Some ideas on resolving causal paradoxes of time travel

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Logic, Relativity and Beyond, 2017

Motivation

- Time travel is an iteresting topic
- Heavily debated whether it is consistent with our actual scientific theories or not
- It is problematic both philosophically and logically
- So we believe it is useful to seek after deeper understanding

Literature

- F. Echeverria, G. Klinkharluner, Kip S. Thorne: *Billiard balls in wormhole spacetimes with closed timelike curves: Classical theory* (1991) in PHYSICAL REVIEW D 44
- A. Lossev, I. D. Novikov: *The Jinn of the time machine: non-trivial self-consistent solutions* (1992) in Class. Quantum Grav. 9
- M.B. Mensky, I.D. Novikov: *Three-Dimensional Billiards with Time Machine* (1996) in Intern. J. Mod. Phys. D5
- J. Dolanský, P. Krtouš: *Billiard ball in the space with a time machine* (2010) in PHYSICAL REVIEW D 82
- J. Dolanský: *Billiard time machine* (2011) as Ph.D. Thesis at Charles University in Prague
- Etc.

Definition

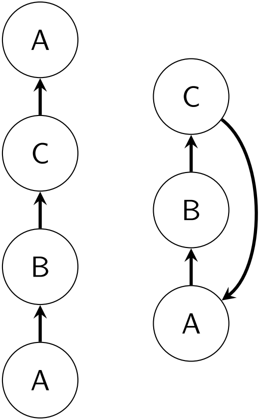
According to David Lewis definition:

> "An object time travels iff the difference between its departure and arrival times in the surrounding world does not equal the duration of the journey undergone by the object."
>
> *Internet Encyclopedia of Philosophy*

We will use a narrower sense, excluding time dilation.

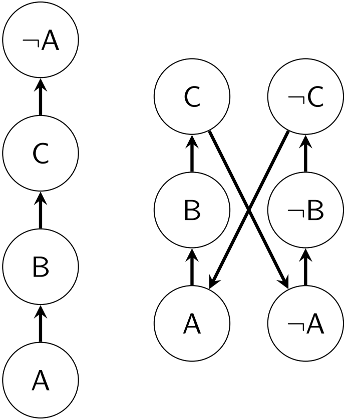
Temporal Paradoxes

- Causal loops
- Grandfather paradox



Causal loops

A causes B
B causes C
C causes A



Grandfather paradox

A causes B

B causes C

C causes ¬A

BUT

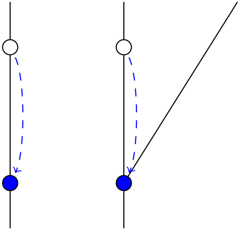
¬A causes ¬B

¬B causes ¬C

¬C causes A

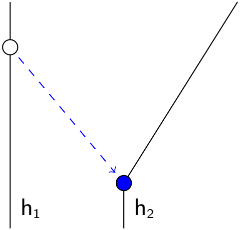
(Possible) Solutions of Temporal Paradoxes

- Branching solutions
- Selfconsistent solution



Branching solutions

Whenever something travels back in time, it arrives not in its own past, but in a *parallel world's past.*



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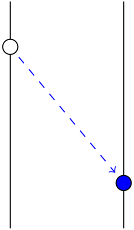
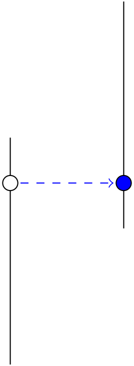


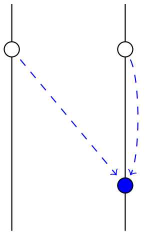
Problems

- No active time travel



Problems

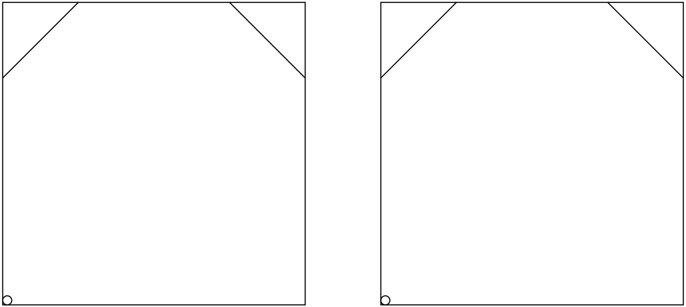
- No active time travel
- Selfsimilar regions of spacetime



Causal loops could be solved

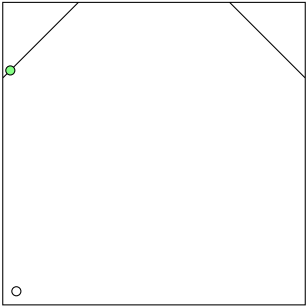
Selfconsistent solutions

Grandfather paradox



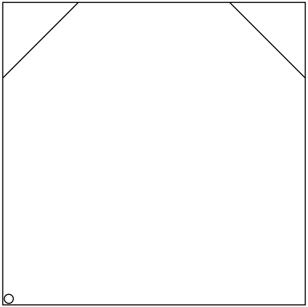
Selfconsistent solutions

The "censored" solution



Selfconsistent solutions

A non-trivial solution: the Jinn



Our idea to generalize

Goal: Develop a general method to find a selfconsistent solution for paradoxical scenarios.

