Biologically Inspired Cognitive Architectures (2013) **6**, 96–108

Available at www.sciencedirect.com

ScienceDirect

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

RESEARCH ARTICLE

Development of a self sustaining cognitive architecture

Anjan Kumar Ray *, Gang Leng, T.M. McGinnity, Sonya Coleman, Liam Maguire

Intelligent Systems Research Centre (ISRC), Faculty of Computing and Engineering, University of Ulster, Magee Campus, Londonderry BT48 7JL, UK

Received 19 May 2013; received in revised form 13 July 2013; accepted 14 July 2013

KEYWORDS
Self-organising system;
Fuzzy logic;
Neural network;
Reasoning model;
Cognitive architecture

Abstract
A context-aware cognitive system is a prime requirement for a sensor rich smart home environment. In this paper, we discuss the development and evaluation of a self-sustaining cognitive architecture for the RUBICON (Robotic UBIquitous COgnitive Network) system which builds its knowledge as per the environmental situations. The proposed cognitive architecture consists of a reasoning module, a decision module, and a supporting memory module. An online sliding-window based self-organising fuzzy neural network (SOFNN), which explores relationships between the event inputs and desired reasoning outputs, is developed for the reasoning module. We also propose a prediction model based on event information to support the reasoning module for continuous training in the absence of external training data. The decision module generates control goals for the robots according to the status outputs from the reasoning module. We develop a MySQL based database for the memory module which supports the overall system by storing processed information about the states of the environment and providing historical information for enhanced understanding. The architecture is trained and tested with environmentally realistic synthesized data to show its adaptation capabilities. The results demonstrate that the proposed system can learn activities and track them within a smart home environment. This initial implementation also highlights the potential of the architecture and will serve as a very important test-bed for future work. We envisage that the proposed combination of the prediction model and the reasoning module will eventually result in a general purpose, self-sustaining, self-organising cognitive architecture for different applications and thus the proposed architecture enters into the sphere of the biologically inspired cognitive architecture (BICA) challenge.

* Corresponding author. Tel.: +44 2871675499.
E-mail addresses: ak.ray@ulster.ac.uk (A.K. Ray), g.leng@ulster.ac.uk (G. Leng), tm.mcginnity@ulster.ac.uk (T.M. McGinnity), sa.coleman@ulster.ac.uk (S. Coleman), lp.maguire@ulster.ac.uk (L. Maguire).

2212-683X/$ - see front matter
http://dx.doi.org/10.1016/j.bica.2013.07.006

Introduction

Cognitive architectures are frequently used to model human behaviour and reproduce aspects of such behaviour, in artificial systems. There are a number of cognitive architectures in the literature (Duch, Oentaryo, & Pasquier, 2008; Langley, Laird, & Rogers, 2009; Vernon, Metta, & Sandini, 2007). SOAR (State, Operator and Result) is a rule-based cognitive architecture designed to model general knowledge (Laird, 2008, 2012). The learning mechanism in SOAR is an explanation-based learning (EBL) technique to formulate rules. SOAR has been used, for example, to develop computer games, human language processing and categorization (Laird, 2008; Lewis, 1993; Magerko, Laird, Assanie, Kerfoot, & Stokes, 2004; Tambe et al., 1995). The cognitive architecture ICARUS, designed for physical agents (Langley & Choi, 2006), relies on symbolic manipulation of knowledge. The architecture includes modules for perception, planning and execution where concepts are processed in a bottom-up way to match perception and goals that are processed in a top-down way to match skills. In Prodigy (Carbonell & Gil, 1990; Carbonell et al., 1991; Haigh & Veloso, 1996), the learning and reasoning modules produce mutually interpretable knowledge structures. Its general-purpose problem solver searches through a set of control rules that are based on 'select', 'reject', and 'prefer' to accomplish a set of goals. NOMAD, also known as Darwin automata (Edelman, 1993), uses a reward mechanism that drives learning in a large-scale neural network. It is mainly used for real-time pattern recognition such as visual scene understanding and invariant object recognition. ACT-R (Adaptive Components of Thought-Rational) is a hybrid cognitive architecture. It aims to model human behaviour (ACT-R., 2013; Anderson et al., 2004). ACT-R has three main components: modules, buffers and pattern matcher. There are two types of modules named perceptual-motor modules and cognitive memory modules (Byrne, 2001). Perceptual-motor modules create interfaces with the real world. There are two types of memory modules named declarative memory consisting of facts and procedural memory which represents knowledge about different procedures. A production system coordinates the action of the modules by matching the information stored in several buffers, where each module places a limited amount of information. The pattern matcher searches for a production that matches the current state of the buffers. The ACT-R architecture is used in different application areas including different aspects of memory, perception, attention, reasoning and decision making, problem solving, and language processing (Peebles & Banks, 2010; Taatgen, 2005; Trafton et al., 2005). Kismet, as part of an articulated robotic head (Langley, Cummings, & Shapiro, 2004), has five distinct modules in its cognitive architecture; a perceptual system, an emotion system, a behaviour system, a drive system, and a motor system. It tries to understand the dynamics of social interaction by cues like gaze direction, facial expression and vocal babbling. CLARION is also a hybrid architecture that stores both action-centred and non-action centred knowledge in implicit form using multi-layer neural networks and in explicit form using

