Human Computing and Super Forecasting

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This column is coordinated and edited by William D. Fraser, M.Sc. These articles are not peer-reviewed. The AsMA Science and Technology Committee provides the Watch as a forum to introduce and discuss a variety of topics involving all aspects of civil and military aerospace medicine. Please send your submissions and comments via email to: fraserwdf@gmail.com. Watch columns are available at www.asma.org through the "Read the Journal" link.

The term "computer" was originally used to describe a person who performs mathematical calculations.[4] With the advances in computing technology, the use of human computing almost disappeared from any field requiring solutions to complex sets of equations. Recently, the use of "human computers" has had a revival, addressing scientific, financial, and geopolitical problems, and has the potential to assist in medical diagnosis and prognosis, and complex civilian and military operations.

Early Human Computers

Before the development of mechanical and electrical computers, humans were used, usually as members of teams, to generate numerical solutions to complex sets of equations inherent in navigation, astronomy, code breaking, and military problems, including those necessary for the development of atomic weapons. These individuals would work on one small component of the problem following written procedures, which could be combined with the output of others to generate the final solution. These written procedures were the forerunners of the algorithms used to develop modern computer code, thus these individuals were basically fulfilling part of one small piece of computer code running on a modern computer.[7]

Modern Human Computing

With the development of analog and digital computers, the use of humans to undertake the tedious calculation of numerical solutions to systems of equations is no longer required. However, teams of humans are now being used as human computers, not for blindly following an algorithmic procedure, but for the ability of the human brain to be used as a powerful analytical tool. This is referred to as "human-based computation,"[3] a computer science technique, where, for certain steps in the processing sequence, a computer outsources microwork to humans. The most well known of this type of human computing can be seen in the Zooniverse science web portal,[10] which allows large numbers of volunteers (or Zooites), currently over 1 million, to participate in crowdsourced research, often by taking advantage of the human brain's ability to process and categorize images. Projects have involved research in astronomy, ecology, meteorology, particle physics, humanities, and climate science. Other than one retired project classifying archived tumor images,[11] there has been no use of this approach in basic or applied research in medicine, psychology, or human performance.

Super Forecasting

Another area of human computing is super forecasting, which uses large scale, multiyear competitions to identify individuals and their personality characteristics, under development by Philip Tetlock and his colleagues, who are consistently better at generating, at least in the short term, "accurate subjective probability estimates of geopolitical events"[5,8,9] with support from the U.S. intelligence community. These individuals are not necessarily so-called experts in particular academic or professional fields, or even have significant postsecondary education. They do tend to have a common set of characteristics: above average intelligence (but not necessarily geniuses), have at least an intuitive grasp of probability and statistical concepts, have a thirst for lots of data and information, and desire feedback on accuracy and error and are willing to modify their predictions accordingly. They work well in teams, although they are not participating in the classical brainstorming approach to a problem. They are often described as "foxes" who recognize that the world is complex and issues and problems cannot be reduced to simplistic talking points.[8,9]

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Computer Implementation of Human Computing

Both crowdsourcing of large scale pattern recognition problems and identification and use of super forecasters may be useful in aviation medicine and human performance research and applications. However, there is significant effort required to test, identify, and train both types of human computers. Another approach would be to implement or simulate the capabilities and characteristics of these individuals in computer algorithms, just as the earlier "human computers" that were used to solve numerical problems were replaced by analog and digital computers. Though algorithms for generating analytical and numerical solutions to systems of complex equations would not be appropriate, neural network and fuzzy logic algorithms have long been used to address less well-defined problems of image analysis and complex data analysis from a wide variety of disciplines, but for the most part neither approach has been used to emulate how real human brains process complex multidimensional data.

Interestingly, the U.S. Intelligence Advanced Research Projects Activity (IARPA), which sponsored super forecasting competitions along with the U.S. Office of Naval Research, is also funding research into what is essentially efforts to 'reverse engineer' the brain, where instead of a single neural network structure with a fixed learning algorithm being used, networks that are based on actual neural architecture of the various components of the brain are implemented in software.[1] Thus, for processing of images, neural networks are implemented that incorporate subnetworks specifically designed to emulate the retina, the thalamus, the primary visual cortex, and higher cortical processing centers (**Fig. 1**). Each of these simulated subnetworks have neurons with specific properties emulating neurons particular to a specific component of the brain anatomy, and connectivity within the subnetworks and among the subnetworks will vary in accordance with what is known about the wiring connections in the brain.[2,6] Another example is a simplified basal ganglia network that can undertake action selection and probabilistic learning (**Fig. 2**). It includes specialized subnetworks simulating the striatum, the globus pallidus, the substantia nigra compacta, and the primary motor cortex.

