A Defense of Dynamicism

Lu Chen

Koc University

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About the project

My Goal

I will argue for a particular brand of dynamicism called *algebraic dynamicism*.

Steps:

- Motivate dynamicism against *geometricism*
- Present *algebraicism* as a response to Norton's objection to dynamicism
- Advance algebraic dynamicism as an improvement over traditional algebraicism

What is geometricism?

Geometricism

The view that some (chrono)geometric properties and relations are fundamental.

Example

- Newtonian absolutism: spatial and temporal distances.
- Leibniz's relationalism: spatial distances at a time.
- Special relativity: spacetime intervals.
- General relativity: the metric field.

Geometricism in special relativity

Minkowski Spacetime

- There exists a four-dimensional spacetime that can be coordinatized by a set of standard coordinates (x, y, z, t), related by "the Lorentz transformation".
- The spatiotemporal interval between events (x_1, y_1, z_1, t_1) and (x_2, y_2, z_2, t_2) is a fundamental property of the spacetime: $s^2 = (t_1 - t_2)^2 - (x_1 - x_2)^2 - (y_1 - y_2)^2 - (z_1 - z_2)^2$

Geometricism in special relativity

How do you "observe" the geometric structure of spacetime?

Chronogeometry-dynamic laws

- Law of inertia. A free system travels along a "time-like" geodesic.
- Law of light. The trajectory of a light ray is a "null" geodesic.
- The clock hypothesis. The recorded time of an ideal clock is the time-like distance it travels.

