Artificial Life and Historical Processes

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This article attempts to describe a central theme of AL research which is a mode of explaining the phenomena of interest that appeals to certain properties of the dynamics of the processes involved, namely that these are *historical processes*. The precise meaning of this term will be explored and illustrated by the use of some examples. To this aim, the idea of what constitutes a *constraint* to a process will be examined, as well as how it relates to the dynamics of the process both in operational and explanatory terms. This will permit a specialization of the word 'historical' to processes that are able to introduce some temporal heterogeneity due to the interplay of variations at different timescales. As a corollary, it will be found that any process leading to innovations or transitions (which generate much interest within AL) is, by definition, historical.

Some of the concepts presented here are related to the ideas of scientists who have been influenced by A. N. Whitehead's metaphysics, [4–6]. However, the purpose of the article is to make a basic presentation of some central concepts in order to facilitate their subsequent use and not to provide a review and comparative exposition of the philosophical and scientific extent of these ideas.

1 From homogeneous time to historical time

There are different senses in which the word 'historical' may be applied to a process. For instance, a process may be so called if its unfolding involves a set of contingencies that cannot be predicted until the moment they occur. Such factors could take the form of discrete events (e.g., founder effects or catastrophes in biological evolution) or they could operate with constancy, in which case their effects may become manifested over long periods of time (e.g., random fixation of alleles due to genetic drift).

Another related criterion would consider adequate to apply the name 'historical' to a process if an explanation of how its current state has been attained would be best given in historical terms. Such explanations (see [7, pp. 25 – 26] and [8, pp. 283 – 284]) would account for a state or event in a process in terms of previous *key*

1.1 Constraints

All observable events and processes are underdetermined by the fixed universal laws that are presumably at play in them. The trivial reason for this is that such laws can only be universal because they are disembodied and refer to no concrete system in particular. In order to apply them to the understanding of a specific process a description must be provided of how these laws are constrained by the actual structures and conditions that make up that process.

There are two senses for the word 'constraint'. Consider a physical pendulum. A finite mass is hanged from the ceiling by a piece of string. A description of this system could be offered that would permit the application of universal dynamical laws. Thus, a series of idealisations would allow a description in terms of a zero-dimensional particle hanged from a fixed point by an inelastic string under the exclusive influence of gravity, and so forth. In mechanical terms a constraint describes those relations that place direct limitations to the variation of the variables with which the system is described, (see [9]). For the pendulum, such a constraint is found in the position of the particle which must, at all times, conserve its distance to the point in the ceiling from which it hangs.

In a second, more general sense, a constraint indicates not just these relations but also the set of parameters and other relations that make it possible to embody a universal law into a description of an actual system. If the system remains ideally isolated and such contextual factors remain fixed, it seems that calling these factors 'constraints' would be unnecessary. However, the meaning of the word is recovered when one considers that the system may participate in time-dependent coupling with other systems which, through their effect in such contextual factors, may influence the system's behaviour. Thus, the ceiling may vibrate and the length or the elasticity of the string may change with time – changes that would necessitate a redescription of the system.

It is clear though, that any addition of new boundary conditions or any re-description will end up with a new fixedly defined system and a known relation to its environment. Such a tendency for re-describing actual systems is obviously limited since future changes in the contextual (and internal) conditions need not be predictable either because of random factors or because of unexpected effects of the dynamics on the conditions which granted validity to the initial idealisations. In view of this, it makes sense to associate all these contextual factors and a description of the internal structures of the systems involved in a process under the single name of 'constraint'. In this more general sense, a constraint indicates any factor which may exert some influence on the evolution of a process as described by some generalised dynamical principle.

