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Asymmetry of Behavior and Evolution

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Abstract

In this paper I discuss the relevance of asymmetric processes in living systems, both in a procedural and structural perspective. I do not consider behavior as ahistorical logical problem-solving. Rather I emphasize the anticipation-driven nature of behavior and hence cognition. On a structural level it is evident that the growth of behavioral competence, similar to biological structures, has to build on previously available components. However, reversibility can occur. Finally I will outline the implications of asymmetry for the design of artificial life systems.

1 Introduction

When a snake is chasing a mouse, it uses its eyes exclusively. None of the other sensing modalities of the snake are involved [Sjölander, 1995]. When it comes to strike the mouse, the snake switches to olfaction. It then "assumes" that the prey is no longer able to move and starts to swallow it by employing its touch sensors. An observer will evidently get the impression that the hunting strategy of the reptile is like a relay race in which each modality passes the courier over to the next one, trusting the fact that the predecessor did its job correctly and provided a context in which the current modality will suffice. In other words, the phylogenetic development of the snake equipped the animal with some kind of implicit anticipatory mechanism which draws on the fact that each action will generate a new context suitable for the next piece of the action sequence. Such an anticipatory strategy is not limited to animals unable to integrate various sensor channels into one coherent picture [Riegler, 1994]. Sjölander [1995] pointed out that a dog hunting a hare "does not need a full picture of a recognizable hare all the time to conduct a successful hunt. It is able to proceed anyway, guided by glimpses of parts of the hare, by movements in vegetation, by sounds, by smell, etc. If the hare disappears behind a bush or in a ditch the dog can predict the future location of the hare by anticipating where it is going to turn up next time, basing this prediction on the direction and the speed the hare had when seen last." We hypothesize from these examples that animals seem to be able to *anticipate future events.*

As I will show in the remainder of the paper, the anticipation-driven character of behavior has implications for not only the procedural, i.e., observable level but also for the internal structural level of biological systems. The structural design of artificial life systems should therefore bear similarities to the physiological structure of existing biological systems.

2 Irreversibility of Behavioral Performance

Although the presence of anticipation as the basic element of behavior is somewhat fundamental in nature, in artificial systems the computation of behavior is performed differently: It corresponds to the information-processing paradigm that defines the cognitive system as a bottleneck. A wealth of "information" is provided by the "outside" environment from which some essential features must be selected in order to decrease the enormous amount of complexity. This methodology requires high computational performance: In particular, one has to provide the simulation of the entire visual environment and to provide a mechanism to extract all its important features.

Furthermore, the information-processing paradigm leaves many basic issues open. The most prominent are (1) the Frame-Problem, which testifies the fruitless hope that we could formulate knowledge about the world and possible actions therein in an appropriate symbolic way; and (2) the Symbol-Grounding Problem which addresses how the meanings of symbols can be grounded in anything but other symbols, thus rendering the entire system meaningless. Alone these two problems leave the question of appropriate representation of non-trivial environments open [Peschl and Riegler, 1999]. Dennett's well known analogy [1984] illustrates the shortcomings of the assumption that creatures can tackle their struggle for life in terms of such an ahistorical logical reasoning. Too many logical implications of even the simplest actions have to be taken into account in such a framework. This results in endless computations that prevent creatures from taking those actions.

Evidently, the information-processing paradigm resembles what Popper [1979] calls the *Bucket Theory of Mind.* This is the idea that "there is nothing in our mind which has not entered through our senses". Cognition — and here cognition can be understood in its broadest sense, namely as the capabilities necessary to successfully cope with an environment—is metaphorically seen as a bucket that is incrementally filled with knowledge through or sensory organs, like an information retrieval agent fills its database with information chunks from the internet.

Popper also offers an opposite perspective. The *Searchlight View* emphasizes that individuals[1] actively construct knowledge in the form of apriori unjustified theories. Experience does not provide these theoretical conjectures. Rather, observations are used to select among competing theories and eventually weed out unsatisfactory ones. In other words, we first construct our world-view. This leads to anticipations which can be tested. As long as expectations match with ongoing experiences we maintain our scaffolds of conjectures. Whenever anticipations are not fulfilled we are likely to re-construct them. The Searchlight view therefore corresponds to what I initially called anticipation-driven behavior.

Indications in support of this view are abundant. The egg-retrieving behavior of geese is yet another example for embedded anticipations in animal behavior [Riegler, 1994]: Although ridiculously simple-minded at first sight, the behavior of the goose is evolutionary successful as it integrates the proper anticipations. With regard to perceptual competence, Sacks [1995] delivers an excellent example. He describes the case of a man, Virgil, who had been blind since early childhood. At the age of fifty his eye light was restored. In contrast to the general expectation, this was no help for Virgil since the way he has been living as a blind was incompatible with the way normal sighted people perceive and organize their world. With effort and practice, he was able to interpret some of the visual data in terms of the world as he had known it through his other senses, but he has immense difficulty in learning these interpretations. For instance, visually he cannot tell his dog from his cat. For him, due to the lack of visual impressions, the temporal aspect of his world had priority. He recognized things by feeling their surface in a particular order. His didn't get lost in his own apartment because he knew that after entering he would encounter the various pieces of furniture in a particular sequence which he perceived in a temporal order. To put it differently, he was living in world of anticipation, of subsequent checkpoints which act like the handing-over in a relay race. A particular cupboard was followed by a table, so once he reached the cupboard he anticipated to go to the table with the next step. Apparently we live in another world, where items are recognized "immediately" by visual perception. But are they? Lessons from artificial intelligence show that image recognition can't simply rely on visual clues only. More likely, we also apply a certain order of recognition steps when we look at things.

