HYBRID AI

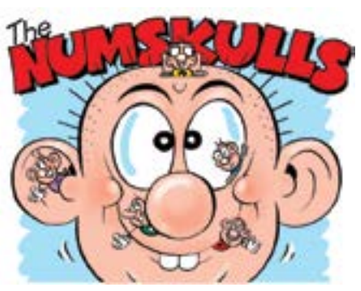
There are many definitions of artificial intelligence (AI), but I often use this one: the science of mimicking human mental faculties in a computer. One of the criticisms of this definition is that it stops at human intelligence rather than superhuman intelligence, says Adrian Hopgood FBCS CITP, Pro Vice-Chancellor and Dean of the Sheffield Business School at Sheffield Hallam University.

The criticism is justified since superhuman intelligence is already routinely achieved among humans in business and society through teamwork. For example, the Airbus A380 aircraft is the result of painstaking design that would not have been possible by a single individual.

So, to really stretch the capabilities of artificial intelligence, a multiagent approach is required. Each agent brings a specialist capability. They all work together as a team, or even as a society in which dispute, confrontation and negotiation can produce positive outcomes.

Even if the goal of AI is constrained to mimicry of a single brain, human intelligence is so multifaceted and current AI techniques are so one-dimensional that a collection of different approaches is needed. The different types of intelligent human behaviour can be represented as a spectrum of intelligence in which the level of understanding increases from automatic behaviour (e.g. regulation and reaction), through sub-conscious behaviour (e.g. perception and interaction), to specialist expertise.

Mimicry of all of these types of intelligence requires a multiagent system, each of which handles a single aspect of the overall intelligent behaviour, like the Numskulls cartoon characters.



Current AI techniques include rules, frames, objects, model-based reasoning, case-based reasoning, Bayesian updating, fuzzy logic, multi-agent systems, swarm intelligence, evolutionary algorithms and neural networks. They can be roughly divided into two types: knowledge-based systems, in which knowledge is explicitly represented in words and symbols, and computational intelligence where the knowledge is implicitly represented by numbers that are typically adjusted as the system improves its accuracy. To build an artificial intelligence requires us to bring the best of these techniques together as a hybrid – a multiagent system that allocates each subtask to an agent that contains the most appropriate technology.

A collection of expert individuals does not constitute a team or a functioning society. To benefit from the collective capabilities of multiple agents, they need to communicate. The blackboard model has re-emerged from its 1970s origins to achieve this aim, with diverse software agents working together like a team of boffins that share their ideas by writing them with chalk on a blackboard. This approach has achieved some notable practical successes, from processing medical images to controlling and managing complex manufacturing processes. The framework behind those examples is DARBS (Distributed Algorithmic and Rule-based Blackboard System), which is now available as free open-source software.

Types of hybrid

Hybrids can be classified according to four distinct types of task:

1. Dealing with multifaceted problems. As noted above, most real-life problems are complex and have many facets, where each facet may be best suited to a different technique. Therefore, many practical systems are designed as hybrids, incorporating several specialised modules, each of which uses the most suitable tools for its specific task.
2. Parameter setting. Techniques such as neuro-fuzzy, genetic-fuzzy, and genetic-neural systems are based on the idea of using one technique to set the parameters of another.
3. Capability enhancement. One technique may be used within another to enhance the latter's capabilities. For example, Lamarckian or Baldwinian inheritance involves the inclusion of a conventional local search within a genetic algorithm by incorporating steepest-gradient descent before evaluating the candidate solutions. The aim is to raise the fitness of individual candidates and to speed convergence of the genetic algorithm towards an optimum.
4. Clarification and verification. Neural networks have the ability to learn associations between input vectors and associated outputs. However, the underlying reasons for the associations are opaque, as they are effectively encoded in the weightings on the interconnections between the neurons.

Efforts have been made to extract equivalent rules from the network automatically. The extracted rules can be more readily understood than the interconnection weights from which they are derived, thereby providing clarification of the neural network's output. Verification rules can apply additional knowledge to check the validity of the network's output.

Benefits of hybrid AI

Although an artificial intelligence that is convincing and affordable remains an unfulfilled ambition, AI systems are nevertheless delivering real practical benefits. These benefits can be categorised into five distinct types:

- Reliability and consistency. An intelligent system makes decisions that are consistent with its input data and its knowledge base (for a knowledge-based system) or numerical parameters (for a computational intelligence technique). It may, therefore, be more reliable than a person, particularly where repetitive mundane judgements have to be made.
- Automation. In many applications, such as visual inspection on a production line, judgemental decision making has to be performed repeatedly. A well-designed intelligent system can deal with the large majority of such cases, while highlighting any that lie beyond the scope of its capabilities. Therefore, only the most difficult cases, which are normally the most interesting, are referred to a human.
- Speed. Intelligent systems are designed to make automatic decisions that would otherwise require human reasoning, judgment, expertise, or common sense. Any lack of true intelligence is compensated by the system's processing speed. An intelligent system can make decisions informed by a wealth of data and information that a person would have insufficient time to assimilate.
- Improved domain understanding. The process of constructing a knowledge-based system requires the decision-making criteria to be clearly identified and assessed. This process frequently leads to a better understanding of the problem being tackled. Similar benefits can also be obtained by investigating the decision-making criteria used by computational intelligence techniques.
- Knowledge archiving. The knowledge base is a repository for the knowledge of one or more people. When these people move on to new jobs, some of their expert knowledge is saved in the knowledge base, which continues to evolve after their departure.

Hybrids and the future of AI

Early examples of intelligent systems were mostly consultative in nature, e.g. diagnostic expert systems that reached a conclusion following dialogue with a human, or neural networks that produced classifications from data stored in a file. However, many of the more modern intelligent systems are situated, i.e. they interact with their environment through sensors that detect the environment and actuators that operate upon the environment in real time.

If intelligent systems are to become more widely situated into everyday environments, they need to become smaller, cheaper, and more reliable. The next key stage in the development of artificial intelligence is likely to be a move towards embedded intelligence, i.e. intelligent systems that are embedded in machines, devices, and appliances.

A version of DARBS has been shown to run effectively on a set of parallel low-cost processors like those found in basic mobile phones. This demonstration was significant in showing that even a hybrid system with many parallel processes can be made cheaply, thereby opening the door to affordable embedded AI.

AI has made significant advances from both ends of the intelligence spectrum, and is closing in towards the middle. The gaps relate to behaviours that we tend to take for granted, such as language, perception and common sense, by which I mean making sensible decisions in unfamiliar situations.

Hybrid systems are the key to bridging the spectrum of intelligent behaviour and are already delivering practical benefits in real deployed software, whether or not its users regard the software as truly intelligent.

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A range of free software for AI, including DARBS, is available from www.adrianhopgood.com/aitoolkit.

regulation - reaction - coordination - perception - common sense - interaction - planning - expertise

level of understanding

Numskulls image courtesy of DC Thomson

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