Abstraction-Based Information Technology: A Framework for Open Mechanized Reasoning.

Jacques Calmet

University of Karlsruhe (TH)
Am Fasanengarten 5, 76131 Karlsruhe, Germany
calmet@ira.uka.de

Abstract. OMRS (Open Mechanized Reasoning Systems) was designed for Automated Theorem Proving and then extended to Computer Algebra. These are the two domains at the heart of the Calculemus approach. An obvious question is to assess whether such an approach can be extended to new domains either within AI or outside of AI. There have been several attempts to turn the world into a computational system. This talk stays away from such general attempts and introduces a framework that is fully set within AI. It extends the basic concepts of OMRS to diverse fields ranging from information technology to sociology through law as illustrated by examples. The main motivation is to claim that whatever the selected approach, Artificial Intelligence is gaining enough strength and power to reach new frontiers and to turn challenges that are not a priori of a purely computational nature into AI domains.

Keywords: mechanized reasoning, abstraction, computational modeling,knowledge, agent.

1 Introduction

OMRS (Open Mechanized Reasoning Systems) [10] were designed for Automated Theorem Proving (ATP) and then extended to Computer Algebra (CA) [2] .These are the two domains at the heart of the Calculemus approach. An obvious question is to assess whether such an approach can be extended to new domains either within AI or outside of AI. There have been several attempts to turn the world into a computational system (model of everything [7], Fredkin's view of the universe [8] as a global cellular automaton, Stephen Wolfram's definition of computing [18] or simply diverse models of the philosophy of sciences [9]). Within AI the very early work of John McCarthy and Patrick Hayes [13] did investigate philosophical problems from the standpoint of AI. Our approach stays away from such general attempts and introduces a framework that is fully set within AI. It extends the basic concepts of OMRS to diverse fields ranging from information technology to sociology through law as illustrated by selected examples. The main motivation is to claim that whatever the selected approach, Artificial Intelligence is gaining enough strength and power to reach new frontiers and to turn challenges that are not a priori of a purely computational nature into AI domains.

The relationship between Calculemus and mathematics cannot be overlooked. We outline some mathematical concepts, such as works of Jacobi and Herbrandt or the problems for the Millenium of the Clay institute, in the framework of ATP and CA. We will survey briefly their links to mechanized reasoning.

Another motivation for our work has its roots in information technology. We are entering an area which will see methodologies based upon artificial intelligent surpassing human capabilities. At the same time knowledge is becoming the building stone of our society. The amount of available knowledge is blowing up. This implies that knowledge management must be modeled along new abstraction paradigms. In other words, artificial artifacts will be substituted to humans in constructive ways enabling an "average" person to mechanize several arts of reasoning in an AI fashion. It will take several years before mathematics delivers constructive methods applicable to ATP or CA in many domains. AI offers ways to design in the near future approaches that can be implemented and used in real world applications. To this goal, we rely more bottom-up (as opposed to top-down) knowledge methodologies. Indeed, the increase in available knowledge leads to huge knowledge whare-houses which are not prone to an easy handling. Using the concept of virtual enterprises (and virtual knowledge community) that is gaining importance in today globalized economy, we try to illustrate that we can approach problems that where never attempted within AI. For instance, we propose an approach to mechanize cultural reasoning that is fully disconnected from today solutions to resolve intercultural differences. These are becoming sensitive issues in today globalized and virtual economy. We extend thus the concept of open mechanized reasoning beyond computer science to cognitive sciences in general.

It is worth noticing that the attempts to introduce abstraction mechanism in Artificial Intelligence (AI) were found mainly in reasoning. Abstraction supposes here a generic process that is proven to lead to the right processing of a problem. This goes beyond the selection of a specific logic since the abstraction concept must be goal oriented, not method oriented. This requires some sort of abstraction mechanism. Abstraction is a paradigm with very many different meanings, usually specialized to a field or subfield of a discipline. For instance, computer science favors abstraction described in the language of category theory but it must compete with different ones (type, semantics, specification, algorithms ...).

