·科学技术哲学·

路径个别化和回溯式奠基

Path Individuation and Retrospective Grounding

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摘　要：一个（非决定论框架下）常被忽略的事实是，任何结果的路径依赖方向是与自然时间相反的，即路径的下游组分循序地依赖其上游组分（哪怕路径形成过程渗透着偶然性）。本文提出一种个项导向进路，以克服类型导向进路对路径相关现象在解释上的局限。对个项导向进路的论证，建基于一个PD定义格式，该格式最核心的元素是一递归性反事实条件句公式。尽管PD与刘易斯的“因果链”相通，却更利于探讨迄今少被触及的路径个别化。本文检视了路径生产的两种模式，第一种可区分现实与可能的路径分叉，第二种则涉及路径内下游事件对上游事件（之因果地位）的回溯式奠基。本文用五子棋游戏直观地例示了个项导向如何进行路径个别化，及其易被忽略的深层原因。

关键词：路径个别化　回溯式奠基　个项导向进路　路径依赖　历时差异制造

Abstract: This paper purports to expound a special (technical) notion of paths. A neglected fundamental fact (especially under indeterminism) is that the path-dependent direction of any diachronic outcome is backward, i.e., later steps depend on earlier ones successively, despite the ineradicable chance in their respective formation. In this paper, a token-oriented retrospective approach is proposed to overcome the limitation of the type-oriented approach in explaining path-related phenomena. My argument for the validity and utility of this approach is largely based on the elements of (PD), a definitional schema for diachronic sequences subject to a recursive counterfactual formula. I explore certain aspects of path individuation that have so far not been discussed, despite (PD)'s formal congeniality with Lewis's 'causal chain'. Two basic patterns of path generation are examined: the first is for distinguishing actual vs possible branching paths, while the second introduces a metaphysical theme regarding the retrospective grounding of the causal status of an upstream event by its downstream (joint) effect. A central example of the paper, viz., the Gobang game, is used to illustrate how the token-oriented approach works for path individuation.

Key Words: Path individuation; Retrospective grounding; Token-oriented approach; Path dependence; Diachronic difference making

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Everyone seems to have the following nontrivial awareness of a seemingly trivial universal fact: one always finds a unique continuous path in retrospect. Like a sequence

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of footprints left behind in the snow by a walker, a 'path' qua visible trace seems always to be associated with both temporal passage and spatial extension. This retrospective dimension of paths seems also associable with our sense of causal history, or to convey some token-oriented intuition about the ontic dependence of present things on their past states (or predecessors). Such an intuition appears to involve certain metaphysically interesting but largely unrevealed aspects of the retrospective dimension of paths. Let me broach this subject in a more precise way.

Intuitively, the path of something is the course along which it moves continuously in a particular direction. In mathematical terms, a path can be minimally defined as 'a single continuous unbranched series of nodes and lines in a graph'.[1] Let us call this second, minimal sense of paths 'thin paths' ①, [2] and the first, intuitive sense 'thick paths'. Obviously, that 'something' in the thick sense must have some (more or less stable) identity over time; or its identifiability must figure in the individuation of the path in question.

This paper purports to expound a special notion of paths. This notion will not presuppose the diachronic identity of the thing by which a thick path forms, but may hopefully explain such an identity or its formation when combined with some evolutionary framework. This notion is closely related to David Lewis's notion of a causal chain (and is in fact a better substitute for 'causal chain' for certain metaphysical jobs. ②)[3] At the same time, a companion use of path dependence is not only inseparable from this proposed notion of a path but also conducive to illuminating the significance of the latter. But before turning to formal definitions (in section II) and our central illustrative case (i.e., Gobang, in section I), let me first make some preliminary remarks, starting with the use of path dependence in classical physics.

Here is a simple example from physics. Mechanical work is the amount of energy transferred by a force. In the simplest case, the work (W) is given by the formula: W = FD, where F is the scalar measure of the force while D is the object's displacement along the path of its movement. W is path-dependent in a derivative sense of D being path-dependent: i.e., not only in that the longer the path, the larger D (hence W) is, but also in that if the path is not a straight line but a curve with the same starting and ending points, D (hence W, assuming a constant F with varying directions tangential to the curve at every point) will be larger than in the straight line case.

The natural use of 'path' here seems in the thick sense, which has not (yet) drawn on any modal notions such as causality or counterfactual dependence for its definition. Suppose that the variable D can be used to stand for a certain type of path-related quantities in which physicists are interested for measurement (e.g., the upper semi-circle counts as the same type of path as that of the lower semi-circle, with respect to movement from a left-hand point to a right-hand one). That is, if 'displacement' is the only path-related feature that is measured at present, then D may be a good surrogate variable for various paths (e.g., there is no need to further distinguish the upper from lower semi-circles). Under that supposition, the formula W = FD may serve to illustrate a particular, distinct sense in which the variable W is path-dependent, given the mathematical function mapping alternative values of D onto those of W. In other words, W is the dependent variable upon the independent (path-)variable D, other factors (here, F) being fixed. Let me call this sense of path-dependence the functional sense.

Generally speaking, for any given or hypothetical path variable in some abstract space, we can have a well-defined sense of path dependence regarding any variable that depends on the former variable in the functional sense

My targeted notion of a path (dependence), however, is very different. Roughly, it is supposed

①Pearl's paths in his graphs (not just DAGs) seem closer to the thin sense than the thick one.

