Biologically Inspired Cognitive Architectures (2016) xxx, xxx–xxx

Available at www.sciencedirect.com

ScienceDirect

journal homepage: www.elsevier.com/locate/bica

RESEARCH ARTICLE

Link intelligence establishing neurocognitive knowledge-processing capabilities in a knowledge network

Meenakshi Malhotra [b,c,*], **T.R. Gopalakrishnan Nair** [a,b]

[a] *Brain and Cognition Group, NIAS, Bangalore, India*
[b] *Advanced Research and Industry Incubation Centre, Advanced Brain Research and Cognition Studies Division, R R Group Institutions Bangalore, India*
[c] *Department of Computer Science and Technology, SET, Jain University, India*

Received 12 January 2016; received in revised form 1 April 2016; accepted 5 April 2016

KEYWORDS
Neurocognitive knowledge network model (NCKM);
Link intelligence;
Self-directivity;
Self-organizing;
Equilibrium

Abstract
The objective of this paper is to demonstrate link intelligence that characterizes neurocognitive knowledge processing capabilities through dynamic knowledge development, learning and stability within a given knowledge network. The existing knowledge networks connect two or more data nodes with edges that have no intelligence embedded into them and provide for static information connectivity and retrieval. This paper focuses on the link intelligence that contributes towards the development of neurocognitive knowledge network model (NCKM) with autonomous processing nodes. Links in NCKM exhibit neurocognitive knowledge processing characteristics by virtue of its four properties viz. efficient knowledge assimilation, self-directivity, self-organization, and equilibrium. The simulation results comprise searching different concepts from NCKM to retrieve knowledge threads for the searched concept. The results exhibit the significance of link-weight gradation in self-directivity and self-organization of links for intelligent knowledge retrieval. The results also demonstrate the significance of equilibrium process to maintain stability in the knowledge network, by limiting the link-weight values within the saturation limits. Additionally, the results depict the criticality of

Abbreviations: NCKM, NeuroCogntive Knowledge network Model; KNN, Knowledge Network Node

* Corresponding author at: Department of Computer Science and Technology, SET, Jain University, India. Tel.: +91 9880858358.
E-mail address: uppal_meenakshi@yahoo.co.in (M. Malhotra).

http://dx.doi.org/10.1016/j.bica.2016.04.001

Please cite this article in press as: Malhotra, M, & Nair, TRG, Link intelligence establishing neurocognitive knowledge-processing capabilities in a knowledge network ..., *Biologically Inspired Cognitive Architectures* (2016), http://dx.doi.org/10.1016/j.

coupling retrieval of random concepts with equilibrium process in providing knowledge build-up and learning within NCKM. NCKM with its intelligent links and processing nodes finds its applicability in many cognitive and intelligent systems.

Introduction

Information processing and knowledge retrieval are the two basic functionalities that facilitate understanding the intelligent behavior of a human brain. An average adult human brain consists of approximately 86 billion neurons where each neuron connects to hundreds of thousands of other neurons (Herculano-Houzel, 2009).

The interconnection between neurons provided by synapse and axon, form an intricate network of neurons commonly referred as brain network (Kandel, Schwartz, & Jessell, 2000). The connectors between neurons in the human brain network are primarily responsible for imparting intelligence into the network. The researchers from the field of cognition define intelligence as the ability to reason, respond, and learn quickly from experiences to plan and solve problems (Gottfredson, 1997). Numerous psychologists and brain scientists define intelligence as the general mental ability that helps in reasoning, problem-solving and learning (Colom, Karama, Jung, & Haier, 2010; Jensen, 1998). Intelligence integrates within itself the cognitive abilities that enable efficient working. Thus, in a brain network, the ability to perform any cognitive task lays significantly on the interconnection. However, for the existing knowledge networks developed so far, the edges that connect nodes in a map or graph network, have experienced the deficiency of intelligence within them. The connection between nodes in the existing knowledge networks is defined statically with one or more property value that fails to incorporate cognitive behavior into the knowledge network system.

The structural representation of knowledge components governs the intelligence of any knowledge system. Malhotra and Nair (submitted for publication) have proposed neurocognitive knowledge network model (NCKM) that aims at structuring a knowledge network innate with neurocognitive properties. Intelligence within a neurocognitive knowledge system, NCKM, provides the ability to respond to queries put forward in distinct ways, reconnecting network efficiently and coherently to provide stability and learning. The above statements have provided a new definition of intelligence in NCKM as the *ability to respond, reconnect and learn* due to its links. This justifies the statement that link intelligence is at the source of intelligent knowledge retrieval.

This paper provides a detailed discussion of the self-directing and self-organizing properties of NCKM liable for providing intelligent linking. The details of the linking mechanism used by various knowledge systems and brain projects under development are provided under Research Background section. Next section provides a brief introduction to NCKM model. Subsequent section illustrates the intelligent link structure provided by NCKM and also provides details on self-directing and self-organizing properties of the links, followed by a discussion of the results of knowledge retrieved from the system in the next section. The last section provides conclusions of link intelligence in NCKM.

Research background

The aspiration to create intelligent systems has led to the continuous developments in the field of Artificial Intelligence (AI). AI is a field of computer science that came into existence with an aim to build a computational system that can be as good as a human brain computation. Marvin Minsky and John McCarthy are among the foremost researchers in the field of AI (Stuart & Norvig, 2010). In his book, Minsky (1988) had proposed interactions between the simple parts called agents, as human intelligence. John McCarthy (2007) had defined the term AI as ''It is the science and engineering of making intelligent machines, especially intelligent computer programs. It is related to the similar task of using computers to understand human intelligence" (p. 2). One of the most commonly referred definitions of AI states ''AI is the study of how to make computers do things that, at the moment, people do better" (Rich, Knight, & Nair, 2009).

One requirement that has held the attention of researchers and scientists in the field of AI is to develop intelligent knowledge systems that embed human intelligence to structure and process the incoming information, to enable intelligent knowledge retrieval.

Preliminary knowledge systems

The initial development of knowledge systems used maps and graphs to represent connection of words. Cognitive maps (Tolman, 1948) and conceptual graphs (CG) (Sowa, 1976) used arcs or edges to connect nodes. A fuzzy cognitive map (FCM) is a blend of fuzzy logic and cognitive maps (Kosko, 1993). Mind maps have been used for structuring and making notes (Farrand, Hussain, & Hennessy, 2002). A concept map is a graphical tool like mind map but is mainly used to search an explicit query (Coffey, Hoffman, Cañas, & Ford, 2002). The semantic network introduced by Sowa in 1992 is a means to provide structured knowledge. A graphical representation of information within these systems utilizes simple graphs where nodes are oval or rectangular boxes representing words, connected by edges that principally involve no intelligence.

Two prominent approaches

Two other approaches namely Artificial Neural Network (ANN) and Semantic Web have provided technology for intelligent computing. ANN targeted at connecting

Please cite this article in press as: Malhotra, M, & Nair, TRG, Link intelligence establishing neurocognitive knowledge-processing capabilities in a knowledge network ..., *Biologically Inspired Cognitive Architectures* (2016), http://dx.doi.org/10.1016/j.