The paper is structured as follows. The next section reminds classical concepts and facts from mathematics or philosophy which have been investigated along the years and that we do not use as a framework of our work. In section 3 we introduce the open mechanized reasoning framework and the basic results obtained in the domains of theorem proving and symbolic computation. Open means that the methodology is generic and not specific to a particular methodology. The original framework for this approach lies at the heart of AI. Indeed, to mechanize mathematics was indeed a goal of the founding fathers of the field at the Dartmouth meeting in 1956. The achieved results show that successful ones have a three level structure: a theory, a control on this theory and a well-understood interaction with the computing environment. The following section points out that this structure can be extended to almost any domain of knowledge, including law. This leads to the concept of Abstraction Based Information Technology (ABIT). The next section illustrates and discusses this concept in different fields of science and humanities including mechanized legal reasoning. The next section illustrates how a possible implementation can be easily designed in the framework of multiagent systems and virtual knowledge communities. The last section is devoted to some concluding remarks.

2 Mathematics, philosophy and AI

In a recent paper, the philosopher of sciences, with an education in physics, Michel Ghins [9] asks whether we need a metaphysics to understand the laws of nature. He describes a scientific theory as a set of models together with a set of propositions some of which are laws. This is in fact a study in philosophy in the line of Descartes. There is, as often in this domain of philosophy, a link to logic reasoning. This is not an isolated research track. For instance, the books of Bruno Latour entitled "Science in Action" and "Politics of Nature" are attempts to discover exactly how science works. They are suggested as a worthwhile reading by philosophers and sociologists to computer scientists. A possible reason is the link of Latour to the "actor theory network" and the sociology of knowledge. These are two references, among very many available, towards a possible framework to set a universal model of computation. But, it does not suits the idea of mechanization well.
Conversely, McCarthy and Hayes write in [13] "A computer program capable of acting intelligently in the world must have a general representation of the world in terms of which its inputs are interpreted. Designing such a program requires commitments about what knowledge is and how it is obtained. Thus, some of the major traditional problems of philosophy arise in artificial intelligence". They go on mentioning that the philosophical problems to be solved become clearer with so-called reasoning programs. Their choice for a world-model was the automaton. This view that the universe is a computer or more specifically a cellular automaton was expressed recently by several computer scientists adopting the point of view that there is computational model of everything [7]. Cellular automaton and Turing machines have often be proposed as a generic computational model. The suggestion of Wolfram is in the framework of complex systems but looks to fall in this class . Another very recent and interesting approach to understand the evolution of scientific ideas is found in [11]. The authors propose a network linking the different fields as a way to learn this evolution. For our purposes, it is enough to state that these models are controlled theories without an interaction to an application universe and thus not suitable for our purposes.
Central to logic and ATP is the concept of universe introduced by Herbrandt. Jacques Herbrand wrote his doctoral thesis in 1930 at the age of 22 years. He died in an accident the year after. He set the framework for mechanical reason-

ing but no one could guess that at that time. As pointed out in [17], he was attending the famous Hadamard's seminar with André Weil, Jean Dieudonné and Claude Chevalley who are legends in French mathematics. This means that mechanized reasoning or a theory for demonstration did not take a very long time to mature. Another student of this Hadamard seminar was Albert Lautman who was working on mathematical structures [12]. It is nowadays probably better known as a mathematical philosopher. However, Lautman was among the founder of the Bourbaki saga. All these mathematicians are central to CA since they do cover algebra and geometry. It may be that the constructive approach of Bourbaki did inspire CA where solutions to problems must be constructive and complete. A side remark is that it looks like Hadamard was a boring lecturer but his legacy is enormous. Some other famous names are quoted in [17], namely Vessiot, Frechet and Picard. They are a prototypical link to on-going research problems of interest to the Calculemus community: the investigation of symbolic solutions to systems of partial differential equations (PDE). When the work in logic of Herbrandt took only a few years to demonstrate its usefulness, the PDE question is around for a few centuries. In [5] it is shown that articles of Jacobi, never previously translated from Latin, have inspired modern mathematics. Computation of normal forms using a sequence of derivations and eliminations, change of orderings, resolvents, characterization of possible normal forms by the rank of Jacobian matrices, a priori bounds on the order of a system, ... these posthumous papers of Jacobi develop many themes quite familiar to contemporay research in differential computer algebra. Picard's and Vessiot's works are still acknowledged when attempting to design symbolic solutions of PDEs. Furthermore, it is known that physics and part of biology are PDE-based. This is thus an area where the challenges are high and no solution can be expected in the near future. Some of the problems for the Millenium listed in the web site of the Clay institute, such as the Riemann Hypothesis or the Poincar Conjecture, need to be solved before CA can propose a constructive solution to this problem. One may think that the abstracted view of algebra, geometry and topology proposed by Grothendiek must be adopted before any significant chance of getting a solution does exist. This is a domain of mathematics where computation is not primarily the main issue which is to understand the suitable mathematical theory and to select a meaningful representation in which to set the problem. We did already mention that the proposed abstraction framework includes a theory, a control and an environment. Therefore, PDEs illustrate that a pure mathematical approach is still a dream and thus, it is not yet suitable for open mechanized reasoning.