We can extend the principle of anticipation even further towards human behavior. Classical experiments reveal the "if it ain't broken, don't fix it"-psychology in human cognition [Riegler, 1998]. Test subjects fail to accomplish given tasks since their minds are set in certain canalized ways of looking at things and problem-solving. Observations from every-day life support this result, as we find ourselves in situations, in which things are used in one particular context. For example, we use a hammer to drive nails into a wall, matches to light a fire. In fact, things do not seem to exist "outside" their domains of functionality because the anticipation of the result of dealing with things very much determines our cognition.

Unavoidably we arrive at the insight that observable behavior and cognition are asymmetric processes which clearly point forward in time. What can be said about the underlying structure of behavioral systems? Are their evolution and ontogenetic development asymmetric too?

3 Irreversibility of Structural Development

To investigate the role of asymmetry in the creation and development of behavioral structures, it is worth considering some examples. For many years evolutionists have been puzzled by a phenomenon known as Haeckel's Law. It states that the ontogenesis of individuals is the shortened recapitulation of phylogeny in the form of extracts, that during the ontogenesis of individuals, phylogenetically old patterns are repeated. For example, in early embryological periods, mammals develop a complete gill circulation although gills are completely useless for mammals in their environment. This phenomenon can best be explained by assuming some kind of "tradition" in the phylogenetic tree. Tradition adds a time scale to the previous principles, i.e., it describes the handing down of identical information. No organic state exists without tribute to its ancestry, so that all building states are subsequent series of coordinations. Within rudimentation processes, to give another example, the chains of information can only be cut at their ends. So it can be stated that the way in which the eye of a cave fish has been decomposed is the exact reverse of the evolutionary process that formed the previously fully-featured eye of the cave fish' predecessor. Apparently, reversions of development can occur[2]. Strictly speaking, such a reversal of biological features cannot be considered an evolutionary process, as it takes place in the absence of evolutionary pressure. The sight of the cave fish did not disappear due to selection for simplicity but because having sight or not has become irrelevant in the environment of the fish. Therefore, the reversed "development" is a result of undirected mutations [Heylighen, 1999]. Transferring this idea to the behavior level we can say that unlearning a certain behavior, for example, is not a directed developmental process but the result of not using it. If we think of the phenomenon of forgetting this becomes quite obvious.

As explained by Riedl [1977], the tradition-principle can be interpreted as the effect of interdependencies among components, which result in system-internal canalizations. Due to these interdependencies and hierarchical structures among genes, the freedom of variability is enormously restricted, compared to the standard model of evolution. Old subsystems like *chorda dorsalis* are

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[1] Although Popper's essay preliminarily addresses philosophy of science, it has a wider range of applications in the sense that scientists are cognitive systems as well as animals of different levels of sophistication.

[2] The probability for the reverse process is smaller. We might therefore better speak of asymmetry rather than reversibility [Heylighen, 1999].

irreplaceable and have high functional burden. Therefore it can be found in virtually all succeeding life forms. The chances of successful mutations are very small. Exactly this is shown in Haeckel's Law. As old patterns are the basis for newer ones, they have to be repeated during ontogenesis.

What can we learn from this biologically motivated example about the behavioral component of artificial systems? Although canalization was primarily proposed for morphological structures, one may apply it to knowledge structures as well [Riegler, 1994]. In this view, thinking is a canalized process which builds upon previous knowledge structures. This yields the advantage of speeding up developmental processes at the expense of building a rigid system consisting of interdependent parts[3].

Suppose we equip an artificial creature with a knowledge system that is composed of sets of connected production rules. Such rules consist of distinctions (A, B) which may have a fuzzy character. The distinctions are connected in the form of elementary predictions ("if A, then B") in which both sides may consist of chains of sub-ordinated distinctions. Learning takes place by modifying the elements of the rules, i.e., adding, dropping, and rearranging. This produces a potentially vast number of combinations, like we find in any natural context. By introducing interdependencies and hierarchical arrangements the evolution of these knowledge systems can be canalized in order to escape combinatorial explosion without becoming arbitrary [Riegler, 1994].