Idea: Define a distance between similar scenarios (worlds). Find a function which always takes us closer to a selfconsistent world as it is iterated. The fixed-point is the selfconsistent world.

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Problem: Grandfather paradox is an actual, logical contradiction.

Idea: "Split" the time gates, so the two ends of the passage are not connected according to the dynamics, rather we examine wether they coincide or not. If not, then we look for a *close world* which has a *lower level of inconsistency*.

Our idea to generalize

Formally: A world is $\langle \mathbf{E}, A \rangle$, where **E** is the set of existents (bodies, gates) and A is the set of appearing bodies.

$$a_i := \langle t, h, m, r, v_j \rangle \in A$$

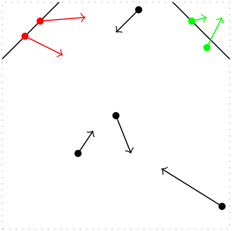
t: time of appearing

h: point of appearing

m: mass

r: size

v_j: velicity vector



Our idea to generalize

We resrict ourselves to the set of worlds which coincide respect to the not time traveling entities.

Let L be the set of bodies disappearing (leaving) in the time gates, similarily defined to A.

$Trav_{\mathbf{E}}(L)$ is a function which gives the set of appearing bodies where L is the set of disappearing bodies, according to the time gates in **E**.

Our idea to generalize

We call a world selfconsistent iff the disappering and appearing bodies suits to the time gates in **E**.

$$CON(\langle \mathbf{E}, A\rangle) <=> A = Trav_{\mathbf{E}}(L)$$

Our idea to generalize

We call a world selfconsistent iff the disappering and appearing bodies suits to the time gates in **E**.

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If a world is not Selfconsistent we look for a *close* world which has a *lower level of inconsistency*.

Our idea to generalize

Close world: as we consider only worlds with the same **E**, we need a distance of worlds A and A'. Technically these are sets of vectors. Euclidian distance is good for the distance of vectors. We need a distance of the sets.

Candidates:

- Hansdorf distance
- Permutation

Our idea to generalize

Degree of Inconsistency:

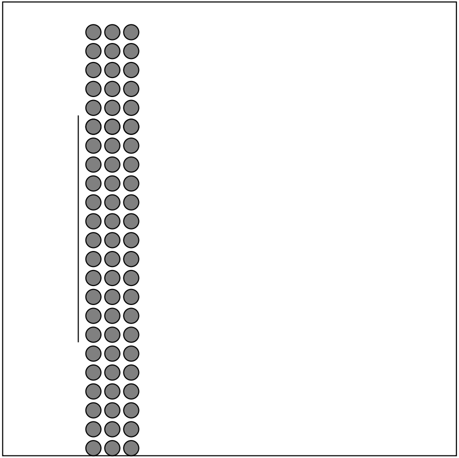
$Dyn(A)$:= set of disappearing bodies if A is the set of appearing bodies

An intuitive candidate for the degree of inconsistency:

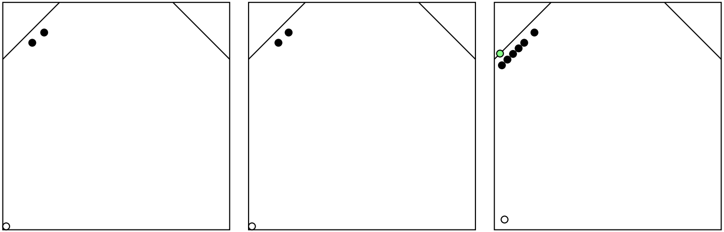
$$icon(A) = D(A, Trav_{\mathbf{E}}(Dyn(A)))$$

Local counterexample

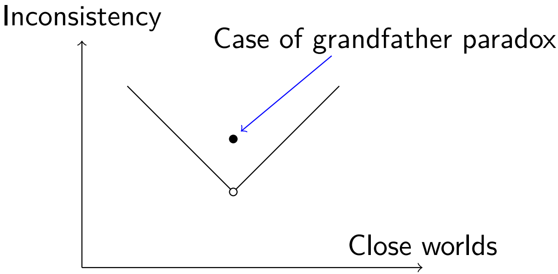
The moving wall



Local counterexample



Inconsistency around the counterexample



SUMMARY

What we already have:

- General framework for handling Grandfather paradoxes
- Ideas how to find the closest solution
- If there is a nearby solution we can find it
- Counterexample where there are no nearby solutions

What is missing:

- Is costructing a global counterexample possible?
- Method to find nonlocal solutions
- Well-behaving definition of distance (infinite cases,empty set)
- Solutions including Jinn

Thank you for your attention!