3 The Open Mechanized Reasoning Framework

In [10], the Open Mechanized Reasoning System (OMRS) architecture was introduced as a mean to specify and implement reasoning systems (e.g., theorem provers) as logical services.

$$\begin{aligned} \textit{Reasoning Theory} &= \textit{Sequents} + \textit{Rules} \\ \textit{Reasoning System} &= \textit{Reasoning Theory} + \textit{Control} \\ \textit{Logical Service} &= \textit{Reasoning System} + \textit{Interaction} \end{aligned}$$

In [2], a similar approach was designed for symbolic computer algebra systems under the name of Open Mechanized Computational System architecture.

$$\begin{aligned} \textit{Computation Theory} &= \textit{Objects} + \textit{Algorithms} \\ \textit{Computation System} &= \textit{Computation Theory} + \textit{Control} \\ \textit{Algorithmic Service} &= \textit{Computation System} + \textit{Interaction} \end{aligned}$$

In [1], an unified description of both classes of systems was derived and called Open Mechanized Symbolic Computation Systems (OMSCS). It synthesizes the previous definitions into that of Symbolic Mathematical Service. It is based upon definitions of symbolic entities and operations which include the previous definitions of sequents and objects, and of rules and algorithms respectively.

$$\begin{aligned} \textit{Symbolic Computation Theory} &= \textit{Symbolic Entities} + \textit{Operations} \\ \textit{Symbolic Computation System} &= \textit{Symbolic Computation Theory} + \textit{Control} \\ \textit{Symbolic Mathematical Service} &= \textit{Symbolic Computation System} + \textit{Interaction} \end{aligned}$$

A key feature is that this is the only example where such a generic approach (e.g., open) is clearly available. Indeed, for logical services and symbolic computation it is possible to prove that a computation always exists and always terminates. In plain words, we have a theory as the initial level, we exercise some control on this theory in the second level while the third one describes how the controlled theory is linked to any environment. In these specific cases, the environment is a computer universe. In [3] an extension to scientific computing was investigated. In this case there is no longer a generic approach but, one may either rely on the standardized arithmetic operations in floating-point arithmetic (IEEE-754 standard) or on specific arithmetics (interval arithmetic for instance) or on routines specific to a given available software. In terms of the previous analysis, this means that instead of considering a generic theory, one may consider various possible theories. For each selected theory, one has to specify the control imposed upon it and the way the interaction with the environment is managed. A general remark is that even for the domains where the problem may be seen as solved, to identify a theory and to analyze its control are rather simple tasks while to formalize the interaction with the environment is always a challenging task. This remark is fully relevant for computational systems where a solution does exist but is often challenging to exhibit it.