Geometricism in special relativity

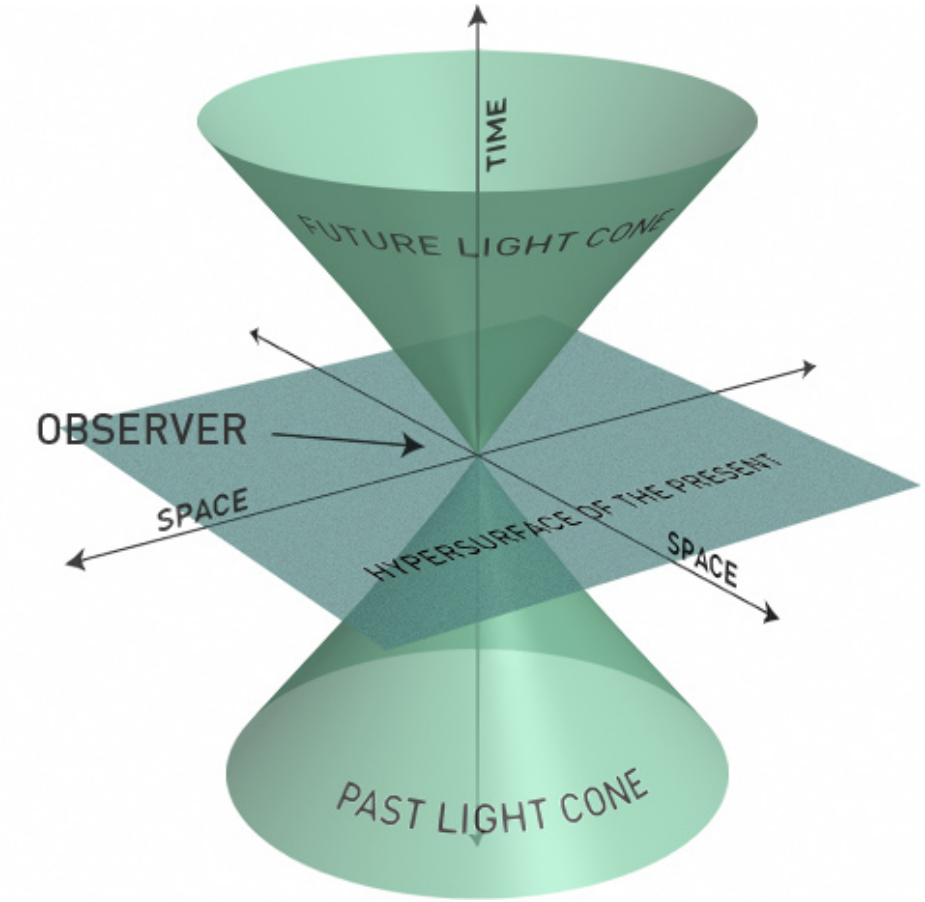

Figure 1. Minkowski Spacetime

Geometricism in special relativity

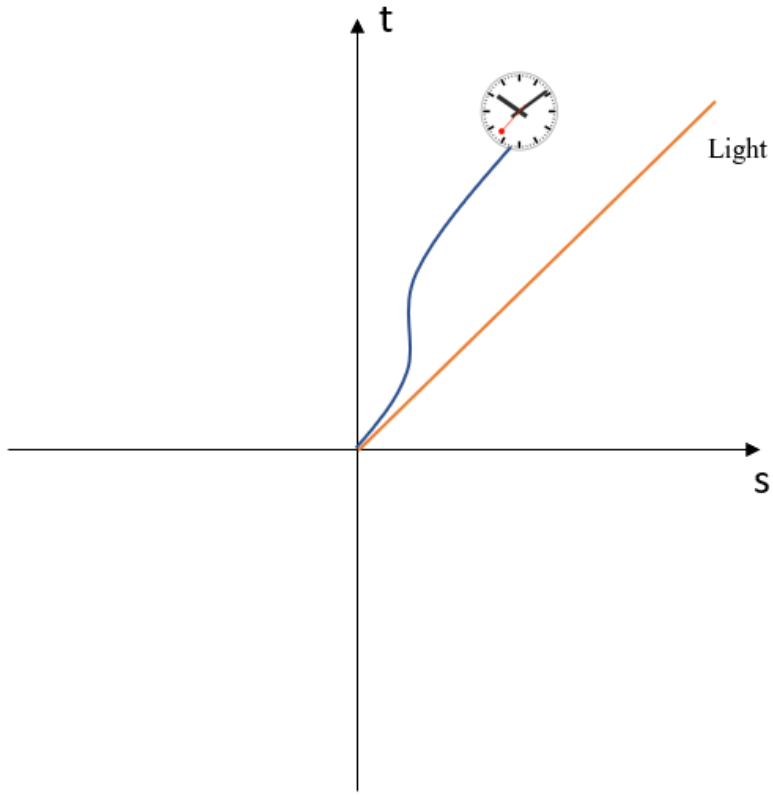

Figure 2. The Clock Hypothesis

Geometricism in general relativity

Spacetime in General relativity

- There is a four-dimensional spacetime that can be represented by a manifold equipped with a metric.
- The metric is determined by the distribution of mass-energy in accordance with the field equations.

Geometricism in the literature

- This approach to relativitistic theories is considered standard, endorsed by Friedman, Norton, Earman, Maudlin and many others.
- It is intuitive, rigorous, and a unifying frameworks for all spacetime theories up to general relativity.
- However, others—notably Harvey Brown—complain that this approach gets the explanatory order wrong.

What is Dynamicism?

Dynamicism

All (chrono)geometric properties and relations are explained by the dynamic laws governing matter.

Example

The fact that Newtonian mechanics distinguishes between constant motions and accelerations explains why we can construct a spacetime with certain geometric properties.

Dynamicism in Relativity

Special relativity

The appearance of Minkowski spacetime is explained by the Lorentz invariance of dynamic laws.

Lorentz invariance: the form of law is the same under Lorentz transformation.

General relativity

The metric field is a matter field. Its chrono-geometric significance is derived from the dynamic laws governing it and other matter fields.