This usage is a generalization of the meaning favoured by S. J. Gould for the case of evolution. According to him, a constraint is "theory-bound term for causes of change and evolutionary direction by principles and forces outside an explanatory orthodoxy", [10, p. 519]. Thus, any source of change apart from the general explanatory framework for the type of process in question would qualify as a constraint. Readers familiar with the work of H. H. Pattee will also

2 Different manifestations of history

The above considerations give a rough idea of how to differentiate historical processes from processes which are non-historical or merely contingent. A historical process is a process subject to fluctuations whose dynamics affects its constraints either directly or though recurrent coupling with other processes. In order to make the meaning of these concepts clearer it will be helpful to consider some examples of historical processes. Many processes that would qualify as paramount examples, such as stigmergy, cognitive development, cultural change and social norms, structural epigenesis, the economics of increasing returns, etc. will not be discussed due to lack of space.

2.1 Trails on grass and Pask's artificial ear

Consider the trails made naturally by pedestrians on areas that are covered with grass. These trails are made by the action of walking which makes it difficult for grass to grow on zones which are frequently trodden upon. The lack of grass makes walking along the trail easier and people tend to use the trail rather than cutting across the grass, even if this implies a small deviation from the optimal route to their destination. Trail formation has been studied using a very simple and powerful individual-based model, [13]. The process is self-reinforcing and, in the bigger picture, it is also a historical process.

Let the process be the set of individual pedestrian trajectories within a piece of land covered with grass (say a square) with a few preferred entry and exit points. Walkers are driven by two preferences: they want to arrive at their destination cutting across the square and they prefer to walk where the grass is less grown. Initially, no path is marked on the grass and walkers choose a direct route to their destinations. As time passes, and for a certain frequencies of crossings, the effect of the initial trajectories will begin to be manifested in areas where the grass is worn. In the most used trajectories the effect of wear will be so much that the grass will not be able to compensate by growing again before the path is re-used. Thus, trails are formed and maintained in a dynamical equilibrium. The

ner. At any moment, the probability of extracting a black ball depends on the accumulate under high plants, etc. These alterations may have both short and long term effects.

In spite of the mutual inter-dependence between organism and environment, evolution has been approximated as non-historical by sweeping all contingent factors under the carpet of independent environmental variation. This variation is external, i.e., not part of the process itself; this is characteristic of non-historical processes. It is, therefore, not surprising that the problems related to novelty in biological evolution cannot be so easily accounted for from this perspective, [20, 21], since such innovation can only take place in historical processes.

3 O en issues and some conse uences for AL

This fairly broad exposition of historical processes, in no way comprehensive, may be enough to suggest that there is some gain in giving expression to the unifying themes implied by grouping together phenomena as diverse as the construction of wasps' nests, the development of a cognitive skill, the maintenance of a social norm, or the evolutionary conservation of a body plan. The main practical consequence of this perspective is a shift in how these phenomena are studied. History implies a subtle dynamical interplay between change and conservation. It cannot be modelled, like the above phenomena have often been modelled, as changes in the external relations between fixed entities themselves not subject to change.

Historical entities are not fixed in the sense that all changes are subordinated to their fixed identity (a point of view giving rise to extreme structuralist thinking), nor are they fully malleable, yielding without inertia to the optimisation of some objective function (a point of view that leads to some forms of functionalism). The historical perspective steers a careful middle course between these extremes by focusing on understanding why certain patterns are *durable* (as opposed to either fixed or unstable) as a consequence of, and not despite, the constant variations that make up the dynamics of the process.

An important notion in this context is that of spontaneous invariants. Once a durable pattern is constituted, understanding the dynamical relations that allow it to persist can provide a powerful frame of reference for addressing specific questions of what goes on in a complex historical process. It allows the researcher to understand why certain things can change while others remain the same. In other words it can provide a *norm* intrinsic to the process. Contained within a spontaneous invariant lies an explanation of its own perpetuation. Even if the properties of the process in need of explanation are not directly related with its maintenance, the invariant sets conditions to how these properties can change usually by limiting a high dimensional space of possibilities into a few ordered modes.

Saying that novelty and qualitative transitions can only occur in historical processes is not the same as having explained how such phenomena happen. This is indeed one of the major areas for development. What causes the disappearance or transformation of an existing durable structure? Does novelty occur when invariants cannot self-maintain any longer? Or does it occur in historical processes that do not lead to new invariants in the first place? These are important open questions that deserve further development, and in which AL simulation models may play an important role. Such models can indeed

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