②I am unable to argue for the comparative advantages mentioned here within the confines of this paper.

to be sensitive to, thus dependent on, the token differences between any numerically distinct paths, such as the two semi-circular paths which variables like D or W fail to distinguish. A platitude concerning such token-sensitive paths would be, again, that travelers always find a unique path in retrospect. This is the primitive, token-oriented sense of paths I intend to emphasise and flesh out, whatever types of other properties they might instantiate. Thus, it could be regarded as a bottom-up approach to paths, with an apparent theoretical virtue if one accepts that concrete tokens, ① rather than abstract types, are better candidates for ground-level entities in metaphysics.[4] Section III will show how important it is not to conflate type-level principles of path dependence with those rooted in such a token-oriented sense. I take the latter as metaphysically basic.[3]

In short, I shall articulate a token-oriented, retrospective approach to path individuation and path interaction while demonstrating how this approach can have metaphysical significance bearing on temporal directions, especially the backward direction which, other than being built into my definition of path, figures explicitly in my proposed ontological notion of retrospective grounding. This approach, though universally applicable, seems most suited to the indeterminist framework.

I. Gobang: An Exemplary Case for Thick Path in Retrospect

The case we examine in this section (as through a case of an interactive game, we will see how its interactive dimension can be represented and incorporated into the approach later.) will illustrate the following simple idea. That is, a sense of unique unbrokenness is readily associable with a player's retrospective cognition of the directional links underlying the contingent thick path she has trodden.

Gobang, also known as five-in-a-row, is a traditional oriental game for two, played with black and white stones on a 19 × 19 GO board. It is very easy to learn, with a simple winning rule: the winner is the player who is the first to attain five stones in a row.

Corresponding to the stipulation of a Gobang winner, there is a conceptual necessity: i.e., necessarily obtaining a pattern of stones which involves a row of five stones in the colour of the winner's side. The necessity should be called conceptual because the modal statement is conceptually true given the stipulation. Or, one may also say, it is analytically true given the defined meaning of winning a Gobang game. Conceptual necessity or analyticity is a species of normative necessity. ('Normative' in a language-involving sense. Furthermore, the necessity in question is also normative in another practically generative or constitutive sense, i.e., it is no part of the natural world without our stipulating, and agreeing to play according to, the rule. However, I shall not discuss the possible relations between these two senses here.)

What I want to emphasise, however, is the fact that this normative conceptual necessity not only is compatible with, but also inextricably relies on, the contingent steps of a candidate winner and they eventually make up the actual winning outcome. The steps are contingent in a dual sense: i.e., nobody has a pre-determinable roadmap towards the eventual outcome, and each step (except the first) depends at least partly on the preceding step of the rival player which, largely or in principle, is unpredictable.

The reason to focus on the intriguing relationship between the necessity and the contingencies in playing Gobang can be briefly explained as follows. Apart from literally seeing a token of the winner-constitutive end-result

①The core meaning of a token (as opposed or relative to its type) I rely on is quite standard: i.e., any concrete particular, such as a material object or person that occupies specific spatiotemporal positions. So, in this broad sense, any momentary or persisting state of such a particular thing can also count as a token. It is important to note that such a broad notion is neutral to any possible issues concerning the diachronic relations tokens can enter. Readers can find a general discussion of type-token relations in ref.3.

(five stones in a row), the actual winner, whoever it turns out to be, and however surprising the winner's manoeuvres or their effects have been, must additionally 'see', in retrospect, a successful, contingent, thick path leading to the particular configuration of laid stones in the end-result. It is a sequence of past steps that must have (albeit contingently in a causal-historical sense)[①] involved five (often diachronically non-consecutive) steps corresponding to the five stones that spatially comprise the winning row.[4]

This additional 'seeing' seems to correspond to a novel sort of modality, whose distinctive features are not captured by the conceptual necessity identified above. Let me elaborate.

Part of what seems missing in this straightforward conceptual necessity has to do with the familiar idea of contingent success, with its unpredictable interactive activities. The identity of the winner can only be known ex post facto, given the inerasable chance factors in the play of the game. Corresponding to such ex post identification of the winner, the actual successful thick path to the winning outcome cannot be identified until the particular game reaches its endpoint. Once the endpoint is reached, the actually unbroken chain of the past steps on the winner's side obtains its very status as the winning path in the thick sense. (in the thick sense) Symmetrically, one can also say regarding Gobang that 'once the endpoint is reached, the unbroken chain of these previous steps on the loser's side obtains its status as the losing path'. Here the centre of gravity, so to speak, lies with the status one chooses to focus on. Winner status in a game may stand out for different reasons, one of which is uniqueness when the game has multiple (i.e., more than two) players but only one winner. A thin sense of the word 'unbroken' here can be obtained via the contrast with its antonym 'broken:' i.e., a player's supposed game-permitted step (typically as a response to the other's preceding step) is illegitimately bypassed by, say, two consecutive steps of the other player, or simply interrupted by other irrelevant factors (and, when resumed, does not keep the original order, etc.). The spatial continuity of the five stones in a row somehow stands for, thus individuates, this actual historical (thick) path of winning steps – 'winning' in a retrospective and thus derivative sense. Regardless of where the row locates on the board, or figures in the eventual configuration of the laid stones (from both players), this invariably unbroken winning (thick) path is ex post facto retraceable.

One likely misunderstanding of my claim about the retrospectively unique (thick) path to a winning pattern of Gobang is this. One might believe, quite naturally, that the final pattern of a particular play of Gobang could be reached in various manners (for that matter, by alternative paths). For example, the actual final step could have been played even if some of the preceding steps (from either player) had been different (for instance, played in a different order), so that eventually all stones could still be located where they are in the actual pattern. (The use of the counterfactual here is not accidental with regard to expressing the sceptic belief. My rebuttal, in the next paragraph, of the mistaken belief essentially appeals to an ontic idea of path dependence. The logical relevance of characterizing path dependence in terms of counterfactuals will become clear in §3.1 when I introduce (PD), i.e., a definitional schema for path-dependent sequences.) Then, one wonders, if the actual order does not play any decisive role in the final pattern, i.e., if only the stones' final positions on the board ultimately count, then why isn't the retrospectively necessary unbrokenness still a form of conceptual necessity (i.e., the winner is, as always, the one who makes five stones in a row)?

