PALADYN Journal of Behavioral Robotics

VERSITA

Editorial · DOI: 10.2478/s13230-012-0006-3 · JBR · 2(3) · 2011 · 109-110

Cybernetic Approaches to Robotics

Nazmul Haque Siddique[1*], Richard Mitchell[2†], Michael O'Grady[3‡], Hamid Jahankhani[4]

1 University of Ulster, UK

2 University of Reading, UK

3 University College Dublin, IE

4 University of East London, UK

The term Cybernetics was coined by Norbert Wiener in 1948 in his book Cybernetics (Wiener, 1948), with the common view of a general science of control and communication in the animal and the machine. Communication means conveying information and control means to produce desired changes using the information. Cybernetics is the science that studies the principles of organisation in complex systems, in other words, systems that behave like living beings. Cybernetics focuses on how systems use information, models, and control actions to steer towards an optimal goal. Being inherently transdisciplinary, cybernetic reasoning can be used to understand, model and design systems of any kind: physical, technological, social, biological, ecological, psychological, and economical or any combination of these. Cybernetics had from the beginning an interested in the similarities between autonomous, living systems and machines (Heylighen and Joslyn, 2001). Therefore, a trend within this research community is to study the functional mechanisms of these autonomous and living systems and apply them to machines to make it autonomous or to behave like living systems.

Through the years cybernetics has found applications in many areas and influenced the birth of various modern sciences. Many researchers in biological and social sciences – physiologist, psychologist, and sociologist – are interested in cybernetics and are applying its methods and techniques to their own field. The application of cybernetics for real-world problems is a natural progression from developing theories and methods.

Cybernetic systems can be understood as a combination of Systems Theory and Cybernetics, with engineering and biological sciences mingling, and is likely to become a turbulent and active research field (Bertalanffy, 1976; Ashby, 1956; Ashby, 1966; Heylighen, et al., 1999; Joslyn and Heylighen, 1992). The technological advancement over the last three decades have provided us with the knowledge, tools, and confidence, which will allow us to focus research on interfacing bio-organisms, exchange information and control biological systems, and intelligent implants into bio-organisms in the years to come (Csete and Doyle, 2002).

A recent publication by the Slovak Academy of Sciences highlighted the research advances in Cybernetics (Britanak et al., 2000). This research monograph shows a present trend of development in the areas of modelling, scheduling, and control of dynamic systems, signal and image processing, and theoretical robotics. This also indicates that alternative approaches for the synthesis of knowledge-based control systems are also a present trend of development (Santos and Xiang, 2002; Britanak et al., 2000).

Difficulty is encountered in maintaining the coherence of such a broad interdisciplinary field. But the most important cause is the rapid growth of more specialised and application-oriented spin-off disciplines, such as computer science, control engineering, artificial intelligence, cognitive science, dynamical systems, neural networks, fuzzy systems, evolutionary computing, computational intelligence, machine learning, artificial-life, soft computing and bio-informatics, which sap away enthusiasm from the more theoretical parent field. The greatest growth has been in the area of intelligent systems dealing with uncertainty and vagueness. Areas such as fuzzy systems, evolutionary computing, neural networks, and adaptive systems, which were relatively unexplored even ten years ago, are now dominating the scope of Cybernetics (Palmer et al., 2003).

Another important interaction is between an entity and its environment, and so artificial life also falls under the cybernetic umbrella. Examples of artificial life include software simulations of life, hardware life such as robots, 'wetware' which includes biological and chemical systems or hybrid systems where biological systems are used to control real robots. Learning is a feedback process, and hence artificial intelligence is a sub set of cybernetics. Here one can study how machines can learn to control devices, such as robots; or to perform a specific task, such as planning; or it can include strategies whereby artificial life learns to explore its environment or to achieve a given task; or even how a human re-learns to function in rehabilitation.

This special issue covers some aspects of Cybernetics as they are applied to robotics. The papers selected are expanded versions of some of the relevant papers presented at the 9th and 10th international conferences organised by the IEEE Systems Man and Cybernetics Society with the theme of Cybernetic Intelligent Systems, held at the University of Reading in 2010 and the University of East London in 2011.

Two of the papers are in the rehabilitation theme. Handzic et al. discuss the pilot design of a gait enhancing mobile shoe, whose aim is to help correct asymmetric walking patterns which often occur in a stroke.