Concretely speaking this means to provide a structure which the snake in the introductory example obviously doesn't have. These three modalities which are employed sequentially could be centralized as attributes of a central construct—a mouse, for example. If such a mouse vanishes into a mouse hole it no longer exists for a snake, while a cat, for instance, remains in front of the hole and waits for the mouse to re-appear. Under normal circumstances, the snake need not know the concept of an entire mouse. It only perceives the mouse in slices of modalities. One could encompass its hunting behavior in three rules. R1: if see mouse then come closer. R2: if close to mouse then strike. R3: if struck then start eating. For a snake these are merely 3 subsequent rules, for us humans (as for most mammals) it forms the concept of a mouse. In this perspective, we can say that any concept is a collection of single rules and other, simpler concepts. We conclude that knowledge is then a hierarchical scaffolding of rules in which rules at a higher level (i.e., concepts) are dependent on lower-level rules. Now evolution made a snake a good hunter. That is, R1–R3 are "approved" by a sufficiently high rate of success of hunting each time the creature felt hungry. Thus there are good reasons for keeping these set of rules (i.e., this concept) rather than any other set of rules—they become "stable forms" in the words of Simon [1969]. The advantage is evident. From now on, the new concept can be used as an elementary component in higher order concepts. Not only mice can be potential preys to snakes but also other small animals. While a biologist would now start a hierarchical classification of the animal kingdom, a wild animal could find this information useful to extend its menu without multiplying the same hunting strategy for different animals[4]. In even more detail, the behavioral component of the artificial system should look separately at conditions and actions. Conditions are interpreted as the "recognition" capabilities of the system—distinctions in the above sense—, whereas the "then"-part specifies possible actions. This way it is easy to assign one and the same action strategy to different perceivable objects. To go even one step further, the system may distinguish between "ontogenetic" and "phylogenetic" sets of rules. Compound rules may contain components from both sets. This way it becomes possible to build individual experience upon inherited ("inborn") knowledge.

Is the evolution of such an (artificial) behavioral system irreversible? In biological systems, clustering of independent genomes is irreversible which renders adaptations to changing environments more difficult. These so-called *genetic loads* [Riedl, 1977] are the reason why a giraffe has the same number of neck bones as a dolphin although it could use more in order to increase its pliancy. In our artificial system we find a similar situation. Compounds that have been approved by their evolutionary success are treated as elementary components by compounds at higher levels. The earlier a compound appeared in the history of the system the more likely it is that many other structures are dependent on it. Deleting such an old component (say, the concept that describes a prey) will let the entire system collapse like a card house. While there is always a theoretical chance that a component can be replaced by another component that fulfills an analogous role, chances are higher that components are successfully added than removed[5]. This evokes the idea of a non-strict irreversibility (or asymmetry) again. Systems, whether natural or artificial, are driven into a continuous complexification of their structure thus yielding asymmetry in time.

The implications for evolution are evident. The inherent tendency of evolution is to always explore the neighborhood but this is constrained by the interdependencies among components. Any evolutionary explanation has to take this into account. So have artificial learning techniques which employ evolutionary principles. In such evolutionary scenarios, complexification of structures is implicitly assumed. Gould [1996] pointed out that the identification of evolution with complexification is the result of a heavily biased and hence misleading view of the course of evolution. As the successful existence of single-cell animals shows, there is no evolutionary pressure in the traditional sense towards complexification of structures, including the development of higher cognitive abilities. But clearly, behavioral and cognitive competence have been developing over millions of years. In absence of any evolutionary pressure, the responsible mechanism is canal-

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[3] Similarly, Simon [1969] pointed out that "hierarchic systems will evolve far more quickly than nonhierarchic systems of comparable size" since the "time required for the evolution of a complex form from simple elements depends critically on the number and distribution of potential intermediate stable forms".

[4] We apply the same principle when we partition a computer program into subroutines.

[5] This finding is supported by Ho and Saunders [1976].

ization which is a result of the interdependency of subcomponents. Given this perspective evolution has a direction and is asymmetric without being equivalent to progress.

4 Conclusion

In this essay I discussed the relevance of temporal asymmetry for biological, and by extension, for artificial life systems. Both performance and developmental aspects of such systems are irreversible in a weak sense. On the one hand, behavioral competence is grounded in the ability to generate anticipations, and thus clearly headed forward in time. On the other hand, the evolution and development of living systems follows the principle of canalization which forces irreversible complexification upon the system in question. I conclude the paper with some general guidelines for artificial life which follow from the these ideas.

1. Artificial life systems should be capable of generating anticipations. This not only reverses the usual way of information processing, thus eliminating its bottlenecks, it also renders exogenous fitness functions obsolete. The success of a creature is determined by how often the anticipations are met. To this end a rule contains checkpoints which try to match the current state of anticipations with observations of selective endo- or exogenous variables.
2. Learning can be easily attached to such a system. A rule is deleted or modified in case the anticipations are not fulfilled at its checkpoints.
3. Systems that can evolve their components in a hierarchical way are faster than flat systems. Evolution-approved components are integrated into compounds, thus re-usable for similar tasks.
4. An easy way to take advantage of hierarchical behavioral systems is by employing a rule-based system. It has the additional advantage of keeping the system within reasonable limits.

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