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BRANCHING FOR A TRANSIENT TIME

Abstract. In this paper I analyze this variety of transient time theory that relies on the notion of open future. I present algebraic models of phenomena with transient time, understood as above. The models are then linked to relativistic spacetimes. I finally address some interpretational issues and defend the theory of branching time against David Lewis' objections.

Keywords: *transient time, branching spacetime.*

1. INTRODUCTION

Transientism is a doctrine that the central aspect of time is, or derives from, the objective transition of the future into the (momentary) present and then the past, with future events becoming actualized in some 'now', and then passing into the past. Following the popular terminology of (McTaggart, 1908), such a succession of events is referred to as an *A-series* and contrasted with the earlier-later relation, whose relata form a *B-series*. The description of events by means of a *B-series*, if once valid, is always valid: if one event is earlier than some other event, it was always so and it will ever be so. In contrast, the description of events by an *A-series* must change: an event that is now in the future, will be once at present, and later on in the past. The appeal of transientism comes from the fact that a mere *B-series* hardly makes justice to our intuition of the passage of time. Algebraically speaking, the relation earlier-later is indistinguishable from the below-above relation, but clearly a vertical (and infinitely thin) stick, with its points being ordered by the below-above relation is not an adequate model of finite time.

In contrast to this popular, as I take it, appeal of transientism, the doctrine fares badly in physical sciences. As far as I know, neither the particle physics, nor gravitational theories, nor familiar cosmological models offer a clear perspective for accommodating transientism, or, as it in essence boils to the same thing, becoming. At this point it is perhaps worth observing that the task of accommodating transientism goes far beyond the introduction of the arrow of time, as the latter is concerned with finding a physical basis of the earlier / later distinction. What is then the task of accommodating transientism? To get clear about it, and leave a rather misty field, where physical sciences confront our temporal intuitions, we need to clarify transientism considerably, preferably by finding a class of models of temporal becoming that are both mathematically precise and intuitively correct. It is my hope that the models of stochastic outcomes in branching spacetime (SOBST), which I present in Sections 2 and 3 satisfy these desiderata to a reasonable extent. I also believe that these models shed some light on what accommodating for transientism involves on the part of physical theories. But, since the extant physics does not support the transientist's view of time, must the transientists bet on future

physics reforming itself to the effect of accounting for transientism? Or, may they maintain that their favorite doctrine is independent of future findings of physics? Helena Eilstein's powerful claim that '[i]f there is Becoming, but physicists cannot know it, nobody can' (Eilstein, 2002) is a clear voice for the first option. However, I advise to take as a default option the independence of transientism of physical findings. I take transientism to be a modal concept that builds upon the notion of open future. Accordingly, those who tie the fate of transientism with the progress of natural sciences believe that at some stage these sciences will arbitrate between competing modal claims. As I see the matter, our evidence from extant physics supports the opposite belief. Take for instance the modal claim that natural phenomena are indeterministic together with the popular view that this indeterminism is intimated by quantum physics. The view is half true about Hilbert-space quantum mechanics, as its measurement algorithm usually yields a set of possible results of a given measurement, without any indication which of these will occur on a given occasion. Yet, the other half of the truth is that temporal evolution of quantum states, as described by the Schrödinger equation, is fully deterministic. The conflict between the measurement algorithm and the smooth temporal evolution of states is known as the measurement problem of quantum mechanics and seen as a scandal in the foundations of physics. But the situation is even worse, as there is a perfectly deterministic Bohmian quantum theory whose predictive power is exactly like that of Hilbert-space quantum mechanics. Thus, witnessing that quantum theories yield so disparate verdicts about the truth of determinism, it is doubtful whether the more subtle view of transientism could ever be validated or refuted by physics. Moreover, if the theory of transient time is what I take it to be, namely a modal doctrine, it is rather collaborated efforts of logicians and logically minded philosophers that might intimate whether or not it is true. Be that as it may, to obtain clarity about the concept of transient time is necessary for anyone investigating if this view is true.

