

# Abstraction Based Information Technology

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## Extended abstract

This is a position statement on what is an abstraction. We start from a definition arising from works on mechanized reasoning and extend it to different fields of science. Usually, any researcher in any field labeled with the adjective “theoretical” claims to set his/her work in an abstract formalism. A first goal is to assess whether such claims are true. In fact, we intend to show through some selected examples that this would imply that an abstraction is “only” a model or a theory. This is not satisfactory or sufficient. The examples are based upon many years of experience in domains as diverse as theoretical physics, computer science (CS) or the interdisciplinary field of culture. A motivation for this work is coming from the evolution of artificial intelligence (AI) resulting from the extraordinary progresses achieved in recent years by computer technology, both at the hardware and software levels. The claim that within a few years computers will be more efficient than (most) human brains can no longer be disregarded, although this may seem very unpleasant for many scientists or humanists. In addition, the hypothesis that brains have mainly a virtual approach to the world enables to investigate a concept of abstraction in AI. A first assumption is that AI is not simply a subfield of CS but a paradigm to mechanize reasoning processes when dealing with the real world. A second one is that we interact with the world through computers and thus we need to model information technology through abstract models. We call this abstraction ABIT (abstraction based information technology).

## Abstraction in AI and CS

In the early days of CS, algorithms were often seen as an abstract formulation of procedures. Nowadays, this workshop illustrates well that category theory is associated to an abstract formulation of CS. The example of computer algebra teaches us that such methodologies do not amount to a full abstraction paradigm. Giunchiglia and Walsh introduced theories of abstraction for mechanized reasoning in a context of logic. This was probably the first “reasonable” and complete attempt at abstraction in AI. Giunchiglia and Talcott built on this approach to design the Open Mechanized Reasoning System. Calmet and Homann used a similar approach for computer algebra. The two attempts were combined for symbolic computation systems (OMSCS). Relevant references are found in [1, 2]. Recently there has been a renewal of interest in abstraction in AI through the SARA workshops held at IJCAI 2005 and 2007.

The open mechanized approach defines an abstraction as a three levels architecture: Theory, control and environment. One needs first to have a theory (algorithms for instance), then one adds control (a programming language for instance) and finally one considers the environment in which this controlled theory will be active. It is possible to prove that computations do terminate, are unique and correct. Extension to numerical computations has been investigated [3].

Although the Open Mechanized approach looks mainly meaningful for computational processes, its three levels structure is suitable to abstract the concept of multi-agent systems (MAS) when one adopts the Agent Oriented Abstraction (AOA) paradigm. AOA consists of 6 definitions [2]. The first four ones deal

respectively with the definition of an agent (annotated knowledge coupled to a decision mechanism), the decision mechanism, the knowledge annotations and the utility of a decision mechanism. This first group defines a theory. Definition 5 introduces the concept of a society of agent. This corresponds to the control imposed on a theory. The final definition is related to the specialization of the theoretical concepts defined so far and illustrates the interaction of a controlled theory with its environment. AOA was designed without noticing first that it is a facet of open mechanized reasoning. In fact, it is only when trying to get a formal view of AOA through category theory that the link became apparent.

Computer algebra is a domain where category theory has always been a bit controversial. Axiom was the first system based upon category theory. However, it used more words than facts from category theory. Then, only types (the domains of definition of operators) were specified not the properties of operators on these domains. Another attempt [4] was more ambitious but does not lead to an efficient computer algebra system. A lesson learned from these attempts is that none of them is truly a full abstraction. They do address the theory (the algorithms), partly the control part but never the link to the environment. The extension to scientific computing teaches that it is only necessary to select a given theory to represent objects. In this case one may select either the basic 5 numerical procedures or some specialized arithmetic such as the interval arithmetic.

### **Information technology**

We interact more and more with our environment through service oriented architectures (SOA). They cover a large scope of tasks such as access to web services or legal component of trust systems. It is worthwhile noticing that legal reasoning is suitable for the ABIT approach [5]. A useful application of AOA is the design of a decision support system applied to the domain of insurance where decisions are made under uncertain knowledge [6]. Another application deals with the sharing and exchange of knowledge. A tool coming directly from AOA is called virtual knowledge communities (VKC). It allows representing corporate knowledge for instance. Relevant references are found in [7].

### **Physics**

The goal of this section is to illustrate that a theory is mainly a model and, but this is very controversial, does not warrant to be given the label of abstraction. An example taken from history was the computation of the anomalous magnetic moment to prove that quantum electrodynamics is a theory. This amounted to validate the existence of a renormalization group model. By the way, such computations have certified computer algebra systems as reliable computational tools. When the integration into the theory of the weak and strong interactions became necessary, the “model” evolved. It is well known that to extend the renormalization group model to gravity, leads to the so-called string theory. This may be seen as successive theories with some control but, in the case of string theory, with little understanding of the link to environment since the universe might be too small for an experimental validation of the theory. What are the links with information technology? Besides the computational requirements, we base quantum computing on these theories. Also, we investigate the design of algorithms to solve systems of partial differential equations (PDE). We will simply outline one feature of each problem. Physics is described by systems of PDEs, any such system is set within a given physical model such as Einstein’s equations. To have an abstract formulation we must understand first the mathematical problems before modeling some physics: How to construct the general solutions of such systems. We do not have yet the right solutions. The GIFT project (Global Integrability of Field Theories) [8] was devoted to study this problem. Quantum computing has many facets. One of them is entropy as illustrated by Shannon or by von Neumann. A remote problem is whether the structure of spacetime is linked to the existence of minimal distance in physical theories. In [9] a very interesting approach mixing logic, categories and spacetime is presented. It is as abstract as one may expect but by no means an abstraction. For such problems, the environment

part in ABIT covers both the experimental results and the underlying mathematics (in the meaning of Grothendieck). It could inform whether it is possible to design and build quantum computers. Links with mathematics and technology are discussed.

## Culture

This is a topic with facets in, at least, philosophy, sociology, psychology, economy, geography and education. Consulting companies are training employees of international companies to solve problems arising from intercultural differences. We want to make such problem solving part of information technology. This means that understanding intercultural differences ought to be an assigned goal of AI. This is only possible when an abstract view of the problem is available. A first sketch is outlined in [10]. Technically this means that we can abstract cognitive problems. The features to be outlined are the following ones. First, abstraction is suitable to model virtual enterprises. Second, it is possible to derive then a business model for virtual institutions. Third, at the time of a worldwide economy, cultural differences cause the failure of or at least serious troubles for numerous collaborative ventures. To design IT based models will lead to design real world products.

The talk will in fact demonstrate that there is a way to abstract cognitive problems and tasks. It is not necessary to have a mathematical formulation of a problem to derive an abstract formalism. Conversely, a high level mathematical description is not sufficient to fully master a problem. This implies to assess anew the agenda of AI. The challenging part in ABIT is the link to the environment. But, this is to be expected.

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