4 Abstraction Based Information Technology

A first motivation to extend this work is coming from the state-of-the-art 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 sound very unpleasant for many scientists or sociologists or humanists. In addition, the hypothesis that brains have mainly a virtual perception of the world enables to investigate a concept of abstraction in AI. A reason is that the images transmitted by the retina to the brain are possibly virtual images. A second motivation is the need to investigate inter/multi/trans-disciplinary problems. The meaning of these concepts have been thoroughly discussed by the French philosopher Edgar Morin, sometimes in collaboration with computer scientists in the framework of complex systems. This implies that we need a common abstraction framework valid for as many disciplines as possible. An underlying 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 assumption 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). It is summarized as follows.

- A theory,
- a control on this theory,
- an embedding environment.

It turns out that the three levels of the open mechanized reasoning framework can be used as a basis to design such an abstraction. A further step is to recognize that this ABIT approach is suitable to introduce a concept of abstraction into domains as diverse as physics, philosophy, sociology or even culture [6]. A possible exception is Mathematics, a domain where only theories look to be meaningful since control and link to the environment belong to applications rather than to Mathematics itself.

5 Examples of abstraction in various fields

We present now some simple examples of how ABIT can be defined in various fields of science and humanities.

5.1 Computer algebra

This is a direct application of the previous sections.

- A theory is a module of algorithms,
- the control consists of a programming language,
- the environment is the computing environment.

5.2 Legal reasoning

Legal reasoning is thoroughly introduced in [15] that we adopt for reference purposes. The second part of the volume, entitled Legal Logic, provides a large collection of possible theories. Each section or even sub-section can be selected to be a theory. The choice is not limited however to this second part since already in the first part several facets of legal reasoning are presented. The domain is known to be very complex and fragmented. It is thus not surprising to be faced with a large number of optional theories. Some notions, such as for instance doxification [15] , could be used to describe a possible control on theories as well as the embedding into an environment. However, we select a different scheme to introduce legal reasoning. The three following facets define mechanized legal reasoning in ABIT.

- A theory is a set of laws (as voted by legislators),
- the control consists in application decrees,
- the environment is defined by jurisprudence and litigation procedures.

A first limitation is that such a scheme is not universal. For instance, the second step does not look to exist per se in the UK. In fact, laws are valid in a country or in a cluster of countries as anyone working on ciphering for instance quickly notice. The attempt to define, implement and enforce a so-called European law is a good illustration of the complexity of the system. The above mentioned scheme may appear as an over simplified view of legal reasoning but it is very often the view non-experts have. Also, it is suitable to be extended to less trivial approaches. The control may be extended to rules and regulations also as shown for plagiarism or copyright protection. In fact the theory and the control are defined by the administrative, political and judicial instances. They are also responsible for the third level. Law is a domain where electronic agents are investigated for many years and is offering high level conferences such as Jurix or ICAIL or LEA for instance. Thus, there is a proximity to distributed AI. As a summary, straightforward applications amount to select one of the methodologies described in [15] and to verify that the three level architecture is indeed technically suitable. We need to select a specific application to check the third level of ABIT. A natural choice for us is publication rights and plagiarism. The following comments are obviously from a non legal expert. In fact some of the questions we raised were put to lawyers and always got as generic answer: there is a solution since there are laws governing this domain (lawyers without computer culture) or this is under investigation (lawyers with computer culture). It turns out that either as the editor-in-chief of a journal, or as researcher investigating security of mobile systems or as a professor having to fire a student from the university because of a stupid case of plagiarism, some disturbing features and consequences of fully relevant laws have been encountered. This is a motivation to introduce a heuristic tool at the third level: a legal social network. Indeed, plagiarism in projects or thesis is becoming increasingly bothering in the education world with the facilities provided by internet. Tools exist, such as the Turnitin or Copy Tracker or Plagium or Nopliagia or many others software, to check whether part of a report is extracted from a previous publication. Plagiarism is reaching enormous growth since it has been estimated that 20 % of all German master thesis suffer from some sort of plagiarism. We need fast an informative tool to make the students aware of the existence of plagiarism detectors. Since a student signs a form stating that the thesis work presented is his/her own only, plagiarism has legal consequences and a guilty student is thrown out of the university. A legal social network could be very helpful but in any case, mechanized legal reasoning is a requirement.

