A Creative Dance: Symbols, Action and the Bringing Forth of Meaning

Tim Taylor[†,‡]
[†] Timberpost Ltd
[‡] School of Informatics, University of Edinburgh
tim@tim-taylor.com

Extended Abstract

In our attempts to understand the evolution of biological, cognitive and cultural systems, critical questions arise concerning the origin of meaning. I argue that the key to success in attempts to create computational systems that exhibit the same capacities as their natural counterparts to evolve new and creative ways of interacting with their environment, beyond that which is simply "programmed into" the system from the start, lies in answering these questions.

The nature of the problem is laid bare when we consider the origin and evolution of life. A fundamental question is this: how is it possible for organisms, that follow their own goals and behave according to their own rules, to emerge in a world governed by the laws of physics and chemistry? More generally, how can agents and agency emerge in a system governed by universal laws? And even once our agents have emerged, how can the evolutionary process produce new agents that interact with their environment through previously unexploited modalities? That is, how can new sensors and actuators emerge (such as the origin of a magnetic sense in migratory birds, or the ability of some species of fish to generate electric fields), where the modalities upon which they act were not exploited in earlier species?

This second question may perhaps have more significance for attempts to *build* artificial creative systems; in the biological world the solution is largely related to the fact that the organs and structures that comprise organisms possess multi-functional properties across different modalities (e.g. strength, elasticity, electrical conductivity, sensitivity to light, etc.), and that a structure evolved for one function may turn out (initially by accident) to have beneficial properties in a different modality which may then be exploited by evolution (a phenomenon known variously in the biological literature as exaptation, cooption or preadaptation). However, when we create artificial systems, particularly software systems, the building blocks of the system are not generally multi-functional, and this is one of the reasons why the evolution of new sensors and actuators has become an important issue in this context.[1]

However, the solution to the problem of evolving new forms of interaction requires more than just using multi-functional building blocks. To make progress in this area, and on the more fundamental question of the origin of agency, requires a shift of focus away from the properties of individual agents, to consider the dynamic nature of the environment and the relationship between agents and environment. In a previous paper I set out an argument for modelling agents and environment as a single dynamical system (Taylor, 2004) [see also (Taylor, 2001)]. The argument was influenced by the biosemiotics literature, and, in particular, the work of Howard Pattee; biosemiotics offers important insights for addressing these issues.[2]

Pattee argues that the distinction between the material and symbolic aspects of living organisms, seen as an example of the more general epistemological distinction between laws and initial conditions, is a defining feature of life, and also a necessary condition for open-ended evolution (Pattee, 1995a; Pattee, 1995b). He explains the relationship between the two as follows:

> Writing symbols is a time-dependent dynamic activity that leaves time-independent structure or record. . . . Symbols are read when these structures re-enter the dynamics of laws as constraints. Any highly evolved formal symbol system may be viewed as a particularly versatile collection of initial conditions or constraints, often stored in a memory, producing significant or functional behavior that is usefully described by locally selected rules rather than physical laws. . . . [A]ll symbol systems must have material embodiments that obey physical laws. But for the reasons just stated, the lawful description of symbols, even though correct in all details, can reveal no significance. (Pattee, 1995b)

The symbols recorded on the genome ultimately acquire se-

[1] See (Dautenhahn et al., 2001) for a special issue of the *Artificial Life Journal* devoted to the topic of sensor evolution.

[2] Also of interest here is work on phenomenology and existential philosophy that asks similar questions from the point of view of the agent rather than the system; that is, how does an agent learn to distinguish itself from its environment? See, for example, (Jonas, 1966; Macmurray, 1957).

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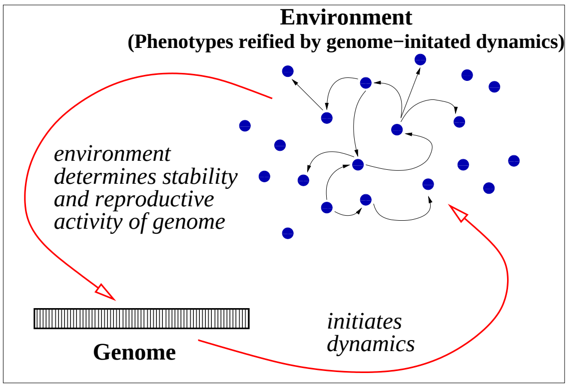

Figure 1: Semantic Closure: Closing the loop between genotype, phenotype and environment

