Biologically Inspired Cognitive Architectures xxx (2016) xxx–xxx

Contents lists available at ScienceDirect

Biologically Inspired Cognitive Architectures

journal homepage: www.elsevier.com/locate/bica

Review article

# Epistemological foundations of investigation of cognitive evolution

Vladimir G. Red'ko *

*Scientific Research Institute for System Analysis, Russian Academy of Sciences, Moscow, Russia*
*National Research Nuclear University MEPhI (Moscow Engineering Physics Institute), Moscow, Russia*

ARTICLE INFO

*Article history:*
Received 10 September 2016
Revised 2 October 2016
Accepted 2 October 2016
Available online xxxx

*Keywords:*
Modeling of cognitive evolution
Cognitive agents
Animal cognitive features
Epistemological foundations

ABSTRACT

Epistemological foundations for modeling of cognitive evolution are characterized. Cognitive evolution is the evolution of cognitive abilities of biological organisms. The important result of this evolution is the human thinking, which is used at scientific cognition of nature. The related epistemological viewpoints of David Hume, Immanuel Kant, Konrad Lorenz, and Eugene Wigner are outlined. The sketch program for future investigations of cognitive evolution is proposed; initial models of these studies are outlined. According to the presented analysis, it is possible to believe the following. Investigations of cognitive evolution are directed to analyze the fundamental problems: "Why is *human* thinking applicable to cognition of *nature*?", "How did human thinking origin in the process of biological evolution?" There are powerful backgrounds for considered investigations: (1) models of autonomous cognitive agents, (2) biological investigations of animal cognitive features. Studies of cognitive evolution would have broad interdisciplinary relations. These studies should contribute significantly to the development of the scientific point of view.



**Contents**



* Address: Scientific Research Institute for System Analysis, Russian Academy of Sciences, Moscow, Russia.
*E-mail address:* vgredko@gmail.com

http://dx.doi.org/10.1016/j.bica.2016.10.001
2212-683X/

Please cite this article in press as: Red'ko, V. G. Epistemological foundations of investigation of cognitive evolution. *Biologically Inspired Cognitive Architectures* (2016), http://dx.doi.org/10.1016/j.bica.2016.10.001

## Introduction

The goal of this work is to describe epistemological foundations of investigation of cognitive evolution. Cognitive evolution is the evolution of cognitive abilities of biological organisms. The important result of cognitive evolution is the human thinking, which is used at scientific cognition of nature. Approaches to modeling of cognitive evolution have been described in several our papers (Red'ko, 2000, 2015, 2016).

It should be underlined that modeling of cognitive evolution is directed to investigation of the fundamental problems:

- How did human thinking emerge in the process of biological evolution?
- Why is the human formal thinking applicable to cognition of the nature? In particular, why are the human formal logical inferences (which are used in mathematical proofs) applicable to cognition of the real nature?

The main method of study of cognitive evolution is investigation of models of autonomous cognitive agents.

There are backgrounds for modeling of cognitive evolution both in several areas of computational science, which include investigation of models of autonomous agents, and in biological studies of the cognitive abilities of animals of different evolutionary levels.

The current paper pays the special attention to epistemological foundations of investigation of cognitive evolution. Initially we will characterize the epistemological problem of the applicability of human thinking to the cognition of the nature. Then the conceptions of philosophers, who were thinking about similar problems, are outlined. Further, we will describe some conceptual approaches and schemes that can be used in future investigation of cognitive evolution. Additionally, the sketch program of modeling of cognitive evolution and first models, which were developed in accordance with this program, are outlined.

The essential idea of our approach is the following: the most serious cognitive processes are processes of scientific cognition.

## Philosophical backgrounds for modeling of cognitive evolution

### *Epistemological problem*

So, what is the problem?

There is the science. The science is the cognition of the nature. However, are humans able to cognize the laws of the nature?