5.3 Mathematics

Throughout the paper abstraction means solely the abstraction we did introduce. There are obviously many meanings to this word and the next sentences might sound controversial in any other context. A theory is not necessarily an abstraction. Mathematics is about building theories, such as differential algebra for instance, but cares less to set a control on these theories and investigates the link to the environment when moving to applied mathematics. This means that we adopt the old-fashioned distinction between pure and applied mathematics. Thus, differential algebra is a theory. and will become an abstraction when it can be labelled computer algebra. This happens when modules of algorithms are designed. They are controlled by a programming language and the links to the computing universe is fully mastered and understood. Other similar examples are scientific computing or ATP. Topology is another fascinating case. It is obviously a theory but seldom constructive. Although we do not request an abstraction to be constructive, it must be since to master the embedding in a relevant universe, one must master all possible links. The Kenzo specialized system of Francis Sergeraert, an expert on constructive homological algebra, is available from his home page. It is however very difficult to use by non-expert users meaning that the control is not optimal. Thus, we cannot rate the state-of-the-art in this domain to be an abstraction. This is, surprisingly, the only branch of science or humanities that is not concerned with our concept of abstraction although it is the branch where the most abstract knowledge, in the usual meaning, is available.

5.4 Physics

Physics underlines the fact that an abstraction can be time dependent since it depends on our understanding of a domain. Most parts of physics are without doubt abstractions. This statement is also valid for nanotechnology or quantum optics (lasers). But, this is not always true since theoretical physics is still under development. An example taken from history was the computation of the anomalous magnetic moment of leptons 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. For instance, one way 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 it is virtually impossible to probe this model experimentally.

Quantum computing is a fascinating area since it is still an open question to know whether an efficient quantum computer will ever be available. Without entering a detailed discussion, one may say that we have an abstraction based on quantum mechanics as a theory, quantum computing provides the control on this theory while the link to the universe is the assumption that quantum computers will be built when technology is adequate.

5.5 Sociology and political sciences

Sociology is an area attracting lot of research activities nowadays and where some sort of mechanization is looked for. We will outline in the next section an abstraction in the domain of multiagent systems (MAS) which could be duplicated here. But, on a very general level, we adopt the point of view that sociology is concerned with many possible theories expressing what is the role of agents (human or artificial). The control on the agents with their given roles defines a society. The abstraction is defined as:

- A theory is a set of agents with well defined actions,
- The control consists in defining a society based upon the theory,
- The environment is defined by how this society is governed.

Theories and their control in this abstraction constitute what is usually defined as sociology while the step society to government is the domain of political science. History tends to show however that the form of society implies some constraints on governance. Thus, it is possible to introduce as third level a simulation of the society activities for instance.

5.6 Culture

This is a topic with facets in, at least, philosophy, sociology, psychology, economy, geography, education or business. Consulting companies are training employees of international companies to solve problems arising from intercultural differences. An international transport company such as Hamburg-Sud equips its employees with a booklet listing some trivial cultural differences in the countries they do business with. Numerous examples of cultural problems result from setting up international companies or exchanging international students. Three simple examples are listed here.

- A French-German company hires engineers. They have a health insurance coverage: meaning?
- Exchange of students: What is the aim of education in different cultures?
- Process of decision making in international enterprises.

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.

Mechanized cultural reasoning is better described in [6]. A simple introduction is to state that the theory is an ontology, the control is to infer facts from this ontology. Finally, the environment consists in specializing these facts to a specific culture. Technically, this requires that we can abstract cognitive problems.