Tug of War on Explanation

It is not an essential property of localized bodies that they run along the ruts of spacetime determined by the affine connection... In Newtonian mechanics and SR, the conspiracy of inertia is a postulate, and its explanation by way of the affine connection is no explanation at all. (Brown 2005, 141)

Tug of War on Explanation

Inertia, in GR, is just as much a consequence of the field equations as gravitational waves. For the first time since Aristotle introduced the fundamental distinction between natural and forced motions, inertial motion is part of the dynamics. It is no longer a miracle. (Brown 2005, 163)

Tug of War on Explanation

[I]nertial motions are distinct, having different speeds and directions; how much more different would they have to be to not constitute a conspiracy? It does not sway me that Brown flashes a usual rhetorical device to claim that he's right: "that anyone who is not amazed by this conspiracy has not understood it". What behavior could bodies well have which could not be construed so liberally as a conspiracy? (Martinez 2007, 211)

My Case for Dynamicism

Step 1

I will identify four interconnected problems with geometricism and argue that dynamicism does better on these fronts.

- Radical underdetermination
- Extravagant ideology
- Unnecessary restrictions on behaviors of matter
- Not conducive to the search for quantum gravity

Radical Underdetermination

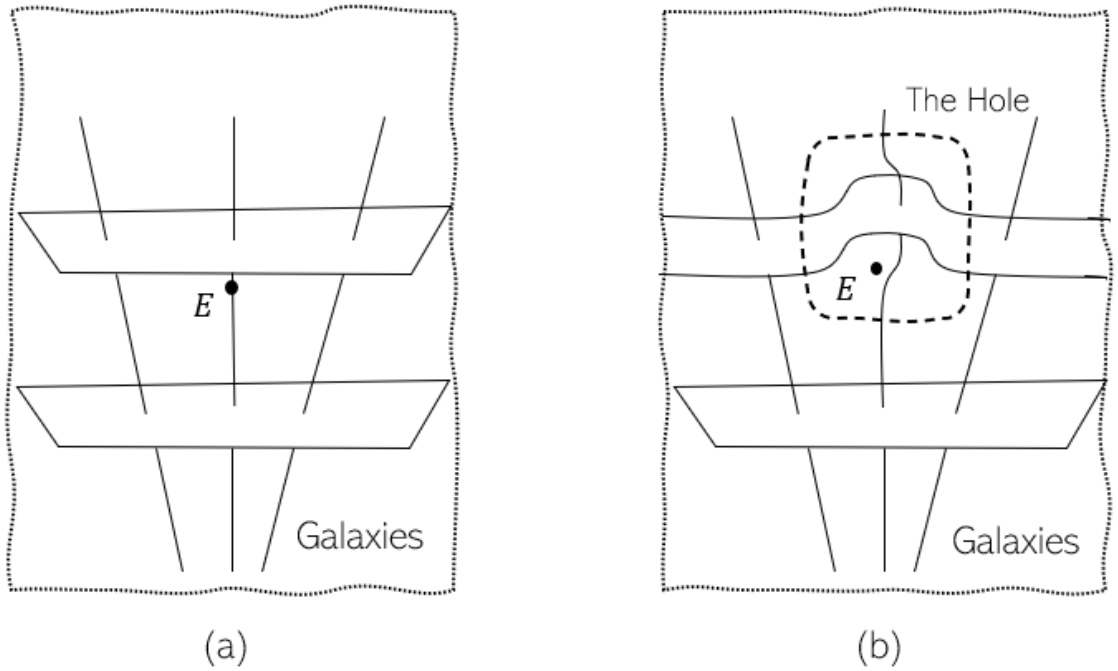

Figure 3. The Hole Argument

Extravagant Ideology

Geometricism in SR

- Minkowski spacetime
- Law of inertia
- Law of light.
- The clock hypothesis.

Dynamicism in SR

- Lorentz invariance of dynamic laws

Unnecessary constraints

Example

Light is an electromagnetic wave. The light ray characterization is obtained through geometric optics approximation. Law of light assumes that the limit solutions to the Maxwell equations approximate exact solutions to arbitrary accuracy, which may not be true (Menon, Linnemann, and Read 2018).