The misunderstanding lies in failing to regard (whereas my claim requires so to regard) 'the same end state' as a token (as opposed to type)

①I use 'causal' here, as elsewhere, in a (broadly) Lewisian counterfactual sense, as opposed to the alternative nomological sense. However, as we will see, it had better be based on my (PD) than on the 'causal chain' as originally presented by Lewis.

state that causally depends on another token state, viz., its immediate predecessor, for the formation of the actual link, which in turn depends on its predecessor, and recursively so, thereby for the entire token chain to actually constitute the winning path. (Such dependence will be fleshed out in section II, where the discussion bears on the uniqueness of the path itself qua diachronic token.) Suffice it to say, at this point, that the actual diachronic order of steps matters to the claim of retrospective unbrokenness along the path, even though it might not matter to the actual winner (e.g., when the particular order between two successive steps could be switched without affecting the final winning configuration as a specific type).

Gobang, being representative of a whole category of artificial games (here I do not mean just 'board games', of which Gobang happens to be one, but any well-designed artificial games that involve sequences of steps leading to well-defined winning outcomes), thus illustrates the unique, invariable unbrokenness of a (thick) path, or a course of actions, that on one hand is not due to any nomological or conceptual necessity, but on the other hand seems to have a non-accidental connection with the backward direction embodied by retrospection at the endpoint of the path. The hindsight associated with such an endpoint does not concern any new information about the design or rules of the game, but concerns only one's actual status as the winner (or loser, for that matter; hence a contingent status of a posteriori discovery) in the unique historical (thick) path one cannot but tread.

Readers may have noticed that I put 'thick' in parentheses before 'path' several times – which rightly signals that the thick sense is dispensable. In fact, however, my official technical definition of path, as presented in §II.2, does not presuppose such thick diachronic identities of players as in Gobang.

The general point I wish to stress is that my proposed approach to path phenomena has a distinctive token-oriented cum retrospective feature, whose theoretical utility is not found in any other approach (as far as I am aware).

II. PD-sequences and a Retrospective Understanding of Paths

1. Definitions of PD-sequences and Paths

As a prerequisite technical device, here is the definition of diachronic sequences of a very broad and distinctive kind, viz., what I call PD-sequences: [5]

(PD) For any diachronic sequence of n steps qua distinct events, ① s_0, ... s_i, ... s_n ($0<i<n+1$) at world w is a PD-sequence if and only if the following counterfactual applies recursively to any step s_i that has a preceding step s_{i-1}: had s_{i-1} not been obtained, s_i would not have been obtained.

I present five explanatory notes before proceeding with this precise notion of paths and path dependence.

First, 'w' is the variable index for the actual world i.e., any world one chooses as the reference base for the counterfactual formula in (PD).[6]

Second, 'PD' is meant to stand for path dependence. Merely as an acronym, whatever PD encapsulates depends not only on one's semantic theory of counterfactuals, ② but also on what kind of worlds one wants to study.[2, 7-9] Although there is no explicit restriction on w in (PD), I intend to take

①Here I take for granted that the individuation of events is a well-defined notion. Furthermore, the attribute 'diachronic' presupposes the temporal order of the steps/events whose temporal positions are indexed by the subscript variables i/n.

②The two main types of semantic theory of counterfactuals are based on truth conditions and acceptability conditions, respectively. I assume Stalnaker/Lewis's ontological framework for the former type for interpreting counterfactuals. It is beyond the present paper to settle whether, or to what extent, my token-oriented approach can accommodate (or be applied to critiques of) other accounts of counterfactuals in either semantic type. For instance, I think my approach would hold if I adopted a certain Ramsey-inspired nomic account, or one such as Pearl's directed acyclic graph (DAG)-based theory. One can get a sense of the spirit of Pearl's approach from the following passage: 'In contrast with Lewis's theory, counterfactuals are not based on an abstract notion of similarity among hypothetical worlds; instead, they rest directly on the mechanisms (or 'laws' to be fancy) that produce those worlds and on the invariant properties of these mechanisms'. My ideas about worldly paths and path dependence are compatible with either Lewis's theory or Pearl's world-producing theory.

w as typically featuring both chance events and determined ones, i.e., under the broad indeterminist framework.

Third, as the subscript 'i' is an integer variable, the recursive formula involving s_i and s_{i-1} represents a series of counterfactuals to be respectively applied to successive pairs of neighbouring steps.

Fourth, steps qua distinct events are meant to be ontic tokens rather than any describable type, they can thus take a certain form of referential proposition,① or fit the Lewisian notation: $\sim O(s_{i-1}) \mathbin{\square\!\!\rightarrow} \sim O(s_i)$.

Fifth, a PD-sequence is finite in having both a starting step s_0 and an ending step s_n whose subscript n may be indefinitely large or extendable, depending on either the artificial context (such as Gobang) or certain natural, de facto contingencies (e.g., a fundamental contingency appears to be the constantly updating present). In the case of a natural game, for instance, the starting step can also be indefinitely remote in the past, depending either on the observer's interest or its salient natural origin. In short, neither the starting nor ending step need be absolute; they are typically relative to the context or interest of whoever assumes the retrospective stance.

With (PD), we can now give a formal, and distinctively retrospective, definition of path.

(P) *X* is a path at t_n iff *x* is a PD-sequence looked back upon from its ending step s_n at t_n.

Though not required, a nice way to take t_n qua moment for the relative ending s_n is to construe 'n' as also standing for 'now', the natural temporary cut-off point for retrospection, and the implicit observer behind the participial phrase 'looked back' need not be actual or worldly, but could be, say, Laplace's demon.[10]

Path dependence, accordingly, is nothing but the universal property of all possible paths, i.e., the property corresponding to the set of all PD-sequences under retrospection at any possible world. (Given the spatial constraints, I shall not argue for the existential singularity of such a universal property, nor expound on how this defined sense fits the ordinary connotations of path dependence, given that the latter is not (PD)-based.) Suffice it to say that all my uses of 'path-dependent' below are based on the technical notion of path defined by (P).

