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COGNITIVE SCIENCE: INTEGRATIVE PERSPECTIVE IN ARTIFICIAL INTELLIGENCE AND HUMAN-COMPUTER INTERACTION

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ABSTRACT

Cognitive science, whose genesis was interdisciplinary, shows signs of reverting to disjoint collection fields which include psychology (especially cognitive psychology), computer technology, linguistics and psycholinguistics, philosophy (especially philosophy of mind), neuroscience, logic, anthropology and biology (including biomechanics). This paper focused on effect of cognitive science on computer science, especially artificial intelligence (AI) and Human-computer interaction (HCI). Also, various ways by which cognitive science was integrated into artificial intelligence were analysed.
Keywords Cognitive Science, Cognitive Engineering, Artificial Intelligence

INTRODUCTION

The science and engineering of artificial systems that exhibit mental capabilities has a long history, stretching back over sixty years. The term mental is not meant to imply any dualism of mind and body; mental faculties entail all aspects of robust behaviour, including perception, action, deliberation, and motivation. The term "cognitive" in "cognitive science" (CS) is "used for any kind of mental operation or structure that can be studied in precise terms" [16] or it implies an ability to understand how things might possibly be, not just now but at some future time, and to take this into consideration when determining how to act. The field is highly interdisciplinary and is closely related to several other areas in which artificial intelligence (AI) and human-computer interaction (HCI) (in computer technology) are among [13]. Building cognitive models is very much a research area at the forefront of AI research and psychological research. The research in AI overlaps considerably with cognitive science.

Cognitive engineering is the application of cognitive science theories to human factors practice. As this description suggests, there are strong symbioses between cognitive engineering and cognitive science, but there are also strong differences. The development of the production-system-based architectures most strongly associated with cognitive engineering [Adaptive Control of Thought - Rational and Soar] was motivated by the desire to explore basic cognitive processes. This paper is focused on how cognitive science has been integrated into computer science, especially AI.

HISTORICAL PERSPECTIVES

Cognitive science emerged in the mid 1970s out of a realisation that a multidisciplinary approach was required if we were to understand higher mental processes and structures. It attempts to bring together what is known about the mind from many academic disciplines: psychology, linguistics, anthropology, philosophy, and computer science. In line with cognitive science the concept of cognitive psychology emerged as an outcome of computer technologies by assuming that the computer can provide a new paradigm for psychology. In this trend Psychology at large was declared a science of information processing. Although AI, cognitive science and cognitive psychology have different aims and methods of investigation, they basically all share an understanding of human thinking as information processing.

Artificial Intelligence (AI) aims at creating computer software and hardware that imitates the human mind or functions of the human brain. The role of the computer is to replace the human in intellectual spheres, such as mathematical calculations, manipulation of numbers and letters, decision-making, problem solving, and so on. Rosenblatt viewed building a computer to execute some algorithm dreamed up by a programmer was not as important as building a computing machine that could learn from experience [22]. He thus set out to propose a procedure that could be programmed into a computer that would allow it to learn any function anyone wanted it to be able to compute. According to Neisser, the invention of the computer made it possible for psychologists to overcome their reluctance to think in terms of processes they could not directly observe, and it contributed to the demise of behaviorism [18]. Some works were made towards the construction of intelligent artefacts such as expert systems, which purport to be models of experts' problem solving and expert knowledge automatizised in information programs. [11]. Others view artificial intelligence as 'theoretical psychology' seeking information processing models of human thoughts leading us to a view of AI as the study of 'cognitive' phenomena within the machine.

HCI is an interdisciplinary area of applied research and design practice which attempts to understand and facilitate the creation of user interfaces. In order to understand the cognitive aspects of this interaction, the HCI field uses the knowledge accumulated within AI, cognitive science and cognitive psychology. From AI research HCI may use a variety of cognitive models for representing the user, as well as the means to test these models. Cognitive science offers HCI knowledge of what users understand and how they understand it. From cognitive psychology HCI uses the knowledge about cognitive processes and structures as well as the method of investigation: an empirical approach to the study of human behaviour [1].

