Intelligently Engineering Artificial Intelligence Engineering: The Cognitive Architectures Competition

Dan Diaper[1], Christian Huyck[2], Bala Amavasai[3], Xiaochun Cheng[2] and Mourad Oussalah[4]

[1] DDD SYSTEMS, 26 St. Marks Road, Bournemouth, Dorset, BH11 8SZ, U.K.
[2] Middlesex University, School of Computing Science, The Burroughs, Hendon, London, NW4 4BE, U.K.
[3] Faculty of Arts, Computing, Engineering & Science, Sheffield Hallam University, Sheffield, S1 1WB, U.K.
[4] Electronics, Electrical and Computer Engineering Dept., University of Birmingham, Edgbaston, Birmingham, B15 2TT, U.K.
ddiaper@ntlworld.com c.huyck@mdx.ac.uk b.p.amavasai@shu.ac.uk x.cheng@mdx.ac.uk m.oussalah@bham.ac.uk

Abstract

Since the early nineties, interest has been growing in different facets of cognitive architectures and, inspired by advances in AI tools and methodologies, competing proposals have been put forward by various research communities. This gives the task of evaluating the various architectures importance. This paper outlines our proposals for the design and running of a Cognitive Architectures Competition to tackle this issue. Especially, this will involve creating an international community of researchers, developers and users, current and potential, who will have vested interests in the design of the competition. To evaluate entries, the competition's community will be required to develop a classification of Cognitive Architecture-based systems' current, and near future, capabilities and their potential range of desirable, practical applications. The community will need to address important technical issues and in doing so will help set a future research and development agenda.

Introduction

A rubric for applied psychologists is, 'Trust no psycho-social engineering technique that requires secrecy'. Psycho-social engineering is the blunt name given to how applied psychologists deliberately change what people do, how they think, and what they think about. Often, but not always, an individual subject is a willing participant in their behavioral and psychological modification. Willing subject or not, however, our rubric following applied psychologist can, and we think should, explain what will be changed and how this will be achieved, to the subject of their manipulations.

As with individuals, the same rubric applies to group modification. This paper is intended to be a public manifesto to explain to our subjects, who form a large slice of the applied Artificial Intelligence (AI) community, how we wish to engineer desirable change and suggest what such changes might, in outline, be. As our paper's title obliquely suggests, what we make public is the intelligent application of a psycho-social engineered system, a competition, that will promote the research, development and use of a variety of types of AI in many practical applications; and our title implies that our manifesto provides readers with intelligence of our intentions. We hope that many in the AI community will be willing, enthusiastic participants in our open and honest endeavors to accelerate the successful, practical use of Cognitive Architecture-based AI systems.

We have proposed a Cognitive Architectures Competition (CAC); we recently submitted an initial proposal for U.K. Government funding for this project and we've been encouraged to, and will, resubmit shortly. We have specifically targeted Cognitive Architecture-based systems as our AI focus for a number of reasons.

First, our proposal defines Cognitive Architecture-based systems as requiring "not an adherence to any particular computational technology, but to systems that are structurally and operationally similar, at least in some respects, to intelligent, biological systems". This includes the most common, symbolic cognitive architectures such as ACT (e.g. Anderson and Lebiere, 1998; 2003), Soar (e.g. Rosenbloom *et al*., 1993) and EPIC (e.g. Kieras *et al*., 1997). The definition also subsumes a large range of other AI system types such as neural network architectures.

Second, we believe that, as defined above, Cognitive Architecture-based AI is one of the main candidates for a wide range of future practical applications.

Third, we admit our vested interests as our AI research group at Middlesex University is centrally in the field of Cognitive Architecture-based intelligent systems. Our currently funded research test-bed involves developing a computer game agent with vision in the game's virtual world, with natural language processing between the human player and the intelligent agent, which will be able to suggest and carry out tasks within the game's environment, autonomously or in cooperation with the player (Huyck *et al*., 2006).