It is important to observe that a path, thus defined, has its unique reference point for individuation, which is nothing but the ending step of the corresponding PD-sequence. Thus, when such a (temporary) ending step is moving forward, the corresponding retrospective path is automatically extended with the updated reference point. No less important is the observation of the built-in role of the retrospective stance indicated by the phrase 'looked back upon' in (P)②.[11, 12] One might say that such use of 'path' is just what is ordinarily understood by 'historical path', hence it might seem narrower than path simpliciter. But part of my overall argument is precisely about the essential, historical status of any paths. (Thus it is supposed to reach truth beyond mere stance-generated stipulation.) A quick caution seems necessary: we should distinguish between two kinds of difference-making, i.e., functional vs diachronic sense of path-dependence. The former (given spatiotemporal locations) concerns alternative paths at different worlds, whereas the latter concerns an intra-world path, with different downstream steps depending on their (updateable) respective upstream paths (or path-stages). Section III addresses a possible conflation related to this

① For instance, s_i, representing a token event itself (not any properties thereof), can assume a Lewisian $O(s_i)$-style proposition: this event s_i occurs. 'Counterfactual dependence among events is simply counterfactual dependence among the [one-to-one] corresponding propositions'. For the distinction between such $O(s_i)$-style propositions and description-satisfying referentialpropositions, see ref.4, especially its 9th footnote.

② An exemplary case of philosophical stance-assuming is Dennett's 'intentional stance': an octopus emitting inky stuff when a predator is around legitimises our ascribing to it the belief that it had been spotted by a predator. Millikan instead adopts the 'design stance' in such contexts.

distinction.

A token-relevant retrospective fact about any PD-sequence is this. Any counterfactual missing step therein would undermine all later, remaining (i.e., subsequent to the temporal position of the step in question) links in the sequence as a whole, i.e., undermining the actual path that contains this (counterfactually missing) step. That is to say, the integrity of a path, relative to any reference step S, is sensitive to the existence of any (intra-sequence) step earlier than S, but not to later steps in the (linear) PD-sequence – even though all steps in the sequence may be equally contingent①. [13]Under indeterminism (or its presentist version), if S is the present step, there should be no (or not yet) actual token steps in the future of S – even though, according to prevailing laws at w, there can be only one type of future event given S and its surroundings.

Therefore, the minimal thing we can (or, should, under indeterminism) say is that a path is always retrospective with respect to any reference step S, despite that it is in fact continued after S.

2. Testing Gobang: the Path Status of Its Actual Winning (Losing) Courses

For a concrete view of the application of (PD), let us test the case of Gobang by the viability of the PD-construal of any player's actual course in playing Gobang.

As Gobang involves two players, let us designate one of them as *p* (say, with black stones) and the other as $p^{\#}$ (with white stones). Suppose that *p* is the winner. The candidate PD-sequence associated with the winning path should consist of all *p*'s actual steps in the order of the play. Intuitively it would seem impossible for p to take the actual token step s_i ($i > 0$) if he had not taken s_{i-1}, the preceding token step of his actual play at w ② .[6,14] Such impossibility does not have to imply that, at a type level (say, of game strategies), *p* cannot make the same spatial-type positioning of a black stone as his actual positioning of it at t_i at w if the actual step at t_{i-1} is different from that of s_{i-1}. It simply means that the counterfactual, synchronically and transworldly type-identical positioning s_i* qua action-step at t_i at w*, ③ could never be the action-step that is token-identical to s_i in a path-bound sense for the identity of a step. One might grasp the identifying sense of 'path-bound' here by comparison with Davidson's causal criterion for event identity: i.e., just as the individuation of an event is secured by both its cause(s) and its effect(s), the token-identity of s_i is determined by the very path comprising it ④ .[5] Because s_i and s_i* belong to divergent worldly paths (at least back to t_{i-1}), given that s_i* occurs at w* while s_i is at w, the token-identity of s_i* thus determined by its own intra-w* path cannot be that of s_i.

More realistically, at w*, certain inseparable psychological properties in the makeup of the counterfactual action-step s_i* (albeit type-identical to the actual one in the stone-involving aspect) would be different from those associated with s_i at w. Such differences (robust or subtle as they might be) make perfect sense qua familiar differences, say, in *p*'s perceptive response (at w*) to the path-historical difference of s_{i-1}*. *P*'s perceptive response would also be sensitive to the correspondingly different step of the opponent $p^{\#}$ at w* at $t_{i-1/2}$, i.e., in between two consecutive steps of *p*'s. (I shall pick up this point in section V in

①One may also claim that a path, with respect to S, is independent of any contingent steps downstream to S. This claim seems to resemble Lewis's anti-backtracking point, which I do not have space to discuss here.

②Here, for brevity, and with no impact on our explication, I ignore the distinction between p's counterpart at w* (if one follows Lewis closely) and p (designated rigidly according to ref. 14) qua individual with a transworld identity, hence also existing at w*.

③In that counterfactual location of s_i* (at t_i at w*), the preceding step s_{i-1}* is, by hypothesis, different from s_{i-1} at w. It does not matter, however, whether or not s_i* involves the same token stone as the one actually taken in s_i at w.

④The comparison to the Davidsonian criterion 5 in the present context merely serves to facilitate comprehension of what I mean by 'path-bound'; it does not imply my commitment to the Davidsonian thesis itself (at least not in its original, non-counterfactual formulation). Any further explication or exploration in the comparative direction (perhaps even a diachronic version of Davidson's anomalous monism) is obviously beyond the purview of the present paper.

relation to difference-making.)

In other words, each step of any (normal) intentional play of Gobang on the side of p (or $p^{\#}$, for that matter) must be sensitive to various factors, at least some of which are intrinsically chancy. These factors centrally and always include the preceding step qua part of the unique path in which the player always finds himself (as far as the game play is concerned). Hence, a proper interpretation of Gobang as an interactive game cannot but treat the winning path of p as a PD-sequence①. (By the same token, the corresponding losing path of $p^{\#}$ is also a PD-sequence.) Thus Gobang passes the test of qualifying for the contingent multistep path, i.e., supporting the PD-construal of the actual course p or $p^{\#}$ took.