5.7 From an ontology to a methodology

We have so far outlined a possible paradigm for abstraction that is fairly straightforward. Since the goal is to design and implement a mechanized reasoner, we have to define the methods and techniques required to reach this goal. They are based upon the following assumptions. First, we adopt the framework of distributed AI and of multiagent systems. Second, the basic ingredients consist of knowledge. Third, we adopt a bottom-up approach. This means that we want to tailor the solution of a problem to the needs and means of potential users. An overall goal is to define a framework where mechanized reasoning, as understood in AI, is available. A second goal is to design systems that can be used easily by customers. We investigate whether it is possible to use a constructive approach for cognitive systems or complex systems. Consider as example the first cultural problem above. When a company is facing intercultural troubles, it usually calls on a consulting company that will propose a solution. This is very similar to calling on a psychiatrist to solve psychological disorders. We want to design systems using AI mechanized reasoning as a substitute to consulting companies. By the way, health insurance is a generic word with very different. specific meanings in different social systems. Similarly, it is astonishing to set up a double diploma open to top students of two countries, Germany and France specifically, and to notice that after one year of studies these top students do not really understand what is the goal of studying in the partner country. These students will be labelled to have an international experience and probably hired as manager in international enterprises. Then, the third intercultural trouble will likely surface. This is a new goal of AI that we wish to derive from mechanized reasoning and establish as an item in the agenda of AI. We may simply state that culture belongs to the corporate knowledge of a country. This is likely to be received as an horrible point of view by most humanists or cultural experts.

6 Knowledge methodologies

This section outlines very briefly some methods that have been designed and and do enable to propose a meaningful solution for the ABIT framework describe in the previous sections.

6.1 Agent methodology

We set our approach in the framework of multiagent systems (MAS). They were originally designed as a tool in distributed artificial intelligence. In [4] an Agent Oriented Abstraction (AOA) was proposed to abstract a multiagent system and also to specify what is a society of agents along the line of Weber's fundamental work in Sociology. AOA is based upon six definitions itemized as follows.

- An agent is an entity made of annotated knowledge coupled to a decision mechanism.
- The decision mechanism of an agent is the process by which an agent can reach its assigned goals. It is based upon the contents of the knowledge component. A decision mechanism is characterized by its utility.
- Knowledge annotations are classes or types structuring the knowledge possessed by or associated to agents.
- The utility of a decision mechanism is a measure of the efficiency of this mechanism. It is structured into utility classes.
- A society of agents is the societal organization arising from the actions performed by individual agents in the agent world assigned to a problem.
- A specialization is an implementation of the abstract classes for knowledge or utility.

In our abstraction framework, definitions 1 to 3 define a theory, definitions 4 and 5 define the control on this theory while the last definition acknowledges the link to the environment. A facet of the Agent Oriented Abstraction (AOA) mentioned previously is to enable to select virtual knowledge communities (VKC) as a methodology to represent knowledge.

6.2 Virtual Knowledge Communities

Virtual organizations (VO) are emerging in the information society as a requirement for a new information distribution scheme. They can be defined as a collection of individuals, companies or organizations which have agreed to work together to achieve a purpose. The concept of virtual knowledge communities (VKC) is an specific aspect of knowledge management in the frame of VO. A reasonable denition for VKC can be: Groups of people or agents with similar interests and purposes communicating and interacting by means of information technologies. VKCs are built upon three ground concepts: different entities (the members), similar interests of the members, and electronic communication channels. Since VOs are based on interaction between different entities, it appears natural to consider the concept of virtual knowledge communities within an agent-based abstraction. Indeed, MAS are based on the model of autonomous entities (agents) interacting with each others. AOA considers that agents are composed of two entities: A knowledge component and a decision mechanism. There are several ways to define the knowledge component. VKC is one of them. It is then possible to design the basic operations that can be performed on VKCs and to implement them. Several VKC's implementation have been performed including one for portable devices. Relevant references can be found in [14] and [16] .

7 Conclusion

Our goal is to demonstrate that the very basic ideas that are at the source of Calculemus can be extended to provide an abstract framework for most fields of science and humanities. We have outlined a string of ideas and methods to assess that it is possible to switch from logical frameworks to cognitive systems to identify abstraction concepts.

An important motivation lies in the belief that artificial intelligence will be more effective than human actors shortly. At a time when a car is able to run 1,000 km without a driver, we may expect that managing and exploiting knowledge bases may be partly mechanized. Here knowledge is assumed to come in many different arts. We also acknowledge that our technical view of the world is becoming more and more virtual. This concept is changing the way enterprises do collaborate. It is worth designing methodologies that will enable to think of collaborative international management and cultural systems. Although the features of decision making and trust are not considered in this paper, they are central to any knowledge management methodology. Our approach suits this concern.