METHODS OF INTEGRATION

This section discusses the different ways by which cognitive science can be integrated into artificial intelligence and Human-computer interaction.

Cognitive Approach to AI

There are three approaches by which cognitive science can be integrated to AI.

i. Creativity Cognitive Approach to AI

There always has been a great interest in how the great creative minds manage to invent something completely new. Unfortunately, these creative minds are mostly not able to explain how they came up with the unexpected, or from what source they got their inspiration, so creativity stays surrounded by a mystical aura. In psychology, creativity is usually defined as the production of an idea, action, or object that is new and valued, although what is considered creative at any point in time depends on the cultural context [9]. Creativity has been the topic of research within many branches of cognitive science. The creative cognition approach focuses on the cognitive processes and structures that underlie creative thinking [24].

Creative cognition is applicable in AI. As a theory in the philosophy of mind, AI assumes that human cognitive mental states can be duplicated in computing machinery. Claims made within research towards creativity are usually weak AI. A certain creative ability, such as writing poetry, composing music, or painting is modeled within a computer program. This does not imply that the computer has mental states or that the same causal relations found in the human brain are involved (the claims of strong AI). The major contribution of AI towards a better understanding of creativity is that the theoretical concepts used to build AI-models can enlighten certain aspects of creative thinking. Furthermore, AI doesn't provide us with just theoretical concepts, but also with working computer programs.

ii. Cognitive Modularity Approach to AI

What is considered to define a module varies a great deal both within and across the cognitive science disciplines, but a simple definition of modularity according to Flombaum: "Modularity is the thesis that the mind contains independent input systems that, when engaged, are restricted in the types of information that they can consult." Modularity is an important attribute for systems that have to interact with a complex, changing environment. It is used widely for mobile robotics, virtual reality and user interfaces. It has also often been suggested for managing networked resources (whether load balancing or exploiting e-services on the Internet), but these applications are not yet well established. There are three distinct approaches to modularity that have been developed in AI in the last twenty years. [7, 8]

a. Modules as Agents

The first well-known modular model of mind at least described by an AI researcher is the 'Society of Mind' [17]. An individual's actions are determined by simpler individual agencies, which are effectively specialists in particular domains. Minsky's agencies are compositional — they exploit hierarchy for organisation. Minsky's agents have both perception and action, but not memory, which is managed by a shared facility Memory (K) agencies are interconnected both with each other and with the other, actor (S) agents. K agents and S agents can each activate the other type as well as others of their own type. Keeping the whole system working requires another horizontal faculty: the 'B brain' which monitors the main (A) brain for internally obvious problems such as redundancy or feedback cycles.

b. Modules as Finite State Machines

The term "behaviour-based artificial intelligence" (BBAI) was invented to describe a simplified but fully-implemented system, originally used to control mobile robots. This was the subsumption architecture [3, 6]. The subsumption architecture is purely vertical. The modules were originally each finite state machines and arbitration between them was conducted exclusively by wires connecting the modules - originally literally, but soon as encoded in software. Each wire could connect one module to another's input or output wires, the signal of which the first module could then either monitor, suppress or overwrite. Brooks initially asserted that most apparent horizontal faculties (memory, judgement, attention, and reasoning) were actually abstractions 'emergent from' an agent's expressed behaviour, but had no place in the agent's actual control. However, his system was rapidly extended to have learning systems either inside modules or local to layers of modules [2].

c. Agents as Modules

At the other end of the modular-complexity spectrum are multi-agent systems (MAS) [28, 29]. Here, the modules composing the system *are* agents, but not in Minsky's sense. Rather, these agents were meant at least initially to be themselves complete software systems — often the agents themselves use the sort of hybrid behaviour-based architectures just described [10, 12]. MAS practitioners generally consider themselves to be modeling not individual minds, but societies. They nevertheless typically do have 'horizontal' modules / agents / components for connecting agents with complementary needs and abilities together (directory agents) or for enforcing behavioural norms of participants. However, to date there are a few fundamental differences between a MAS and a single, modular agent. These differences are due to issues of communication and arbitration between modules/agents. The MAS community is concerned with interoperability between unspecified numbers and types of agents, and with distribution across multiple platforms.

