Challenges in the field of expert systems

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Abstract

Most of tasks involved in the building, exploitation and maintenance of KBs are far from being trivial. In fact, there are many issues to be addressed in order to empirically prove the technology for expert systems to be mature and reliable. One of the major reasons is that it is difficult to find a way how new and prior knowledge can interact appropriately, and which unanticipated interactions are required by changes in the KB.

1. Introduction

The gist of these problems is to support the complete life cycle for large KBs so that computer systems can reflect the way human experts take decisions in their domains of expertise. These tasks are often pervasive because large KBs must be developed incrementally, this means that segments of knowledge are added separately to a growing body of knowledge. Innovative results in this field can have a great impact in the advancement of many important and heterogeneous disciplines. However, there are a number of challenging problems that should be successfully addressed in advance. We propose a scientific approach for facing these problems which are summarized as follows:

- The first problem concerns the **automatic generation of large KBs**. Every expert system has a major flaw: knowledge collection and its interpretation into rules are quite expensive in terms of effort and time. Most expert systems have no automated methods to perform this task. Instead it is necessary to work manually, increasing the likelihood of errors. In order to develop new methods for automatic knowledge learning, it is important to have a strong methodology for their evaluation and comparison. This problem is even more critical in environments working with large KBs, as it is not viable to manually evaluate the inclusion of new knowledge.

- The second problem concerns the efficiency of **methods for exploiting KBs**. These methods include but are not limited to: knowledge reasoning, knowledge sharing and knowledge retrieval (e.g. Question & Answering tools). Beside quality, the efficiency of this kind of methods is of prime importance in dynamic applications, especially, when it is not possible to wait too long for the system to respond or when memory is limited. Current expert systems are mostly design-time tools which are usually not optimized, this means that many useful systems cannot be practically used mainly due to the lack of scalability.

- The third problem concerns automatic selection, combination and/or tuning of **methods for KB maintenance**. These methods include knowledge integration, meta-modelling or new knowledge validation. For example, the vital task of knowledge integration (inclusion of external knowledge in the KBs) requires complex methods for identifying semantic correspondences in order to proceed with the merging of past and new knowledge. For the detection of semantic correspondences, it is necessary to perform combination and self-tuning of algorithms that identify those semantic correspondences at run time. This means that efficiency of the configuration of different search strategies becomes critical. As the number of available methods for KB maintenance as well the knowledge stored in the KB increases, the problem of their selection will become even more critical.

- The fourth problem concerns **explanation delivery** in order to improve the expert systems, thereby providing feedback to the system, users need to understand them. It is often not sufficient that a computational algorithm performs a task for users to understand it immediately. In order for expert systems to gain a wider acceptance and to be trusted by users, it will be necessary that they provide explanations of their results to users or to other programs that exploit them. This information should be delivered in a clear and concise way so that it cannot be any place for misunderstanding.

2. Innovative aspects

In view of the motivation described above, the state of the art and the open problems that need to be investigated the concrete technical objectives of the proposed project are as follows:

Objective 1 is to develop a methodology for the comparison and evaluation of KBs which have been automatically built. The research towards objective 1 will lay strict emphasis on evaluating a number of success criteria concerning the KBs recently built. This evaluation is going to be performed both formally and by means of examples from some domains. The success criteria are going to be:

- *Accuracy*. We want to determine the precision of the extracted knowledge and its level of confidence.
- *Usefulness*. We want to determine the relevancy of the knowledge for target tasks, its level of redundancy, and its level of granularity.
- *Augmentation*. We want to determine if the new knowledge added something new to the past knowledge.
- *Explanation*. We want to determine the provenance of the knowledge, and if there is something contradictory.
- *Adaption*. We want to determine if current knowledge could be adapted to new languages and domains and how much effort should be made to do that.
- *Temporal qualification*. We want to determine the temporal validity of the knowledge.

Objective 2 is to develop strategies for improving the efficiency of the knowledge exploitation methods. The challenge addressed by 2 will lay on the development of strategies for improving the efficiency of tasks exploiting the KB. Moreover, these strategies should not alter the capability of current methods to produce desired results by comparing them with task requirements. These methods are going to be those concerning to knowledge reasoning, knowledge retrieval, and knowledge sharing. We are going to focus in many different aspects and requirements brought by these exploitation methods. Some of them will concern on efficiency, e.g., time and space complexity of the algorithms developed, and the rest will concern the effectiveness in relation to efficiency, e.g. correctness, completeness, and so on. Therefore, the problem is going to be addressed from a point of view involving multi-decision criteria.

Objective 3 is to develop methods to automatically select, combine and tune algorithms for the maintenance of a KB. The research toward Objective 3 will focus primarily in the development of methods for the maintenance of the KBs. These methods include the maintenance of the meta-knowledge, the knowledge integration tasks, and the knowledge validation using test cases from users. We want to design solutions avoiding choosing these methods arbitrarily, but in automatic way, by applying machine learning techniques on an ensemble of methods. Sequential and parallel composition of methods should be also studied. Hereby we need to learn rules for the correctness on the output of different methods and additional information about the nature of the elements to be operated. The final goal is to leverage the strengths of each individual method.

Objective 4 is to develop methods which can explain what happens inside a KB in a clear and concise way. The challenge addressed by Objective 4 is to provide explanations in a simple, clear and precise way to the users or software applications in order to facilitate informed decision making. In particular, most of techniques used by expert systems do not yield simple or symbolic explanations. It is necessary to take into account that different types of explanations may be needed. For example, if negotiating agents trust each other's information sources, explanations should focus on the manipulations. If on the other hand, the sources may be suspect, explanations should focus on meta information about sources. If a user wants an explanation of the reasoning engine used by the expert system, a more complex explanation may be required.

