# Bayesian methods and Universal Darwinism

John Campbell

Introduction

During its 14 billion year history the universe has evolved from a uniformly low entropy space to a space containing both low and high entropy entities.

Since the Big Bang low entropy entities have evolved including atomic physics, chemistry, life and culture that make up the bulk of scientific subject matter.
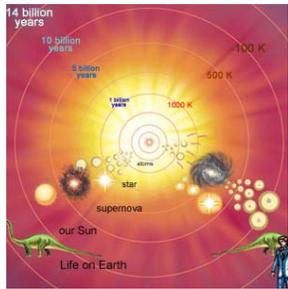

Theories within Universal Darwinism including Quantum Darwinism, Natural Selection and Memetics explain the creation and evolution of these low entropy systems as due to the operation of Darwinian processes.

Continued existence of those low entropy systems that are most familiar such as biology and culture depend on adaptations that constrain the system from reaching states of higher entropy. These adaptations involve sophisticated knowledge or models of the outside world and how to trade off entropy production with their environment.

To maintain internal models that are fit to their environments requires inference and updating. Bayesian methods provide the unique method of performing inference and updating in situations where knowledge is incomplete.

Maximum Entropy predicts that systems will evolve to states of higher entropy unless constrained to do otherwise by prior information or scientific law. Many of these constraints existing in the natural world may take the form of adaptations produced through Darwinian processes.
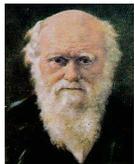
Definitions

Universal Darwinism: The set of scientific theories that utilize a Darwinian process as their central explanatory method. A few examples are evolution by natural selection, evolutionary archeology and quantum Darwinism.

Darwinian process: Any process that follows the three step Darwinian algorithm abstracted from natural selection.
1) Replication
2) Inheritance of some characteristics that have variation amongst the offspring.
3) Differential survival of the offspring according to which variable characteristics they possess.

Bayesian Methods and Darwinian Processes

Evolutionary Epistemology, following on the work of Donald Campbell and Karl Popper, treats systems of knowledge, including science as evolving through the operation of a Darwinian process. In this model of science theories are copied or learned by others, often with variations and the survivability of a varied theory is dependent on how well it is supported by the data.

Of course 'how well it is supported by the data' is a measure supplied by Bayesian methods. The Bayesian process of updating likelihoods in view of new data or additions to the competing theories may be considered analogous to a Darwinian process.

Darwinian process	Bayesian Process
Replication of system	Copies of the competing models brought forward along with the relevant prior data.
Inheritance of some characteristics that have variation amongst the offspring.	Variations in likelihoods amongst the competing models as provided by new data in accordance with Bayes' Theorem.
Differential survival of offspring according to which variable characteristics they possess.	Differential survival of competing models according to their Bayesian likelihood.

Theories within Universal Darwinism treat knowledge structures found in nature including genetics, neurology and cultural artifacts as the creation of Darwinian processes. The evolution of knowledge structures, maintaining high fidelity models of their environments, implies inference and is analogous to Bayesian methods.


Figure 1 A schematic for adaptive systems containing internal models of their environments that are inferred, through Bayesian methods, from prior data. These models are tested by new data or experience in the environment and updated when surprised.

Maximum Entropy and Universal Darwinism

The principle of Maximum Entropy tells us that given the pertinent constraints systems will evolve to the states of highest entropy available to them. The constraints of Maximum Entropy often take the form of prior information or scientific law.

Systems that are able to maintain themselves in states of low entropy must possess constraints prohibiting any avenues of net increased entropy when interacting with their environment. The strategies employed by many low entropy systems found in nature involves the evolution of designs or adaptations specifically fit to their environment that serve to constrain the system from achieving states of higher entropy.
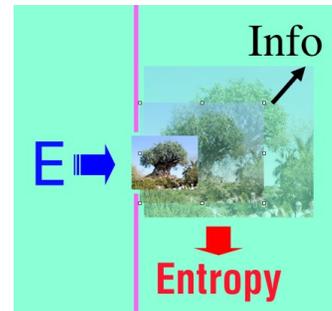
It is proposed that much of scientific law or prior knowledge may be understood as generalizations of those rare but widely distributed design details, discovered by Darwinian processes, that are capable of maintaining states of low entropy and that are central to their continued existence. It is suggested that much of scientific subject matter is the accumulated adaptations discovered over evolutionary history by Darwinian processes.

Discussion

Eugene Wigner famously remarked on the unreasonable effectiveness of mathematics in the natural sciences. Max Tegmark has provided the somewhat obvious explanation that the natural world is isomorphic to a mathematical structure that we are slowly discovering.

The case might be made that wherever knowledge exists in the universe it is most probable to have been created through a process of inference. The unique mathematical method of inferring plausible knowledge is Bayesian methods and the scientifically validated process for the creation and evolution of knowledge systems is the Darwinian process.

Low entropy systems introduced prior in the universe's history to the emergence of life, such as atomic physics and chemistry, are not generally considered to employ knowledge structures in order to maintain their low entropy status.

The theory of Quantum Darwinism argues that each quantum event or 'update' occurring in reality should be understood as a Darwinian process. Theories such as this hold promise for extending the scope of Universal Darwinism to fields such as atomic physics and chemistry along with an Bayesian understanding of their nature.

Literature cited

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Acknowledgments

For further information

Please contact *john@universaldarwinism.com*. More information on this and related research can be obtained at *www.universaldarwinism.com*. A .pdf copy of this poster is available at: http://www.universaldarwinism.com/Bayesian%20Methods%20and%20Universal%20Darwinism%20Poster.pdf