Fourth, we have expertise of taxonomy and how taxonomic processes produce specific classification systems, which we will use to set up the CAC. The competition will involve classifying different Cognitive Architecture-based systems, their capabilities, and their

potential domains of practical application. This itself, we believe, has the potential to make a valuable research contribution to the Cognitive Architectures field. In addition, we believe, that successfully running the CAC annually will help establish, refine and maintain an agreed, public research and development agenda for the practical applications of Cognitive Architecture-based systems. We also expect to encourage more usage, and more diverse uses, of these systems.

Our proposed CAC development method, which is our key device for psycho-social engineering, requires us to establish an international Cognitive Architecture-based systems community of researchers, developers, and private and public sectors users, and potential users, and later perhaps for ubiquitous uses, e.g. domestic applications, and in portable personal devices.

Designing the CAC is an opportunity that we have created as the *raison d'être* for our developing an international community. It is the competition design that will provide the focusing device for our community's discussions, which will be on-line, at workshops and seminars, and through short or extended site visits. It is the taxonomic approach, however, that will ensure that the discourse will have a technical focus far beyond the mere, trivial mechanics of running the competition itself. In any case, through our design, it will be in participants' own interests to become involved, and so have the chance to influence how the competition will be designed, organized and judged. After a brief overview of Cognitive Architecture-based systems, further details about the competition, particularly about its design, are provided in the following section.

Cognitive Architecture-based Systems

There are a large number of Cognitive Architectures, with two popular symbolic ones being ACT and Soar. ACT systems can simulate a range of human behaviour on hundreds of different tasks (Anderson and Lebiere, 2003). Soar has been used for complex tasks, such as large scale air battle simulations and complex video game agents. Unfortunately, these systems suffer from an inability to learn new symbols.

Neural network systems have been proposed as a mechanism for learning new symbols (e.g. Harnad, 1987). These systems can be used to implement rules (Huyck and Belavkin, 2006) and thus may be a basis for Cognitive Architecture-based systems that operate independently of their implementation, and which can still be described symbolically. Systems built using a neural network architecture could be able to learn new domains, and perform in them. The additional ability of these systems to adaptively learn new symbols should, we think, make them much more useful than current purely symbolic architectures that have to be hand-programmed for new domains. We believe that the field of neural network Cognitive Architecture-based systems is a promising way forward.

A Cognitive Architecture-based system should be able to solve a host of problems in an application domain. This, after all, is what biological cognitive systems can do. Current individual systems tend to be based on a single Cognitive Architecture, often using a common implementation shell. There are systems to solve a host of problems, but each system is, however, limited to either trivial problems, very simple domains, or to using highly pre-processed and simplified data. To develop a general Cognitive Architecture-based system capable of solving a wide range of problems would currently be a challenge.

The Cognitive Architectures Competition

In the recent past, other fields have similarly been limited but have eventually made rapid transitions to systems that are industrially viable. For example, in the late 1980s and early 1990s, the Natural Language Processing field made such a transition from trivial systems to industrial applications. While this success involved many factors, it has been recognized that the US ARPA sponsored Message Understanding Competitions (MUCs, e.g. ARPA, 1987) played a highly significant role. Benefiting from the experience of the MUCs and other AI competitions, we intend to develop and run competitions for the future development of Cognitive Architecture-based systems.

The rich discussions that we expect the competition to engender when focusing on developing it, from across many different competition activities, will have to address important, high level issues about, for example, architecture, representation, function and real world use. To be successful, the CAC will have to create a community of researchers, developers, managers, and users, of Cognitive Architecture-based systems. The development of the CAC by its competition inspired community should identify new applications, encourage usage by private and public sector organizations, and clarify and prioritize scientific and engineering research and development agenda. Running the first competition, which should become an annual event, will provide a powerful, additional means of publicizing Cognitive Architecture-based systems, their capabilities and uses, and their near-future likely developments.