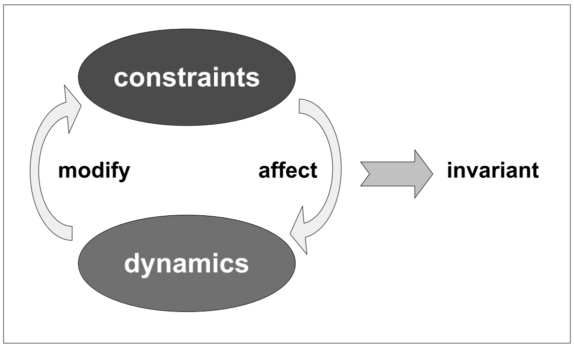

Figure 2: An Historical System

mantics in an organism in the context of the survival value of the dynamics that they initiate (i.e. natural selection of phenotypes). It is this autonomous structure-function self-referent organisation that is entailed in Pattee's term "semantic closure" (Figure 1).

This perspective, then, sees organisms as entities whose phenotypes are embedded within an environment viewed as a dynamical system, and whose genotypes interact with the environment by specifying constraints[3] upon its dynamics, thereby generating the phenotypes. That is, the abiotic environment has its own dynamics and self-organisational properties; genotypes act to "sculpt" these pre-existing dynamics by supplying constraints. From this point of view, the most important distinction is not between organisms and their abiotic environment, but rather between the environment as a whole (including organism phenotypes) and organism genotypes. It is the relatively time-independent genotypes, by supplying local constraints to the dynamics of the environment, that reify phenotypes as distinct entities within the environment.

In (Taylor, 2004) I presented initial results from a model based upon this perspective, and demonstrated simple examples of the evolution of new sensors and effectors, and of genome-regulated self-stablising behaviour (i.e. an example of an historical system as described below).

I argue that this perspective is crucial if we are to understand the origin of agency. However, we can go further and generalise this picture. In so doing, we may find useful connections and analogies between biological, cognitive and cultural systems, and thereby gain a better understanding of how creativity may be instilled into artificial systems.

Pattee's concept of semantic closure is related to what (Di Paolo, 2001) has referred to as an historical process (Figure 2).[4] This describes a situation in which the constraints of the system initiate dynamics, and the dynamics may feed back to affect (select or modify) the constraints. In a situation such as this, the system may exhibit behaviour which cannot be explained purely by the laws of dynamics, but only with reference to the particular history through which the system has evolved from its initial to current state. This mutual interaction (or "creative dance") thereby brings forth novel forms of behaviour, the meaning of which can only be understood by considering how the dance itself has evolved over time.

This general description can be applied not only to the origin of meaning in biological systems as described by Pattee, but to other systems too. Examples of systems where this view may also be of use include:

- *Human cognition*. The embodied mind literature, e.g. (Varela et al., 1993) recognises the mutual relationship between cognition and processes in the environment. The extended mind hypothesis goes further to suggest that external props to cognition, such as the written word, are so closely coupled with internal cognitive processes that cognitive systems should properly be regarded as comprising both the internal and the external components working together (Clark and Chalmers, 1998). The extended mind hypothesis could be cast as a mutual relationship between symbols in the environment and the dynamic processes of the brain. As such it can be seen as fitting into the general description of an historical system.

- *Human cultural traditions, institutions and artefacts*. The historical system view may be extended to cover not only human cognition, but cultural evolution as well. The archaeologist Colin Renfrew has recently argued that human cultural evolution can only be understood by consideration of the particular trajectories through which specific cultures have evolved, and by consideration of how

[3]Throughout this paper the general term 'constraint' is used to cover initial conditions, constraints and boundary conditions. For further discussion of these concepts, see (Pattee, 1995a).

[4]Similar concepts appear much earlier in the literature, such as Ashby's description of an ultrastable system (Ashby, 1952).

institutional facts arise through the mutual interaction between cultural symbols and engagement with the material world (Renfrew, 2007). This view clearly has strong similarities to the general picture of an historical system outlined above. However, when considering cultural evolution, it is also important to ask why other species, such as chimpanzees, exhibit some capacity for the cultural transmission of behaviour, but nevertheless seem to lack the capacity for building more complex behaviours on top of simpler learned behaviours, and therefore fail to show cumulative cultural evolution (Marshall-Pescini and Whiten, 2008).

Consideration of the extent to which such analogies hold between these very different systems, and the commonalities and differences between them, will surely lead to a much deeper understanding of the generative causes of novelty and creativity, and the origin of meaning, in natural systems. And such understanding will suggest ways in which we may create artificial systems with a much deeper capacity for creativity than exhibited by previous attempts.

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