*E-mail: nh.siddique@ulster.ac.uk
†E-mail: R.J.Mitchell@reading.ac.uk
‡E-mail: michael.j.ogrady@ucd.ie

This is a passive device, which can work over varying terrain which it is hoped can be beneficial to patients. Lu et al report their work on upper limb rehabilitation, describing their user-centred design for a portable robotic device to aid stroke survivors retrains their arm muscles.
Two papers are associated with hybrid systems for robots. Spencer et al describe their work of rat brain cultures on multi electrode arrays, used to control a robot, specifically their analysis to determine the dependencies present in and between functional connectivity networks derived from bursts of extra-cellularly recorded activity. They show the persistent co-activation of neuronal pathways in spontaneous bursts, as is seen in the brain. Bamford and Mitchell describe the novel Calvacade neural network, derived from a leaky integrate and fire neuron model, its associated learning algorithm, and then how they can be used to process sensor information on a robot and also to control the robot so it can navigate an environment.

Two papers consider applications of AI methods. Ripon et al.'s describes the use of a hybrid genetic algorithm, incorporating jumping genes operations and a modified backward pass pair-wise exchange heuristic, and demonstrate that this is effective for solving the dynamic facility layout problem. Chandrapal et al. describe their use of neural networks to model the mapping between surface electromyography and knee joint torques, a complex non-linear relationship.

Eversham and Ruiz's paper is in the area of artificial life. They describe their analysis of the classic Reynolds flocking model, measuring flocking area and polarisation, specifically considering how the model can be used in robotic applications.

Finally, Hasson et al.'s paper considers how emotion can be employed in robots. Specifically, they argue that emotions should be considered as a dynamic system linking a controller for social interactions with one for interactions within the physical world.

References

[1] Ashby, W. R. (1956). Introduction to Cybernetics, Chapman & Hall, London, 1956.

[2] Ashby, W. R. (1966). The Cybernetic Viewpoint, *IEEE Transactions Systems Science and Cybernetics*, Vol. 2(1), pp. 7-8.

[3] Bertalanffy, L. Von (1976). General System Theory: Foundations, Development, Applications, George Braziller, Revised edition.

[4] Britanak, V., Frankovic, B. and Sloboda, F. (2000). Research Advances in Cybernetics, Edts, ELFA Publishing House.

[5] Csete, M.E. and Doyle, J.C. (2002). Reverse Engineering of Biological Complexity, *Science*, Vol. 295, pp. 1664-1666.

[6] Heylighen, F., and Joslyn, C. (2001). Cybernetics and Second-order Cybernetics, in R.A. Meyers (edt), Encyclopedia of Physical Sciences & Technology, 3rd Edt, Academic Press, New York, 2001.

[7] Heylighen, F. Joslyn, C. and Turchin, V. (1999). What are Cybernetics and Systems Science? Principia Cybernetica Web, http://pespmc1.vub.ac.be/CYBSWHAT.html.

[8] Joslyn, C. and Heylighen, F. (1992) Cybernetics and Systems Science in Academics, Principia Cybernetica Web, http://pespmc1.vub.ac.be/CYBSACAD.html.

[9] Palmer, J.D., Sage, A.P., Sheridan, T.B., Smith, M.H., and Tien, J.M. (2003). The IEEE Systems, Man and Cybernetics Society: Historical Development, Current Status and Future Perspectives, *IEEE Trans. Sys. Man & Cybernetics - Part C*, Vol 33, No. 1, pp. 13-33.

[10] Santos, E. and Xiang, Y. (2002). Advances on Uncertain Reasoning in Intelligent Systems, *IEEE Trans. Sys.Man & Cybernetics - Part B*, Vol 32(1), pp. 2-3.

[11] Wang, Y. and Wang, Y. (2006). Cognitive Informatics Models of the Brain, *IEEE Trans. Sys. Man & Cybernetics - Part C*, Vol 36(2), pp. 203-207.

[12] Wang, Y. and Kinsner, W. (2006). Recent Advances in Cognitive Informatics, *IEEE Trans. Sys. Man & Cybernetics - Part C*, Vol. 36(2), pp. 121-123.

[13] Wiener, N. (1948). Cybernetics: Control and Communication in the Animal and the Machine", 2nd Edition, *The MIT Press*, Cambridge, Massachusetts.