The first part of the paper is attempting to remind that the search for an universal computational model as always been a goal of humanity. We tried very hard to assert that we do not set our approach within philosophy or any such attempts. A second remark was that although we do believe strongly that pure mathematics will enable breakthroughs towards mechanizing reasoning, we do not set our approach in the framework of mathematics. We have mentioned briefly in the last section bits and pieces that are being shaped up as tools to design abstraction based information technology. A testbed is probably to demonstrate that cultural mechanized reasoning does exist.

References

1. P.G. Bertoli, J. Calmet, F. Giunchiglia and K. Homann, Specification and integration of theorem provers and computer algebra systems. Fundamenta Informaticae, Vol. 39, No. 1-2, 39-57, 1999.
2. J. Calmet and K. Homann, Structures for symbolic mathematical reasoning and computation. In *Proceedings of DISCO '96 - Design and Implementation of Symbolic Computation Systems* (1996), J. Calmet and C. Limongelli, Eds., 216-227, LNCS 1128, Springer, 1996.
3. J. Calmet and V. Lefevre, Toward the Integration of Numerical Computations into the OMSCS Framework. In *Proceedings of the 7th International Workshop on Computer Algebra in Scientific Computing*, pages 71-79, Saint Petersbourg, Russia, 2004.
4. J. Calmet, P. Maret and R. Endsuleit, Agent-Oriented Abstraction, Revista Real Academia de Ciencias (Madrid), Special Volume on Symbolic Computing and Artificial Intelligence, Vol. 98, No. 1, pp. 77-83, 2004.
5. J. Calmet and F. Ollivier, Guest editors, Jacobi's Legacy. AAECC Special issue 20 (1), Springer, April 2009.

6. J. Calmet, P. Maret and M. Schneider, Cultural Differences as a Tool to Assess Trust in Virtual Enterprises. Forthcoming, May 2009.
7. N. Carriero and D. Gelernter, A Computational Model of Everything. Communications of the ACM, 44(119, pp. 77-81, 2001.
8. E. Fredkin, Digital Mechanics. Physica D 45, 254-270,1990.
9. M. Ghins, Laws of Nature: Do we Need a Metaphysics? Principia, 11(2), pp. 12749, 2007.
10. F. Giunchiglia, P. Pecchiari and C. Talcott, Reasoning Theories: Towards an Architecture for Open Mechanized Reasoning Systems. Tech. Rep. 9409-15, IRST, Trento, Italy, 1994. Short version in Proc. of the First International Workshop on Frontiers of Combining Systems (FroCoS'96), Munich, Germany, 1996.
11. M. Herrera, D.C. Roberts and N. Gulbahce, Mapping the Evolution of Scientific Ideas. preprint, arXiv:0904.1234v1, 7 April 2009.
12. A. Lautman, Essai sur les Notions de Structure et d'Existence en Mathematiques. J, Symbolic Logic Vol. 5, No. 1, pp. 20-22, 1940.
13. J. McCarthy and P.J. Hayes, Some Philosophical Problems from the Standpoint of Artificial Intelligence. Machine Intelligence 4, 463-502, 1969.
14. P. Maret and J. Calmet, Agent-Based Knowledge Communities. IJCSA, Vol. 6, No. 2, pp 3-21, 2009
15. G. Sartor, A Treatise of Legal Philosophy and General Jurisprudence. Volume 5: Legal Reasoning. (Volume not available separately), Springer, 2005.
16. J. Subercaze, P. Maret, J. Calmet and P. Pawar, A service oriented framework for mobile business virtual communities. in IFIP International Federation for Information Processing, Volume 283;Pervasive Collaborative Networks; Luis M. Camarinha-Matos, Willy Picard; (Boston: Springer), pp. 493-500, 2008.
17. C.-P. Wirth, J. Siekmann, C. Benzmueller and S. Autexier, Lectures on Jacques Herbrand as a Logician. SEKI Report SR200901, DFKI Saarbruecken, 2009.
18. S. Wolfram, A New Kind of Science. Wolfram Media, 2002