Dynamicism does not posit this constraint because it does not posit Law of light in addition to the Maxwell equations.

Quantum gravity?

- Most versions of geometricism consider the metric field as representing the geometric properties of spacetime.
- Dynamicism considers the metric field as a matter field.
- The latter is a better fit with the current research programs of quantum gravity (e.g. the approach of asymptotic safety).

My Case for Dynamicism: algebraicism

Step 2

I will present Norton's objection to dynamicism ("constructivism") and present algebraicism as a response.

Norton's objections:

- Dynamicism leaves the coincidence between different matter theories unexplained.
- Dynamicism presumes spacetime through tacit use of coordinate systems.

Spacetime coincidence

Consider Clock 1 described by matter theory 1, and Clock 2 described by matter theory 2.

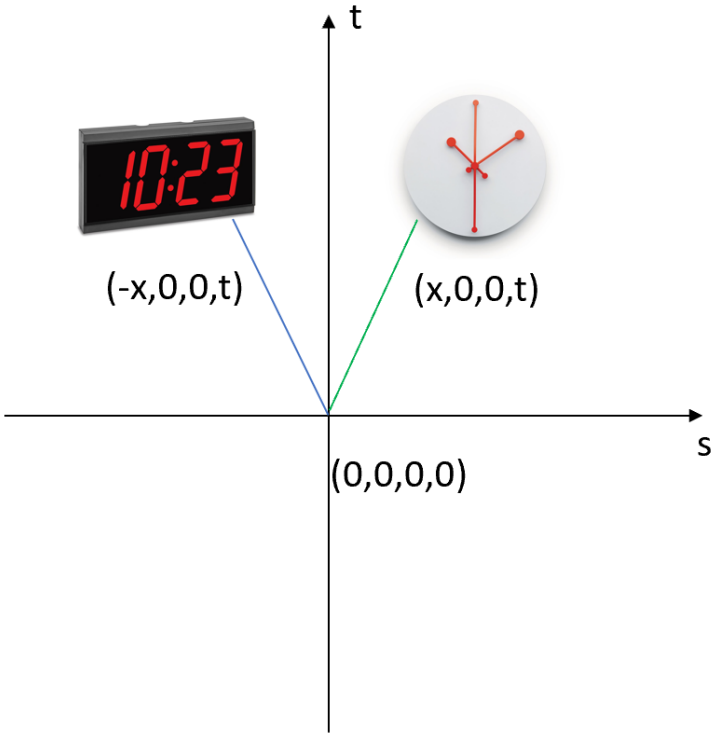

Figure 4. Trajectories of two clocks

Spacetime Coincidence?

Response 1

The two matter fields are coupled.

Norton's reply

- Coupling does not entail spacetime coincidence.
- e.g., the spins of two particles can be coupled without indicating they spatiotemporally coincide.

Spacetime Coincidence?

Response 2

We can just use *one* coordinate system for all matter fields.

Norton's reply

- Without assuming spacetime, we cannot assume all matter fields can be written in the same coordinate system.

Algebraicism Comes to Aid

Norton's challenge is essentially pointing out that not all geometric structures encoded in manifolds & metric—namely the structure encoded in a bare point set—can be explained away by dynamic laws, but must be assumed.

My strategy

The most honest response to my mind is to spell out how we write dynamic laws without positing coordinate systems or manifolds.

What is algebraicism?

Algebraicism

A framework alternative to differential geometry, which enables us to do physics without assuming manifolds.

Traditional algebraicism

The fundamental object is an algebraic structure consisting of all (smooth) functions on a manifold.

- The smooth functions can be interpreted realistically as configurations of a scalar field.
- Note that the reference to manifolds is heuristic.
- The smooth functions are reconceptualized as unanalyzable elements of the algebra, not maps from a manifold to real numbers.

How does algebraicism help?