iii. Computational Cognitive approach to AI

Research in computational cognitive modeling, or simply computational psychology, explores the essence of cognition(broadly defined, including motivation, emotion, perception, and so on) and various cognitive functionalities through developing detailed, process-based understanding by specifying corresponding computational models (in a broad sense) of representations, mechanisms, and processes. It embodies descriptions of cognition in computer algorithms and programs, based on computer science. That is, it imputes computational processes (in a broad sense) onto cognitive functions, and thereby it produces runable computational models. Detailed simulations are then conducted based on the computational models. Right from the beginning of the formal establishment of cognitive science around late 1970's, computational modeling has been a mainstay of cognitive science. [25]

Computer modeling of human cognition was originally mainly done off-line in the sense that the cognitive system is viewed as a hardware independent program, effectively disregarding the surrounding environment and even the importance of a human body. Attempts to apply computational and mathematical modeling techniques to human factors issues have a long and detailed history. Unfortunately, we cannot review that history here; however, we can do the next best thing and point the reader to Dick Pew's [21] very personal history of human performance modeling from the 50's on. Before the cognitive revolution and, arguably, continuing today, most researchers studying cognitive human behavior were trained in experimental psychology. This tradition focuses on teasing and torturing secrets from nature by tightly controlled studies in which small manipulations are made, and humans perform many nearly identical trials. People with this background and training often cannot conceive how someone could possibly study, let alone model, something as complex as driving, the influence of the layout of a graph on performance [20], information search on the World Wide Web [4, 15, 19], or air traffic control (ATC) issues [5].

Models of the Artificial Intelligence are built around computational concepts derived from the computational approach. The computational approach takes cognition to be the operation of a special mental computer, located somewhere in the brain. Sensory organs deliver representations of the state of the environment to the mental computer. Firstly, the system computes a specification of a certain action; the body carries out this action. In the applications and models of computational cognitive a series of assumptions are made, viz; (i) representations are static structures of discrete symbols; (ii) cognitive operations are transformations from one static symbol structure to the next. These transformations are discrete, effectively instantaneous, and sequential; (iii) the mental computer is broken down into a number of modules responsible for different symbol-processing tasks. A module takes symbolic representations as inputs and computes representations as outputs. At the periphery of the system are inputs and output transducers: systems, which transform sensory stimulation into input representations, and output representations into physical movements. The whole system, and each of its modules, operates cyclically: input, internal symbol manipulation, output [27].

Cognitive Approaches to HCI

Rasmussen [23] sees the limitations of an information processing approach to human cognition by observing a difference in the information processes of computers and human mental decision processes. His proposed model is never-the-less within the framework of the information processing paradigm with its traditional cognitive three level model: input (perception), an internal world model (that processes and controls the input), and motor output. This understanding of the human-computer system may be characterised as an 'information processing loop' where the output from the human being, enters the computer's input, and visa versa [14]. Thus, analysis of Rasmussen's approach is seen as one of the cognitive approaches in general, where the human mind is understood as a specific type of an information processing unit.

CONCLUSION

Invention of the computer created the field of Artificial Intelligence and HCI and was essential for Cognitive science and psychology as well. It enabled a way of thinking and a way of assessing the adequacy of this thinking through computer simulation. It provided tools that dramatically extended the reach of the human mind, allowing it to calculate out the consequences of long sequences of operations, which previously had been impossible. This paper has presented different methods by which cognitive science can be integrated into areas of computer technology that cognitive science found mostly romancing, that is AI and HCI. This had drawn a distinction between weak and strong AI. Weak AI holds that suitably programmed machines can simulate human cognition. Strong AI, by contrast, maintains that suitably programmed machines are capable of cognitive mental states.

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