Science and engineering – theory, experiment and more

Balaram's editorial[1] brings out elegantly the disappearance of boundaries between science and engineering in the past 50 years, with computer modelling binding diverse disciplines. It is not surprising that he vividly recalls the era of T-square and slide rule adorning all engineering students struggling in the workshop with lathe machines or tools of carpentry. There is one more dimension of engineering, its deep relationship with humanities, particularly economics and psychology. Neglecting these disciplines is a serious lacuna in engineering education at the Indian Institute of Science, Bangalore. Apart from well-known ergonomics, human factors in engineering and human–machine systems, let me elaborate the role of humanities in the context of one computer science sub-discipline, artificial intelligence (AI).

Herbert Simon (1916–2001), father of AI, was an American psychologist whose research ranged across the fields of cognitive psychology, computer science, economics and management. He won the Nobel Prize in Economics in 1978 'for his pioneering research into the decision-making process within economic organizations'. His observation that human beings have only 'bounded rationality', has led to formulating a decision problem with three steps: (1) identification and listing of all the alternatives; (2) determination of all the consequences resulting from each of the alternatives; and (3) comparison of the accuracy and efficiency of each of these sets of consequences. Anyone attempting to implement this model in a real situation would be unable to comply with the three requirements. It is improbable that one could know all the alternatives, or all the consequences that follow each alternative. This led to the evolution of practical decision support systems and their limitations.

In 1957, Simon with Allen Newell developed the General Problem Solver (GPS) program. GPS was possibly the first method of separating problem-solving strategy from information about particular problems. In his classic, *The Sciences of the Artificial*[2], Simon argues that the purpose of science 'is to make the wonderful and the complex, understandable and simple – but not less wonderful and to show that complexity, when correctly viewed, is only a mask for simplicity; to find a pattern in apparent chaos'. He further wonders that while 'natural science is knowledge about natural objects and natural phenomena', whether there cannot be 'artificial' science, knowledge about artificial objects and artificial phenomena. By the term 'artificial', he means 'produced by art rather than by nature, made in imitation, designed and manufactured'. When we enter the world of design, manufacture and synthesis rather than analysis, we enter the realm of engineering. The design of artifacts (maybe small components or complex systems) with specified goals subject to practical constraints is the goal of engineering. Understanding by computer simulation is the first step in the task of engineering, a full-scale experiment is not often feasible. A computer, as an artifact, is the basis of AI and is an apt analogy for the well-known 'mind–body problem' of philosophy. There are many theories of the mind, such as:

- The dualist theory, where the mind and body are of a different nature.
- The interconnectivity theory, where the mental activity of the brain is a consequence of the large number of interconnections among neurons.
- The identity theory, where the 'mind is the brain' or 'brain is the mind', a theory based on a biological philosophy.
- The data-processing theory (informatics theory), where the mind is the software of the brain.
- The theory of non-existence of the mind.

This discussion immediately leads us to the domains of psychology, philosophy and cognitive science. According to Newell[3], 'One of the world's deepest mysteries – the nature of mind – is at the centre of AI. Its discovery will be a major chapter in the scientific advance of mankind. There will be a coherent account of the nature of intelligence, knowledge, intention, desire etc., and how it is possible for the phenomena that cluster under these names to occur in our physical universe'.

According to Searle[4], 'We in the science community believe that we know a lot about the world we live in. We know quite a lot about atomic physics and chemistry and modern biology. So we have a picture of the world, and it is basically made up of physical particles (or more accurately points of mass energy) in fields of force, organized into systems. Some of them have got big carbon-based molecules with lots of nitrogen, hydrogen and oxygen. And over a period of about three to five billion years they evolved into humans like us. In addition, we are conscious, we have intentionality, we have free will, we have rationality, we have language, we have society, we have ethics, we have a self-conception which we're pretty reluctant to give up on, and we're pretty fond of that self-conception. Now here's the question: How do we reconcile what we know about the world with that self-conception?' And that basically is the dominant question in modern philosophy. The study of complex cybernetic systems is another major contribution of engineering in the past fifty years. Cybernetics was defined by Norbert Wiener[5] as the study of control and communication in the animal and the machine.

The conclusion is that not only the walls between science and engineering, but all walls between knowledge of various disciplines are artificial.

1. Balaram, P., *Curr. Sci.*, 2009, **96**, 321–322.
2. Simon, H. A., *The Sciences of the Artificial*, MIT Press, Cambridge, 1996, 3rd edn.
3. Newell, A., In *Artificial Intelligence* (eds Bobrow, D. G. and Hayes, P. J.), 1985, vol. 25, pp. 375–415.
4. Searle, J. R., *Behav. Brain Sci.*, 1980, **3**, 417–457.
5. Wiener, N., *Cybernetics or Control and Communication in the Animal and the Machine*, John Wiley, New York, 1948.

V. V. S. SARMA

Department of Computer Science and Automation,
Indian Institute of Science,
Bangalore 560 012, India
e-mail: vvs@csa.iisc.ernet.in