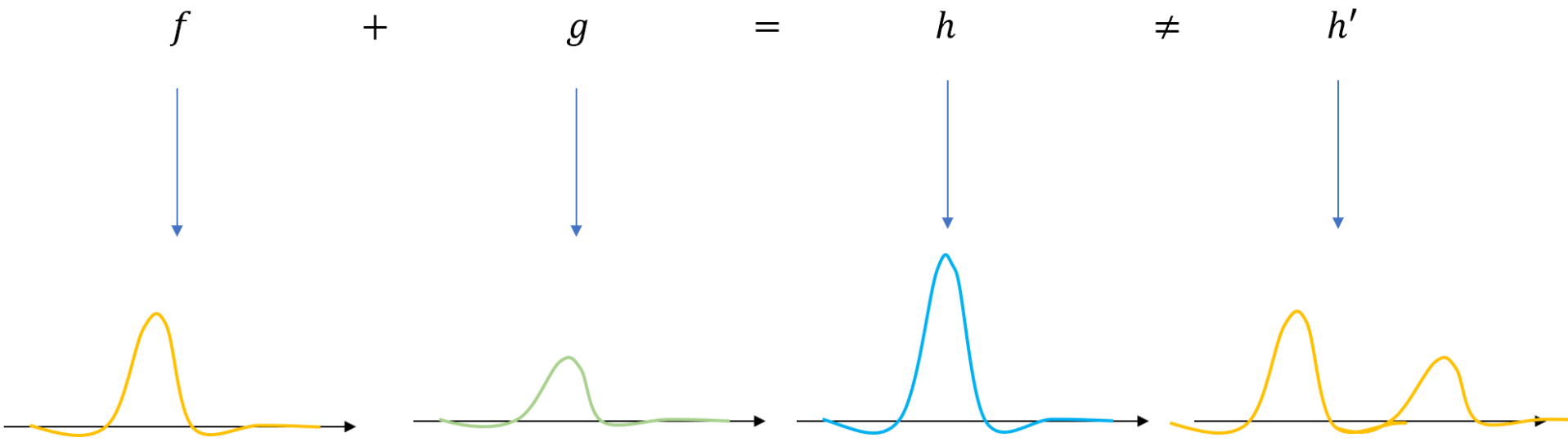

Figure 5. Algebraic structure encodes spacetime coincidence.

The problems

Step 3

I will point out problems for appealing to traditional algebraicism, and advertise dynamic algebraicism as a better alternative.

The traditional framework of algebraicism conflicts with the spirit of dynamicism.

The problems

- The scalar field assumed by the basic algebra is not recognized among fundamental* physical fields.
- It doesn't carry energy and momentum, and does not interact with other physical fields.
- Algebraicists call the structure "spacetime" because it is an algebraic counterpart of spacetime manifold.
- Even there is an actual scalar field, it is arbitrary to privilege it ontologically over other physical fields.

Conclusion

This approach reintroduces a spacetime structure rejected by dynamicists.

Dynamic Algebraicism

A framework of algebraicism in which the fundamental structure consists of physical fields. (Chen and Fritz, under review)

Selected Features:

- The elements of the field algebra are actual physical fields, individuated by its field configurations and its Lagrangian.
- We aim at maximal flexibility in what fields are posited in the field algebra. In particular, a scalar field can be included but is not required.
- When general relativity is considered, the metric field can be included as a matter field.
- Otherwise, it can be encoded in the algebraic operations of the field algebra.

Conclusion

We should endorse dynamicism and the framework of dynamic algebraicism.

—End of Talk—

Future work (Nostalgia)

Project 1. Beyond Spacetime: the C^∞-Algebra of all Fields

(in collaboration with Fritz)
A novel proposal for fundamental algebraic structures.

Project 2. Can Spacetime be derived from Dynamics?

On Geometric versus Dynamic Approaches to Relativistic Spacetime.

—End of Talk—

Work in Progress

Project 1. Where Does Effective Spacetime Fall short

A paper criticizing the effective field theory of general relativity as a theory of quantum gravity.