III. Two basic patterns of path generation for actual paths

Let me illustrate how certain compound cases of intra-world paths might be conflated with their cross-world 'counterparts', and how the former, having been cleared of the conflation, can yield interesting theoretical results. Such results include the issue of path individuation and its connection with the individuation of an event qua a PD step, as well as 'retrospective grounding' (roughly, the grounding of the statuses of certain upstream steps by the downstream common step of converging paths). I first discuss the conflation in this section, and turn to path individuation and retrospective grounding in the next.

There are two basic patterns of intra-world path generation, i.e., branching vs converging, as shown in the two diagrams below.

In Diagram 1, S_n can be taken as a starting point for one of the two 'offspring' sequences (Path 1 and Path 2), and perhaps simultaneously also as the (temporary) endpoint of some (non-depicted) 'ancestral' sequence. In Diagram 2, S_n can be taken either as the (temporary) endpoint for one (or both) of the two ancestral paths (i.e., Path 1 and Path 2), or, alternatively, as the point of ontic synthesis of the two ancestral paths, which terminate therein while simultaneously starting an offspring sequence.

We will see that the anatomy of any actual complex pattern of (candidate) PD-sequences can be formed by iterative operations of the branching and/or converging type on a chosen node in the pattern.

It is important to see that these patterns are concrete and actual②, or occurring wholly at one world.[8] They are not obtained qua trans-world entities of some kind, say, in a probability space (or some 'phase space'③ for that matter) that represents alternative events at some spatiotemporal location (or within some frame of parameters). In other words, step signs such as S_n do not stand for variables (such as in Pearl's DAGs), but rather ontic values (fixed when, for example, the subscript n is taken as a constant).

Diagram 3 illustrates a path-like branching structure in some space of possibilities, in which only the sequence A–B1–O1 represents an actual sequence, or a simple, non-branching path in my sense. All other sequences (e.g., A–B1–O2) are alternative other-worldly paths.[15]

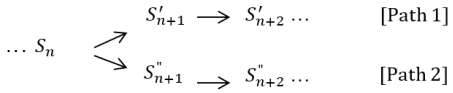

Diagram 1. The branching pattern of actual path generation

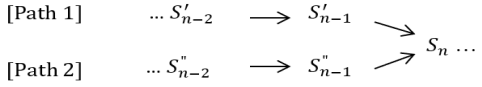

Diagram 2. The converging pattern of actual path generation

①There might be room here for one to argue for lowering the unexceptional tone of my conclusion by allowing some conceivable play to involve 'gappy' or 'sloppy' steps that are not rationally or psychologically sensitive to the preceding step or its essential elements. I do not consider this or other exceptional situations here, except to say that if these could be allowed to count, I would concede that not every possible play of Gobang is a proper PD-sequence on the level of a certain threshold type as distinct from physical token.

②'Actual' in a broader, indexical sense.

③E.g., a sine curve in a phase space (with velocity and time as coordinates of the abstract space) for a simple pendulum in actuality.

Here is an important point of contrast regarding some (representative) discussions of path dependence in the literature which draw on a relevant feature of process having divergent outcomes. Consider the following proposition.

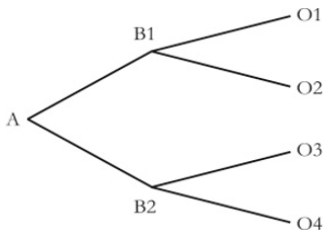

Diagram 3. A branching tree of possibilities with turning points B1 and B2 (adopted from ref. 15)

(A) Path-dependent processes admit of multiple outcomes.

Proposition (A) is claimed by some theorists to capture the generic essence of path dependence.[16] Let us grant that claim. An apparent similarity of this essence to my branching structure in Diagram 1 seems to be that S_n, like A in Diagram 3, also admits of multiple downstream sequences. But a little reflection would show that (A) only applies to processes graphically represented by Diagram 3, not Diagram 1. Therefore, the similarity is misleading: 'multiple' in (A) indicates possible, instead of actual, outcomes①.

It is not that actuality is incompatible with possibility, but rather that the two downstream (branch) sequences in Diagram 1 are both actual token occurrences initiated and diverged (from each other) at the same spatiotemporal location of S_n – e.g., a watershed separating the main river into two branches.

Having said this, however, it is worth noticing that whatever essence of path dependence is supposedly expressible by (A) is not only compatible with my technical PD-sequences at the actual world, but also, given the above clarification, must be presupposed by the latter – the very point of their satisfying the recursive counterfactual formula lies in admitting of multiple cross-world variations, i.e., variations at nearby possible worlds that support each and every pairwise counterfactual dependence. Evidently, that notice does not compete with our main point of contrast here.

Relatedly, to avoid another point of potential confusion, it is perhaps more pertinent to say that each path-candidate formally typified by Path 1 or Path 2 in Diagram 1 admits only of possible path-status, qua an alternative outcome in 'a modal-logical space of (counterfactual) alternatives', for the two S_n-downstream sequences (i.e., not yet warranting PD-sequence status before they pass the counterfactual test, say, via adequate empirical means), even though both are already actual sequences in the physical space of the world. A similar point applies to Diagram 2.

Equipped with this clarification, let us now turn to distinctive aspects of retrospective operations, especially the one associated with the converging pattern.

IV. Retrospective Individuation and Grounding

The thematic point about path individuation in this section applies equally to both branching and converging patterns. For conciseness, let us only use the branching pattern to explicate the point in §IV.1, and reserve the converging pattern exclusively for articulating retrospective grounding in §IV.2.

Although the philosophical significance of retrospective grounding seems unconfined to my present purpose, its articulation here aims mainly to broach the subject in a distinctive, path-exploiting way.