The CAC will use the development of its first competition as a platform to create a large international community from academe and public and private sector organizations. The development of the competition provides an appropriate forum as it will require participants to address longer term, 'Where are we going?' and 'What do we want to achieve?' types of questions; however, we avoid Science Fiction as the competition requires realizable demonstrations. Less prosaically, a key question for researchers and developers will be, 'What are the current and near-future capabilities of Cognitive Architecture-

based systems?', i.e. 'What are their current limitations?', 'What are they good at?' and, 'What should they, soon, be good at?' Simply bringing people together to discuss the broad issues about the future development of Cognitive Architecture-based systems should itself be of benefit. More importantly, the competition should establish future system performance targets and so considerably influence current and future research and development in the area. The competition has a special place for the potential users of Cognitive Architecture-based systems, who would primarily come from private and public sector organizations, as a major part of developing the competition will be identifying and classifying the wide range of application domains to which future Cognitive Architecture-based systems might contribute.

We believe that a key concept will concern domains of application as, of the three weaknesses identified above, "trivial problems, very simple domains, or to using highly pre-processed and simplified data", the first two are explicitly domain related problems and the third is a solution to a complex input domain. While open to change based on the project's activities, our current model of domains divides any Cognitive Architecture-based system into three parts: input, processing and output. The intention is to lead and promote discussion of a large number of systems and their current and future applications to produce a classification of Cognitive Architecture-based system properties, capabilities and their potential application domains. The CAC provides the motivation for developing the classification, which is itself a high value exercise, and the resulting classification will be used as one basis for evaluating competition entries.

To illustrate how the classification will fundamentally drive the CAC, our eventual competition application might, as part of its input specification, benefit from a variety of input media such as text, tablet, speech, graphics, image and video. Similarly, some central natural language processing, with the detailed requirements being specified by the competition's application, might be required. To give an output example, the competition's application might require specific, parallel, real-time control of devices. While not independent in practice, the rational order is first to develop the classification, then to use it to specify the first competition's application, and then to use the classification to construct the judges', complex, evaluation scheme.

The idea is that different entries to the CAC will be more or less successful at meeting the application's requirement specifications. For example, if the application required a vocabulary of several hundred words, with no learning, but with speaker independence, but not against high background noise levels, then judges would use the classification-based scoring categories to evaluate competitors' symbolic, neural network or other AI systems. The above specification might favor the symbolic system, on accuracy and speed, since learning new words is not required, but the neural network might have better performance when dealing with speaker independence. We expect that parsing flexibility, for example, would be another category for judging on this part of the specification.

Hopefully this example makes the point obvious that there is a great deal to discuss about the competition's classification, and that it is in the interests of competitors, and others, to help develop the classification, the competition's application, and the judges' evaluation scheme. We foresee that one of our major roles as the CAC organizers will be to encourage debate, summarize and, because decisions have to be made, present our community with alternative options, for example, with respect to the design of the competition's application. We see our role as organizers to be extremely open, honest-brokers to the CAC's community. As psycho-social engineers, however, we point out that because many very specific decisions will have to be made in the first competition's application's specification, apart from negotiating compromises for the first competition, we might trade-off some specification decisions with the second competition, thus favoring the annual occurrence of the competition.

A major advantage of this competition design is that systems with different Cognitive Architectures, from radically different application domains, can still compete against each other. Overall, however, it will be the domain independent, large scale systems with sophisticated cognitive processes and flexible I/O that will do well, which, of course, is a deliberate intention to be embedded in the competition's design. The first competition, however, will encourage participation by having categories of entry, discussed within the competition's community, of course, rather than one overall winner.

Starting the Competition

Our first task would be to set up an interactive website describing the initial terms of the competition and to develop a forum facility that will allow participants to contribute to developing the initial rules, and eventually all other aspects, of the competition. Apart from advertising the project electronically, we will personally contact several hundred people we know working in the field. They will be asked to nominate half a dozen or so other people, with an emphasis on non-academics. Concerted effort will be put into personally following up contacts, particularly potential users in industry. We would, for example, be looking for technically orientated senior managers who might have significant inputs as to the near-future application of Cognitive Architecture-based systems that they need. We will also provide expert management of the on-line discussions, summarizing

threads and identifying outstanding issues and topics for new threads. This should be a substantial, labor intensive activity throughout the competition's development. Later, we expect the web site to host collaborative tools for future joint proposals by partners and participants in the competition.