As I already hinted, a version of transientism that I am interested in draws on the concept of open future. In this vision the distinction between past and future consists in an asymmetry of the two with respect to possibilities. A future event has a few possible outcomes, but as soon as it becomes past, only one of its outcomes is actualized, the remaining outcomes being no longer possible. The present is where this transition from many possibilities to a single actuality takes place. Thus, to properly model this concept of open future, we need to produce a structure with events and their outcomes, and then introduce a means of 'deleting' the non-actualized outcomes. One might want to express this vision in terms of possible histories, yet the description in terms of events and their outcomes is more in line with SOBST models, to which I soon turn. The SOBST framework is a development of Belnap's *branching space-time* and his *outcomes in branching time* (Belnap, 1992; Belnap, 1995).

The paper is organized as follows. Section 2 briefly sketches the purely algebraic models of stochastic outcomes in branching spacetime, as developed in (Kowalski and Placek, 1999; Placek, 2000; Müller and Placek, forthcoming). In the next section the models are related to geometrical notions of spacetime physics. Finally,

Section 4 defends this version of branching time theory against some popular objections and illuminates a number of ontological assumptions behind SOBST.

2. THE FRAMEWORK OF SOBST

In this section I will use a standard method of logicians who account for modal notions by producing a family of possible worlds or possible histories. The technique of branching that is applied here is perhaps a less popular application of this method. The name 'branching' goes back to early frameworks that accounted for temporal ordering only. Possible histories shared then initial segments and were arranged in tree-like structures. 'Initial' is no more a simple concept once relativistic spacetime is considered, but it still remains true that histories in branching spacetime have common segments. In contrast to most other modal frameworks, the models which are presented here focus on 'little' things, which can be interpreted as events and their outcomes. More precisely, once a modal structure is fixed by specifying a nexus of histories, a net of events and outcomes emerges, and remaining analyses can be carried out in terms of these notions. Significantly, given some algebraic properties of outcomes, this feature permits applications to experimental data.

We begin the construction of a SOBST model by specifying a partially ordered set $W = \langle W; \leq \rangle$. The elements of the nonempty set W are interpreted as spatiotemporal points taken together with whatever is in them, i.e., pointlike concrete particulars. The relation x / y is interpreted as 'x is in the backward light cone of y', or, 'x can causally influence y'. Standardly: $x < y$ iff $x \leq y$ and $x \neq y$. This relation is then extended to subsets of W :

DEFINITION 1 (OF PRECEDENCE)

For $E, F \subseteq W, x \in W$ (1) $E < x$ iff $\forall e \in E e < x$; (2) $E < F$ iff $\forall x \in F E < x$.

$E < F$ means that the whole of event E is in the backward light cone of every point from F .

As W allows for branching, two points can be separated not only spatiotemporally, but also modally, when there is no single course of events that comprise them both. The modally separated points will be characterized as upward incompatible, with upward compatibility defined as below:

DEFINITION 2 (OF COMPATIBILITY)

$x, y \in W$ are upward compatible iff there is a $z \in W$ with $z \geq x$ and $z \geq y$; otherwise, they are called orthogonal (written $x \perp y$).

Some special subsets of W will be called 'histories' (intuitively, possible courses of events). Our definition builds upon an asymmetry between upward forks and downward forks. An upward fork can be interpreted either spatiotemporally (two points have a point in their common past) or modally (the points are upward incompatible). To the contrary, downward forks permit a spatiotemporal interpretation only, namely two points are in the past of a third point.

DEFINITION 3 (OF A HISTORY)

A subset h of W is a history iff h is a maximal upward directed subset of W (i.e., for all upward directed $h' \subseteq W$ we have: $h' \supseteq h$ implies $h' = h$).

The set of all histories is denoted by H .