1. Retrospective individuation in the branching pattern

In Diagram 1, it might seem straightforward that either one of the two 'offspring' paths is

①It is evident, from this point of contrast, that careless amalgamation of possible (and often logically exclusive) states/paths and actual ones (especially their causal interaction) in one diagram is likely to lead to unsound results. See ref.16, Fig. 1 and Fig. 2 in its section 4.2, for a suspect example of this sort.

already individuated qua single path as depicted by the consecutive arrows in the separate lines. However, things could get mixed or conflated as far as actual empirical investigation is concerned, because all depicted steps are parts of the actual happenings, which, epistemically speaking, may not occupy distinct, tidy spatiotemporal locations that clearly belong to steps of one rather than another actual path.①

Specifically, for instance, if S''_{n+2} is to be taken as the reference step (say, in a test for the applicability of the PD-counterfactual), the investigators themselves must assume the diachronic position S''_{n+2} rather than S'_{n+2} as their standpoint to empirically exclude S'_{n+1} rather than S''_{n+2} as the relevant preceding step of S''_{n+2}. Any assumed reference step, though updatable along the candidate path, must be downstream from its dependable source insofar as path individuation is concerned.

Thus, path individuation within any complex diachronic pattern requires a new, empirical aspect of retrospection at each reference step (supposedly occupying some position downstream of a candidate path) – this epistemic point about testable path-identification among alternatives in retrospect seems methodologically prior to demonstration of the metaphysical point about the retrospective unbrokenness of simple (non-compound) PD-sequences. That is, the compound cases in Diagrams 1 and 2 come to take on a specific point about respectively keeping track of two candidate paths, i.e., Path 1 and Path 2, and experimentally retracing each qua such a candidate. Hypotheses about their likely PD-status can be well-motivated, e.g., considering their homologous and parallel issuing from the common step S_n. (In a proper context of talking about causality-relevant processes, the branching node S_n may represent precisely the familiar status of a common cause.)

Alternatively speaking, in some arbitrarily given diagram formally similar to Diagram 1, nobody can take for granted that what is represented by Path 1 or Path 2 is a PD-sequence (even if the hidden ancestral sequence up to S_n is known to be a PD-sequence), or that at least one of them must be. For the branching phenomenon itself does not impose any constraint on what kinds of steps they are, other than their actual occurrences. This means that successfully retracing the intra-world (i.e., factual, not counterfactual) Path 1/Path 2, associated with the trial-and-error application of the PD-formula along the (formally given or presentable) Path 1/Path 2 qua a path-candidate, is thus constitutive of establishing the candidate's genuine path-status, i.e., of path individuation, over and above the identification (or whatever other criteria) of Path 1 and Path 2 qua mere candidates for PD-sequences.

2. Retrospective grounding in the converging pattern

S_n in Diagram 2 can be taken either as a (temporary) endpoint for one (or both) of the two ancestral paths (viz., Path 1 and Path 2; which means that no further downstream sequence is available or of interest), or, alternatively, as the synthetic step for the two ancestral paths as well as the starting point of some future developing sequence (merely represented by '…' in the diagram). No matter which construal one adopts, i.e., whether or not Path 1 and Path 2 are taken as upstream parts of their respectively extendable longer paths passing S_n, we are entitled to treat them as proper (i.e., in the retrospective sense) paths with respect to S_n.

The salient collecting position of S_n with regard to Path 1 and Path 2 (whose individuation is subject to treatment similar to the branching case above) gives rise to a new issue. Its resolution will reveal an important new aspect of post-

①To avoid potential confusion, I use 'location' in its spatiotemporal sense while using 'steps' only with respect to a certain sequence when it satisfies (PD), despite the fact that any token step of a sequence must have a specific spatiotemporal location. The other pair of position-attributives, 'upstream' vs 'downstream', are always used with respect to a path. The largely neutral term 'position', as in the use of 'downstream position', tends to have a structural connotation likely associable with 'status', just as the largely neutral term 'sequence' tends to be associated with the structure-laden (and perspective-laden) term 'path'.

determination associable with the idea of the retrospective unbrokenness of a path.

Take the sexual reproduction of an individual (represented at tn by S_n) as an illustrative example, for its relatively familiar meaning.

Let Path 1 represent the father's lineage and Path 2 the mother's. Obviously, retracing either line would, before long, lead to another step-node, say S_f (unrepresented in the diagram), of a converging type which represents the reproduction of the father; and similarly, say node S_m, as the reproduction of the mother on the other, matrilineal line. Such backward encountering of further converging nodes along either lineage (ignoring, for ease of presentation, 'arbitrary' yet real crossovers such as a line including the father's mother, the mother's father, etc.) is evidently iterative without a clear-cut limit, given some familiar story about lineage and evolution. Although gerrymandering seems likely or unavoidable if an observer tries to individuate any particular path among this immense network of retraceable unbroken sequences by whatever chosen criterion, let us ignore such complication here.

The new issue mentioned can be formulated in the following way.

Both Path 1 and Path 2 are PD-sequences, as obviously warranted by the biological facts of the example, and respectively retracing them would encounter S_f and $\underline{S}_m$. Now a question arises: which path is the essential path, or main path, on which the offspring's identity and existence depend? If the answer is 'both' (which seems plausible for the 'essential' part of the question) or else 'neither' (which seems plausible for the 'main' part), then we should treat the importance of Path 1 and Path 2 as on a par qua necessary ancestral paths. In other words, the unique individual S_n, or its existence at t_n, has (at least) two pre-conceptional outstanding paths, on both of which it similarly depends.

It is evident that, in the converging pattern, the critical step at which the convergence takes place may not have the unique prominent path or history. Nevertheless, given the non-accidental fact that path uniqueness is presupposed by the applicability of the notion of path, it is likely to be true that S_n's two parallel preceding paths are substantively ① independent of each other and independently unique prior to S_n's occurrence, rather than correlated in any substantive way.