For the first competition, we plan to organize two workshops. The first will be focused on developing the competition, addressing the short term capabilities and application domains of Cognitive Architecture-based systems, and discussing the taxonomic processes that will be used to produce the classification, and, of course, discussing the classification itself. This will lead to major additions to the project's website. Many new discussion threads will be started, with the aim of refining the details of the competition. Once we have run the first competition, the results will be reported at the second workshop where all competitors can describe and demonstrate their systems.

Conclusion

This paper, of course, is an example of our directed attempts at psycho-social engineering. We are advertising our plans to establish an annual Cognitive Architectures Competition and are seeking partners, interested parties and, please, sponsors. Apart from it being our idea, we think we are suitable people, happily with others, we stress, to organize and run the first competition. As academics with breadth and depth in the field, we can act as independents, of commercial pressures, for example, and our primary motive is philanthropic, to encourage the appropriate and useful application of Cognitive Architecture-based systems in practical settings.

Our initial focus must be on developing the competition, although we propose that we will also run the first one. The competition provides a device to encourage the establishment of a large, complex network, from a wide franchise, that will become a community. It will encourage debate on important, high level issues of architecture, capabilities and applications by providing a context for discussion.

The development of the competition will provide a motivator because it is in the vested interests of those who become involved to influence the competition's design, so it will cover their architecture's and system's capabilities, and deal with the users' types of applications. Developing the competition will identify what are the important questions, problems, and capabilities, both current and near-future term, of Cognitive Architecture-based systems and their applications. Thus the competition should significantly contribute to institutional, national and international research and development agenda. It should also increase the potential user base, encouraging organizations to use Cognitive Architecture-based systems in domains that have not been previously considered. Finally, for a workshop on 'Evaluating Architectures for Intelligence', our Cognitive Architectures Competition provides mechanisms for current and future stakeholders to act together to discuss and decide how to evaluate Cognitive Architecture-based systems, in general, of course, as well as for evaluating competition entries. We thus provide a practical solution to how to address one of the key problems identified in the workshop's summary, that is, that, "There are no established evaluation methodologies and only a handful of established evaluation criteria.", and as the summary suggests as a desideratum, we are working on a community-based solution.

Acknowledgements: This work is supported by EPSRC grant EP/D059720.

References

Anderson, J.R., and Lebiere, C. 1998. *The Atomic Components of Thought.* London: Lawrence Erlbaum.

Anderson, J. R., and Lebiere C. 2003. *The Newell Test for a theory of cognition*. Behavioral and Brain Sciences 26:5 pp. 587-601.

ARPA (Advance Research Projects Agency). 1998. *Proceedings of the Seventh Message Understanding Conference*. Fairfax, VA. May 1998. San Mateo, CA: Morgan Kaufmann.

Harnad, S. ed. 1987. *Categorical Perception: the Groundwork of Cognition.* New York: Cambridge University Press.

Huyck, C., and Belavkin, R. 2006. *Counting with Neurons: Rule Application with Nets of Fatiguing Leaky Integrate and Fire Neurons.* Proceedings of the Seventh International Conference on Cognitive Modeling, Trieste, Italy, pp. 142-147.

Huyck, C., Diaper, D., Belavkin, R., and Kenny, I. 2006 *Vision in an Agent based on Fatiguing Leaky Integrate and Fire Neurons.* IEEE Systems, Man and Cybernetics Society 5th Chapter Conference on Advances in Cybernetic Systems, pp. 131-136.

Kieras, D., Wood, S., and Meyer, D. 1997. *Predictive Engineering Models Based on the EPIC Architecture for a Multimodal High-Performance Human-Computer Interaction Task.* ACM Transactions on Computer-Human Interaction, vol. 4, no. 3, pp. 230-275.

Rosenbloom, P., Laird. J., and Newell, A. 1993. *The Soar Papers: Readings on Integrated Intelligence.* Cambridge, MA: MIT Press.