Let us consider the physics, the fundamental natural science. The power of physics is directly related to the effective use of mathematics. However, the mathematician proves theorems, deduces the results, using the formal logical thinking, which seems absolutely unrelated with external world. Why are the results obtained by the mathematician applicable to the real nature? Why is mathematics applicable in physics?

Generally, the problem can be stated in the following form: *why is our human thinking applicable to cognition of nature?* This is especially important for the scientific cognition: creating the great scientific picture of the world, the scientists inevitably use their logic, their thinking.

Is it possible to analyze the problem constructively? In order to begin such analysis, we can reason as follows.

Let us consider the simple logical rule that the mathematician uses in deductions, namely: "If there is the statement $A$, and the statement $B$ is the consequence of $A$, then there is the statement $B$", or

$$\frac{A, A \rightarrow B}{B}. \quad (1)$$

For example, we can consider the following case: $A$ is the already proved theorem, and $B$ is the theorem, which is the consequence of the theorem $A$, then, according to this rule, the theorem $B$ is proved too.

Let us go from the mathematician to the dog, which is trained to form a classical conditioned reflex. During the elaboration of the reflex, the following relation is stored in the memory of the dog "*US* follows after *CS*", or $CS \rightarrow US$ (*CS* is the conditioned stimulus, for example, the sound of the bell, *US* is the unconditioned stimulus, for example, the food). After the elaboration of the reflex, the dog after the appearance of the conditioned stimulus, using the stored relation $CS \rightarrow US$, makes elementary "conclusion":

$$\frac{CS, CS \rightarrow US}{US}. \quad (2)$$

And the dog waits for the *US* (for example, when the dog waits the food, it salivates).

Of course, the application of the purely deductive rule by the mathematician and the inductive "conclusion", which makes the dog, are clearly different. The contexts of the causal relationships in these two cases are different: in the first case, $B$ is the formal logical consequence of $A$; in the second case, the causal relationship between the events of the *CS* and the *US*, following one after another in time, is formed and stored during empirical observation. However, in the first and the second cases we consider the causal relationships between mathematical statements or real events: the statement $B$ is the consequence of the statement $A$, the *US* follows after the *CS*. So, could we think about evolutionary roots of logical rules used in mathematics? Yes, we can, because the formal logical conclusion of the mathematician and the inductive "conclusion" of the dog are qualitatively similar.

Thus, we can think about evolutionary roots of logic, thinking, and intelligence. It would be very interesting to investigate the evolutionary origin of thinking. The serious way of such research is to build the mathematical and computer models of the key cognitive properties of biological organisms at different evolutionary levels. In order to illustrate the evolution of the cognitive abilities of biological organisms, we can consider such properties of biological organisms, as unconditioned reflex, habituation (extinction of the response to biologically neutral stimuli), classical conditioning, instrumental conditioning, chains of reflexes, ..., logic (Voronin, 1977), see Fig. 1.

Thus, it is possible to investigate the models of cognitive evolution in order to characterize a general picture of the evolution of cognitive abilities of animals and the evolutionary origin of human thinking.

Naturally, such research is a huge area of investigations, and the task of creating a theory of the evolutionary origin of human thinking, the task of modeling of cognitive evolution can be regarded as an ultimate goal of these investigations. Nevertheless, this task is very interesting and very important from the point of view of development of the scientific worldview, scientific understanding. This study can provide better understanding of the reasons of the applicability of our thinking in scientific cognition. These investigations would be able to strengthen the foundation of the whole building of the science.

However, before developing the models, let us consider, who else was thinking about similar issues. Firstly, let us consider the philosophical aspects, which were analyzed by David Hume, Immanuel Kant, and Konrad Lorenz.

### *Hume → Kant → Lorenz*

In 1748 David Hume wrote "Philosophical essays concerning human understanding" (Hume, 1748), where he called into ques-

Please cite this article in press as: Red'ko, V. G. Epistemological foundations of investigation of cognitive evolution. *Biologically Inspired Cognitive Architectures* (2016), http://dx.doi.org/10.1016/j.bica.2016.10.001