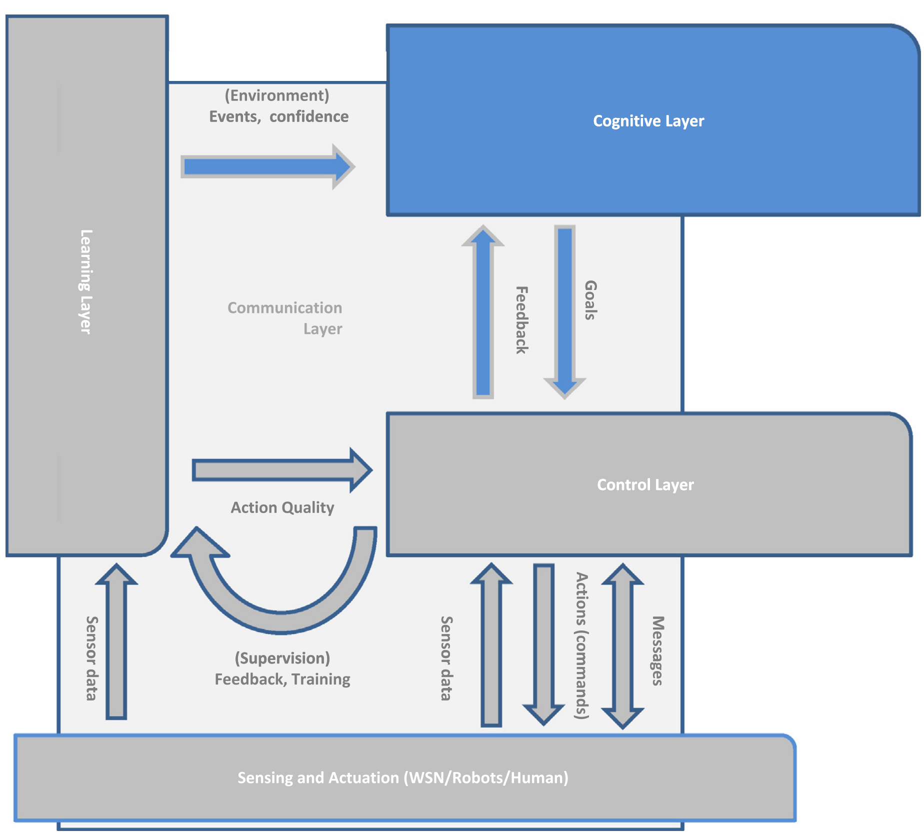

Fig. 1 The Cognitive Layer within the high-level overall RUBICON architecture.