution of the results - the probability of finding the electron at any particular location.

The evolution of the probability wave is given by Schrödinger equation.

\[ i\hbar \frac{\partial}{\partial t} \Psi(r, t) = \left( -\frac{\hbar^2}{2\mu} \nabla^2 + V(r, t) \right) \Psi(r, t) \]
To Collapse or Not to Collapse?
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Wave functions are (highly) spiked for macroscopic objects, for which QM tends to NM. They are spread out for microscopic objects.
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**Copenhagen interpretation:** Wave functions *collapse* upon observation. The larger a wave is at a particular location, the larger the change of it collapsing to *that* location.
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This is the *quantum measurement problem.*
Linearity
Linearity & Measurement

What happens when measuring / observing probability waves with multiple spikes?

**Bohr:** Our equation must then not apply to the act of measurement, since it involves macroscopic bodies.

**Everett** (1957) was not convinced!
Everett’s Many Worlds
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Measuring a complex wave function doesn’t result in a meter & mind simultaneously registering two locations.
Everett’s Many Worlds

Measuring a complex wave function doesn’t result in a meter & mind simultaneously registering two locations.

*It results in two meters & two minds, each registering a unique location!*
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This is the *quantum multiverse theory*.
Time Travel Paradoxes

+ QM
Many Worlds + Paradox 3

In a space-time with CTCs, parallel universes would be connected.

The grandparents marry in one universe, and don’t in another.

Quantum mechanics, even in the presence of CTCs, conforms to the autonomy principle.
Many Worlds + Paradox 4

The universe where the critic comes from is one in which the artist did learn to paint/write well.

If the paintings carried back are plagiarized, we are in an alternate universe.

But now this is no paradox, since the paintings were caused by genuine creative effort, in another universe.
Thanks!