Conclusions

Crowdsourcing, super forecasting, and computer emulation of both technologies have potential applications in basic and applied aerospace medicine and human performance research. The use of amateur volunteers through crowdsourcing and super forecasters, not necessarily having a medical background, may be controversial in medical diagnosis and prognosis, where traditional decision making usually relies on a small group (or single individual) with specialized academic and professional training, as the legal and liability issues may be prohibitive. It would be interesting research to examine the efficacy of both approaches, as the crowdsourced image analysis and the super forecasting competitions have shown that so-called experts were not necessarily the better performers. Gifted and well-trained data analysts and forecasters can be powerful tools for medical, engineering, military, intelligence, financial, geo-political, and organizational applications. In the long run, however, computer-based emulation of these human computers will be more cost effective.

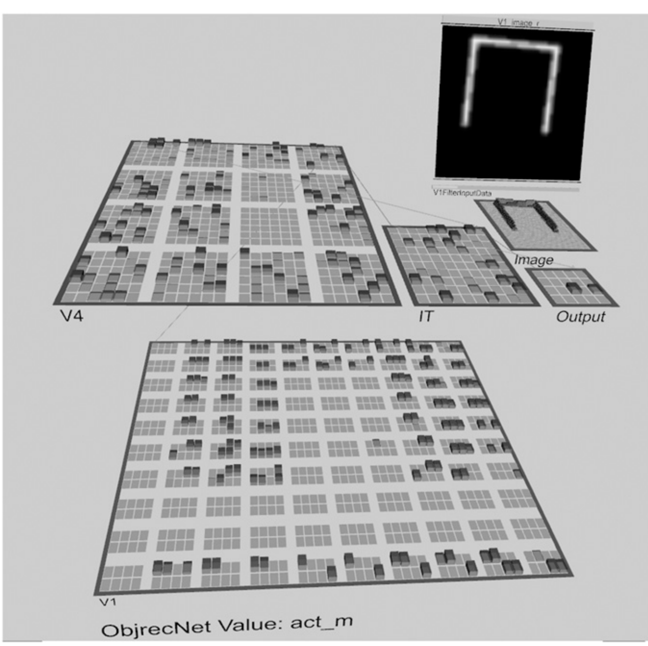

Fig. 1. An example of a neural network that incorporates subnetworks specifically designed to emulate the retina, the thalamus, the primary visual cortex, and higher visual cortical processing centers.

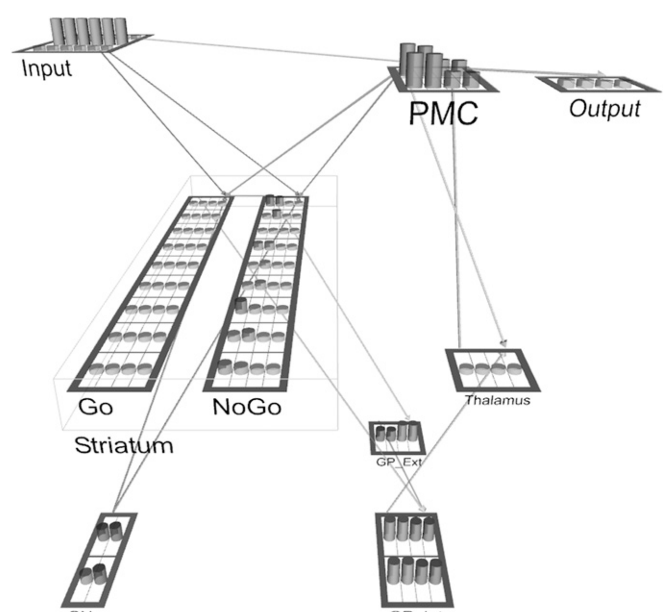

Fig. 2. A neural network representing a simplified basal ganglia network that can undertake action selection and probabilistic learning. It includes specialized networks simulating the striatum, the globus pallidus, the substantia nigra compacta, and the primary motor cortex.

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