The independence between the actual parental paths is better seen in the following conceivable scenario: i.e., S_n might fail to exist at a possible (counterfactual) world at which Path 1 and Path 2 (being upstream identical to their counterparts in the actual world) do not intersect at t_n; hence nothing identical or substantially similar to S_n would have exist at that world. Therefore, a plausible view of the relation among S'_{n-1}, S''_{n-1} and S_n at the actual world where the intersecting convergence takes place should be something like this: (1) S'_{n-1} and S_n belong to an extendable Path 1 (which passes S_n); (2) S''_{n-1} and S_n belong to an extendable Path 2 (which also passes S_n); (3) S'_{n-1} and S''_{n-1} do not directly correlate to each other, but only become indirectly and retrospectively related when S_n occurs in its emerged identity-status as the converging, synthetic step at t_n at w.

With such a tripartite structure, the relation stated in (3) is particularly remarkable for its corresponding attributives, i.e., 'indirect' and 'retrospective'. Any correct application of the two attributives in turn seems to rely on the tenability of the following explanatory relation.

It is the retrospective stance at t_n/S_n that explains why the special relation between S'_{n-1} and S''_{n-1} must be indirect – they are (presumably causally) unrelated or independent until they are collected at t_n by S_n. The key feature that distinguishes the tripartite structure from other familiar types of simultaneous relations lies precisely in the indispensability of such a

①'Substantively' can be understood in, say, the genetic sense of involving certain sets of DNA, or in some other way involving causal powers. The use of 'likely' in the sentence leaves room for the historical possibility of common ancestors for the two parental paths. But such possibilities need not bother us here, especially when they might be in some (relatively) remote past.

retrospective stance to understand the distinctive role of the convergence (depicted by Diagram 2) in revealing a certain important aspect of path unbrokenness. The aspect is about the downstream status of a certain path-bound entity, and also about its essential role. That role lies specifically in determining the nature of certain distinctive relations among these upstream entities which are respectively bound or located in distinct, parallel paths (and which did not partake in such converging relations in the first place, i.e., at their corresponding time t_{n-1}). The distinctive relations in question are further explicable as follows.

The originally and ontically independent upstream states S'_{n-1} and S''_{n-1} (or their respective host sequences, Path 1 and Path 2) derive, in a backward way, their component status (or relative compositional importance) from, and only from, their common downstream collector S_n. In contrast to the notion of common cause, we may call this kind of common collector a 'joint effect'①.

The ontic compositional structure of such a joint effect plays a decisive role, the role (for short) of retrospective grounding. That is, S_n's obtained structure grounds, in a backward way, the relative status of its causal contributors②, S'_{n-1} and S''_{n-1}, qua the last steps of the converging parental paths. With this grounding role of the downstream (relative to S'_{n-1} and S''_{n-1}) joint effect S_n, both S'_{n-1} and S''_{n-1} authentically acquire, at t_n, the status of contributor to the more holistic (again, relative to S'_{n-1} and S''_{n-1}) entity, S_n. By the same token, they respectively acquire the status of a constituent of a more holistic path (i.e., one longer than Path 1 or Path 2) which extends, via S_n, either Path 1 or Path 2 (but not both, on pain of violating path uniqueness).

The authentic acquisition at t_n of the pre-converging steps' contributor status for their own existence at t_{n-1} seems 'belated' in a trivial sense, i.e., tn being later than t_{n-1}. But in another, path-relevant non-trivial sense – a sense whose importance I have endeavoured to reveal – the 'belated' description is misleading. No such belatedness really makes logical or ontological sense. For this path-defined status of each step ought to be their individuation ground, without which their (brute, time-indexed) existence would be of no ontological significance – not as far as the path in question is concerned③.

The ontological authenticity of this holistically relative status of S'_{n-1} and S''_{n-1} should therefore depend on the de facto formation of S_n④, qua a downstream entity, and also on the objective validity of the backward ascription of the status to them qua upstream entities of an ever-extendable path. That is the ascription from the retrospective standpoint of S_n or, for that matter, from any standpoint of its subsequent successors along the extendable path.Thus the converging pattern of path generation can help show the following informative aspect of path unbrokenness, which otherwise would remain concealed. That is, standing at a downstream collective node (for two or more converging parental paths) and looking backward, the relative statuses of previously unrelated entities (which are respectively located upstream in the

①Evidently this application of 'effect' fits Lewis's counterfactual analysis, i.e., it qua relatum forms the counterfactual/causal dependence relation with any one of its causal contributors qua another relatum. Perhaps a caveat: the application of 'effect' here does not imply that it is materially derivable from any one of its causal contributors alone. It is also worth noting that Diagram 2 does not depict redundant causes (i.e., over-determination) of one and the same effect S_n.

②'Causal' in the Lewisian sense of causation grounded in the counterfactual dependence which we assume, say, between S'_{n-1}/S''_{n-1} and S_n.

③If one contends that once they occur at t_{n-1} there are already respective (historic) paths relative to their existence at t_{n-1} (hence the corresponding ontological path-relevant significance), my reply is simply that this is not 'the path in question', i.e., the converging path we are talking about here. And the path-relevant significance raised in such a misplaced objection is only a restatement of our point for the simple, non-compound case.

④ Obviously, that is status dependence on a future occurrence, whose temporal direction is opposite to the path dependence of S'_{n-1} and S''_{n-1} themselves qua ontic occurrences. Roughly, my proposed diachronic holism ought to imply some level-distinct, bidirectional relationship of dependence between upstream and downstream entities. It would take a separate paper to elaborate on such relationship.

paths) invariably acquire their historical-ontological significance due to such retrospection, or such a diachronic-holistic interpretation of the matter.

It seems evident that no such backward ascription is epistemically possible without any (actual or hypothetical) observer of the identity profile of S_n ① .[10] The profile is about the ontic, composite basis of S_n for any of its tenable roles. Thus, the identity profile of S_n cashed out in terms of qualitative type-descriptions, i.e., over and above its mere time-indexed tokenhood, seems indispensable for the observer's decision about which extendable path, as against its likely competitor(s), is more justifiable if, for whatever reasons, such path candidates must be discriminated.