3. Importance of the expected results

As already described before the importance of the research is given by contributions in several areas.

- Concerning the systematic development of a methodology for the comparison and evaluation of recently built KBs; the essence of the creation stage is that no one fully understands the idea or emerging body of knowledge, not even those creating it. The process of creation is messy by nature and does not respond well to formal methodologies or rigid time lines. The design of an evaluation methodology can definitely help to develop automatic solutions for addressing this problem since we can learn the impact of each decision in the final quality of the KB.

- The importance of creating strategies for improving the efficiency of the knowledge exploitation methods is out of doubt. The novelty of this approach is given by the fact that current methods for exploiting KBs are developed without taking into account its efficiency. For example, reasoning is a very complex process which needs a lot of time and memory space to be performed. As the KB grows, this issue become more critical, so it is quite important to build methods that meet their goals but these methods should also meet them efficiently.

- The idea of developing methods to automatically select, combine and/or tune algorithms for the maintenance of a KB is of vital importance. The design of novel approaches that attempt to tune and adapt automatically current solutions to the settings in which a user or application operates are vital for a real automatic maintenance of large expert systems become real. This may involve the run time reconfiguration of the methods by finding their most appropriate parameters, such as thresholds, weights, and coefficients. In this way, tasks than currently are performed by humans can be automatized.

- The novelty of the research concerning explanation delivery in a simple, clear and precise way to the users or software applications can have a better understanding of the knowledge provided by the expert systems. The idea to standardize explanations or proofs of tasks inside the KB in order to facilitate the interaction of expert systems with people or other software programs will have a positive impact in the development of this field and widespread of expert systems.

4. Implications for other branches of science

Most of sciences have a history of making data available, because researchers recognize the benefits of sharing data and made it available to other researchers for the benefit of science [6]. However, because many of the repositories are developed in relative isolation, they tend to use different schemes, incompatible terminology, and dissimilar data formats. This makes it hard for researchers to find all data about an entity of interest and to assemble it into a useful block of knowledge. Moreover, advances in scientific knowledge require regular changes to be made to the underlying data models, and this is not straightforward with a relational model.

The key to advancing scientific understanding is empowering scientists or intelligent software applications with the information that they need to make well-informed decisions. Scientists need to be able to easily gain access to all information about chemical compounds, biological systems, diseases, and the interactions between these kinds of entities, and this requires data to be effectively integrated in order to provide a greater level view to the user, for instance, a complete view of biological activity. However, achieving this goal has proven to be a formidable challenge in fields where data and models are found in a large variety of formats and scales or in systems in which adding sources at a later point is difficult.

Therefore, advances on the automatic building, exploitation and maintenance of large KBs will certainly help scientists and software applications to more easily work with all knowledge of their interest. More specifically, the benefits include the aggregation of heterogeneous sources using explicit semantics, and the expression of rich and well-defined models for working with knowledge.

5. Effects with implications beyond the specific research field

The spectrum of applications of expert systems technology is really wide. Let us summarize some fields which can be benefited from the advancement of our research:

Intelligent scheduling. Expert systems in this field should be able to analyse a set of one or more potentially complex and interacting goals in order to determine a set of actions to achieve those goals, and provide a detailed temporal ordering of those actions, taking into account personnel, materiel, and other constraints. This kind of expert systems has a great commercial potential, which has been recognized.

Failure detection. Expert systems in this field should be able to deduce faults and suggest corrective actions for a malfunctioning device or process. Medical diagnosis was one of the first knowledge areas to which expert systems technology was applied, but diagnosis of engineered systems quickly surpassed medical diagnosis. There are probably more diagnostic applications of expert systems than any other type.

Financial decision support. The financial services industry has been a vigorous user of expert system techniques. Advisory programs have been created to assist bankers in determining whether to make loans to businesses and individuals. Insurance firms have used expert systems to assess the risk presented by the customer and to determine a price for the insurance. A typical application in the financial markets is in foreign exchange trading.

Manufacturing industry. Configuration, whereby a solution to a problem is synthesized from a given set of elements related by a set of constraints, is one of the most important of expert system applications. Configuration applications were pioneered by computer companies as a means of facilitating the manufacture of semi-custom minicomputers. The technique has found its way into use in many different industries.

Question & Answering systems. Expert systems in this field should be able to deliver knowledge that is relevant to the user's problem, in the context of the user's problem. Some of the most widely used expert systems in the world are in this category. For example, a computational advisor which counsels a user on appropriate grammatical usage in a text, or a tax advisor that accompanies a tax preparation program and advises the user on tax strategy, tactics, and individual tax policy.

6. Conclusions

Nowadays there is a lack of opportunities for young researchers to develop independent careers and make the transition from working under a supervisor to being independent researchers in their own right. This structural problem also limits or delays the emergence of the next-generation of research leaders, who bring new ideas and energy, and it encourages highly talented researchers at an early stage of their career to seek advancement elsewhere.

This funding program targets promising researchers who have the proven potential of becoming independent research leaders. For this reason, we think that this project presents a strong potential to support Jorge Martinez-Gil for establishing a proper research team and to start conducting independent research in Austria by the creation of an excellent research team.

References

[1] J. Martinez-Gil. An overview of textual semantic similarity measures based on web intelligence. Artif. Intell. Rev. 42(4): 935-943 (2014).

[2] J. Euzenat and P. Shvaiko. Ontology matching. Springer, 2013.

[3] J. Martinez-Gil and J. F. Aldana-Montes. Evaluation of two heuristic approaches to solve the ontology meta-matching problem. Knowl. Inf. Syst., 26(2):225–247, 2011.

[4] J. Martinez-Gil and J. F. Aldana-Montes. An overview of current ontology meta-matching solutions. Knowledge Eng. Review, 27(4):393–412, 2012.