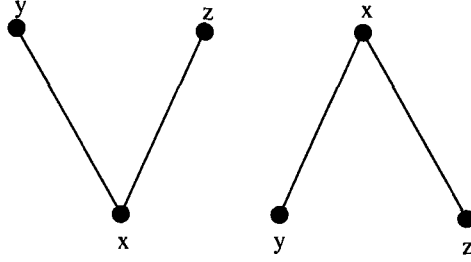


Figure 1: Upward and downward forks; the lines represent the ordering relation $<$.

This definition can lead to counterintuitive results, e.g., if our spatiotemporal world comes to an end, the definition will treat our world as a huge number of histories. The next section shows how to overcome this problem by building $\langle W, \leq \rangle$ from spatiotemporal histories rather than carving histories out of $\langle W, \leq \rangle$.

As histories branch, one can wonder where those things are located that are responsible for some two points being upward incompatible. The concept that we need is that of a set of splitting points for points.

DEFINITION 4 (OF SPLITTING POINTS FOR POINTS)

For any two orthogonal points $x, y \in W$, we define the set of splitting points $C(x, y) \subseteq W$ by putting $z \in C(x, y)$ iff z is a maximal element in $\{z \in W : z \leq x \text{ \& } z \leq y\}$. If x and y are not orthogonal, we put $C(x, y) = \emptyset$.

To ensure that for any pair of orthogonal points x and y , $C(x, y)$ is non-empty and that sets of splitting points behave ‘nicely’, we assume the following two conditions:

(C1) For any $x, y, z \in W$, if $x \perp y$ and $z \leq x, z \leq y$, then there is some $t \in C(x, y)$ with $t \geq z$.

(C2) For any $x, y, z, t \in W$, if $x \geq z$ and $y \geq t$, then $C(x, y) \supseteq C(z, t)$.

Two further notions are required to introduce outcomes of events in W :

DEFINITION 5 (OF RELATIVE ORTHOGONALITY)

Elements x, y of W are orthogonal relative to E , written $x \perp_E y$, iff $E \prec x, E \prec y$ and $C(x, y) \cap E \neq \emptyset$.

DEFINITION 6 (OF ORTHOGONAL COMPLEMENT)

For $F \subseteq W$, the orthogonal complement of F relative to E is the set F^{\perp_E} such that $x \in F^{\perp_E}$ iff $\forall y \in F, x \perp_E y$.

DEFINITION 7 (OF OUTCOME)

A subset F of W is an outcome of $E \subset W$ iff $F = F^{\perp_E \perp_E}$.

This definition ensures that an outcome of E is preceded by E and is located as close as possible to E . What the outcomes of E look like crucially depends on whether and, if so, how many, histories split in E . Given the above definitions, the following claims, proved in (Kowalski and Placek, 1999), hold:

THEOREM 1

The family F_E of outcomes of $E \subset W$ forms a complete and atomic Boolean algebra

$$\mathbf{B}_E = \langle F_E, \cap, \sqcup_E, \perp_E, W, \emptyset \rangle$$

where \cap is the set-theoretical intersection, and, $a \sqcup_E b = (a \cup b)^{\perp_E \perp_E}$ the unit element of the algebra is the set W , and the zero element of the algebra is the empty set.

THEOREM 2

For every complete atomic Boolean algebra B there is a world W and a set $E \subset W$ such that the algebra \mathbf{B}_E of outcomes of E is isomorphic to B .

An *event* is defined as a subset of a history that is bounded from above.¹

DEFINITION 8 (OF EVENTS)

$E \subset W$ is an event iff $E \neq \emptyset$ and $\exists x \in WE \prec x$.

We can also introduce *spacelike* events E and F by saying that E and F are spacelike iff there is a history that contains them both and no part of one event is preceded by any part of the other event.

To comment on our concept of an outcome, note a difference between this (technical) notion and an ordinary notion of an outcome or a result. A SOBST outcome is upward closed, and hence it continues as long as histories it involves continue. To the contrary, an outcome of a measurement, say a scintillation or a click of a detector, is a small well-localized chunk of a history. Thus, the two

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