Although the indispensability of such downstream identities for discriminating upstream entities is an epistemic relation that involves some observer, its objective ontic basis can help reveal the distinctively metaphysical aspect of the retrospective grounding. The distinction of such grounding lies in the ontic, diachronic structure that makes the grounding possible (at some appropriate level of structural abstraction). More concretely, this is a real structure of some causal process that integrates the two (or more) converging paths into one synthetic token step. At the same time, that step may count as starting a type-level new path or continuing as a transitional step for a later stage of some extended path, whose token nature should never exclude emerged essences describable by property variables.

Two quick distinctions should be noted. First, given the fundamental token nature of S_n, Diagram 2 depicts no case of over-determination ②, even when S'_{n-1} and S''_{n-1} contribute to it the same property-wise components (and, for a sharper contrast, even when these type-identical components manifest a homogeneous macro essence). The basic idea is that the counterfactual absence of one converging path in Diagram 2 The basic idea is that the counterfactual absence of one converging path in Diagram 2 would lead to a different token step from S_n, whose momentary 'type identity' is no substitute for the path-determined token identity.

Second, the talk of retrospective grounding harbours no backward causation. There should be no conflation between such a holistically normative recognition of upstream entities in light of the downstream joint effect and the causation of the former by the latter ③ .[13] In Lewisian terms, for instance, one would say that there should be no counterfactual dependence of the upstream on the downstream.

One last comment before concluding the paper. Path individuation in simple cases involving some persisting entities can be regarded as a reduced type of retrospective grounding – 'reduced' in the sense that the upstream-to-downstream passage along a path candidate does not involve any identity change of the entity in question, while the non-reduced, proper retrospective grounding (typified by the converging pattern of path generation) involves identity change, based on the ontic combination of two distinct upstream entities into S_n. Evidently, an observer can select, according to the context of the observer's interest, a particular downstream component of the synthetic entity S_n (or its successor after t_n) as the basis for individuating

①Here we do not impose any restriction on the rationality of the observer in question. It need not be world-bound or endogenous. It could be, say, Laplace's demon, with perfect rationality and computational power, and transcendental to any world.

②In the literature on counterfactual accounts of causation, the issue of over-determination (and relatedly, of pre-emption) looms large in counterexamples. Although I am fully aware of the potential implications, I cannot but leave it for the readers to see the evident application of my path-centred or token-oriented approach to neutralising such counterexamples.

③An alternative way to put it might be this: backward causation, should there be such a thing, has to be some first-order counterfactual relation in a Lewisian account (more strictly, some tenable backtracking counterfactual whose truth conditions draw on objective or 'real' events at some possible world(s) closest to the actual world); whereas the truth of my retrospective grounding must concern the validity/applicability of some second-order, intentional function, i.e., its truth conditions have to be based on some viable mapping between different sets of objects/worlds respectively corresponding to some individual essence and its causal history.

one of the upstream paths, i.e., doing a reduced sort of retrospective grounding (perhaps as part of a full-fledged retrospective grounding).

V. Concluding Observations

As indicated by its title, the paper aims to reveal a largely neglected fundamental feature of path phenomena, viz., a difference-making retrospective stance assumable towards any candidate path in the technical sense of satisfying (PD), whose counterfactual formula takes token-oriented O(s_i)-style propositions as relata. This path-dependent difference-making is distinctively diachronic or dynamic – each 'new' step along the forward-extending path may differ informatively from its upstream predecessor(s) on which it depends – and gives rise to 'new' downstream possibilities. Therefore, this kind of path dependence is importantly distinguishable from the other (standard or functional) kind of path dependence, i.e., one based on the synchronic comparison of alternative paths with respect to variable properties of a given (state of) system. Roughly, the two kinds involve two different modalities: the latter draws on (borrowing a Lewisian term) counterpart paths at different worlds (i.e., each path is as complete as its world in a future-inclusive sense),[5] whereas the former is mainly about the intra-world tense-like properties of a path (i.e., the updateable path is incomplete as far as the present step is taken as its temporary ending step), in particular its retrospective unbrokenness (which is especially remarkable when it involves chance steps in its formation process) ① . For the apparently bigger question about the (modal) logical relationship between these two kinds of path dependence, the present paper hopefully proves instrumental to its prospective exploration.

A very hopeful line in this direction seems the following. Given the intrinsic, counterfactual-specified modal nature of any PD-sequence, my intra-w path already embodies both the standard alethic modality across worlds and the tense-resembling diachronic modality, or (for that matter) is already a dual modality. (This characteristic seems explicitly reflected in the time-defined counterfactual relata of the recursive PD-formula.) Along this line, Hall's contrast between the two concepts of causation might prove to be ill-suited to my notion of path.[18] In a nutshell, my path can hopefully combine Hall's dependence (difference-making) feature and the production (process) feature of causation.

A related observation concerns the paper's priority in motivating (and, to some extent, justifying) my distinctive notion of path (dependence) over possible comparative approaches, drawing on the existing literature which, as far as I am aware, is typically about functional dependence relations with entire paths as free variables, and hence not about the diachronic composition of a path in itself. Having said this, I do not intend to deny the importance or even priority of the functional approach, given typical contexts of third-person scientific explanations. If my use of 'path' is not a misnomer (not only in metaphysics but also against the standard use or its underlying premises), there seems to be no, or less, competition between the two approaches than the mere division of labour.

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①As the main thesis of the paper is not to justify the sui generis modal status of this property, I gloss over the issue by merely highlighting, instead of explaining, the feature of retrospective unbrokenness. A full explanation of its modal status seems to require the elucidation of its relations to notions such as the transitivity of dependence, a posteriori application of (PD), and asymmetry of diachronic inference. Suffice it to say for now that it is not a trivial reformulation of a definition, or a trivial claim such as 'everything that has happened just exists in the past'.

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