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Tetsuya Hoya

Artificial Mind System

Kernel Memory Approach

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To my colleagues, educators, and my family

Preface

This book was written from an engineer's perspective of mind. So far, although quite a large amount of literature on the topic of the mind has appeared from various disciplines; in this research monograph, I have tried to draw a picture of the holistic model of an artificial mind system and its behaviour, as concretely as possible, within a unified context, which could eventually lead to practical realisation in terms of hardware or software. With a view that "*mind is a system always evolving*", ideas inspired/motivated from many branches of studies related to brain science are integrated within the text, i.e. artificial intelligence, cognitive science/psychology, connectionism, consciousness studies, general neuroscience, linguistics, pattern recognition/data clustering, robotics, and signal processing. The intention is then to expose the reader to a broad spectrum of interesting areas in general brain science/mind-oriented studies.

I decided to write this monograph partly because now I think is the right time to reflect at what stage we currently are and then where we should go towards the development of "brain-style" computers, which is counted as one of the major directions conducted by the group of "creating the brain" within the brain science institute, RIKEN.

Although I have done my best, I admit that for some parts of the holistic model only the frameworks are given and the descriptions may be deemed to be insufficient. However, I am inclined to say that such parts must be heavily dependent upon specific purposes and should be developed with careful consideration during the domain-related design process (see also the Statements to be given next), which is likely to require material outside of the scope of this book.

Moreover, it is sometimes a matter of dispute whether a proposed approach/model is biologically plausible or not. However, my stance, as an engineer, is that, although it may be sometimes useful to understand the underlying principles and then exploit them for the development of the "artificial" mind system, only digging into such a dispute will not be so beneficial for the development, once we set our ultimate goal to construct the mechanisms

functioning akin to the brain/mind. (Imagine how fruitless it is to argue, for instance, only about the biological plausibility of an airplane; an artificial object that can fly, but not like a bird.) Hence, the primary objective of this monograph is not to seek such a plausible model but rather to provide a basis for imitating the functionalities.

On the other hand, it seems that the current trend in general connectionism rather focuses upon more and more sophisticated learning mechanisms or their highly-mathematical justifications without showing a clear direction/evidence of how these are related to imitating such functionalities of brain/mind, which many times brought me a simple question, "*Do we really need to rely on such highly complex tools, for the pursuit of creating the virtual brain/mind?*" This was also a good reason to decide writing the book.

Nevertheless, I hope that the reader enjoys reading it and believe that this monograph will give some new research opportunities, ideas, and further insights in the study of artificial intelligence, connectionism, and the mind. Then, I believe that the book will provide a ground for the scientific communications amongst various relevant disciplines.

Acknowledgment

First of all, I am deeply indebted to Professor Andrzej Cichocki, Head of the Laboratory for Advanced Brain Signal Processing, Brain Science Institute (BSI), the Institute of Physical and Chemical Research (RIKEN), who is on leave from Warsaw Institute of Technology and gave me a wonderful opportunity to work with the colleagues at BSI. He is one of the mentors as well as the supervisors of my research activities, since I joined the laboratory in Oct. 2000, and kindly allowed me to spend time writing this monograph. Without his continuous encouragement and support, this work would never have been completed. The book is moreover the outcome of the incessant excitement and stimulation gained over the last few years from the congenial atmosphere within the laboratory at BSI-RIKEN. Therefore, my sincere gratitude goes to Professor Shun-Ichi Amari, the director, and Professor Masao Ito, the former director of BSI-RIKEN whose international standing and profound knowledge gained from various brain science-oriented studies have coalized at BSI-RIKEN, where exciting research activities have been conducted by maximally exploiting the centre's marvelous facilities since its foundation in 1997. I am much indebted to Professor Jonathon Chambers, Cardiff Professorial Fellow of Digital Signal Processing, Cardiff School of Engineering, Cardiff University, who was my former supervisor during my post-doc period from Sept. 1997 to Aug. 2000, at the Department of Electrical and Electronic Engineering, Imperial College of Science, Technology, and Medicine, University of London, for undertaking the laborious proofreading of the entire book written by a non-native English speaker. Remembering the exciting days in London, I would like to express my gratitude to Professor Anthony G.

Constantinides of Imperial College London, who was the supervisor for my Ph.D. thesis and gave me excellent direction and inspiration. Many thanks also go to my colleagues in BSI, collaborators, and many visitors to the ABSP laboratory, especially Dr. Danilo P. Mandic at Imperial College London, who has continuously encouraged me in various ways for this monograph writing, Professor Hajime Asama, the University of Tokyo, Professor Michio Sugeno, the former Head of the Laboratory for Language-Based Intelligent Systems, BSI-RIKEN, Dr. Chie Nakatani and Professor Cees V. Leeuwen of the Laboratory for Perceptual Dynamics, BSI-RIKEN, Professor Jianting Cao of the Saitama Institute of Technology, Dr. Shuxue Ding, at the University of Aizu, Professor Allan K. Barros, at the University of Maranhão (UFMA), and the students within the group headed by Professor Yoshihisa Ishida, who was my former supervisor during my master's period, at the Department of Electronics and Communication, School of Science and Engineering, Meiji University, for their advice, fruitful discussions, inspirations, and useful comments.

Finally, I must acknowledge the continuous and invaluable help and encouragement of my family and many of my friends during the monograph writing.

BSI-RIKEN, Saitama
April 2005 *Tetsuya Hoya*

Statements

Before moving ahead to the contents of the research monograph, there is one thing to always bear in our mind and then we need to ask ourselves from time to time, "What if we successfully developed artificial intelligence (AI) or humanoids that behaves as real mind/humans? Is it really beneficial to human-kind and also to other species?" In the middle of the last century, the country Japan unfortunately became a single (and hopefully the last) country in the world history that actually experienced the aftermath of nuclear bombs. Then, only a few years later into the new millennium (2000), we are frequently made aware of the peril of bio-hazard, resulting from the advancement in biology and genetics, as well as the world-wide environmental problems. The same could potentially happen if we succeeded the development and thereby exploited recklessly the intelligent mechanisms functioning quite akin to creatures/humans and eventually may lead to our existence being endangered in the long run. In 1951, the cartoonist Osamu Tezuka gave birth to the astro-boy named "Atom" in his works. Now, his cartoons do not remain as a mere fiction but are like to become reality in the near future. Then, they warn us how our life can be dramatically changed by having such intelligent robots within our society; as a summary, in the future we may face to the relevant issues as raised by Russell and Norvig (2003):

- People might lose their jobs to automation;
- People might have too much (or too little) leisure time;
- People might lose their sense of being unique;
- People might lose some of their privacy rights;
- The use of AI systems might result in a loss of accountability;
- The success of AI might mean the end of the human race.

In a similar context, the well-known novel "Frankenstein" (1818) by Mary Shelley also predicted such a day to come. These works, therefore, strongly suggest that it is high time we really needed to start contemplating the (near)

future, where AIs or robots are ubiquitous in the surrounding environment, what we humans are in such a situation, and what sort of actions are necessary to be taken by us. I thus hope that the reader also takes these emerging issues very seriously and proceeds to the contents of the book.

Contents

List of Abbreviations

ADF	ADaptive Filter
AI	Artificial Intelligence
ALCOVE	Attention Learning COVEring map
ALE	Adaptive Line Enhancer
AMS	Artificial Mind System
ANN	Artificial Neural Network
ARTMAP	Adative Resonance Theory MAP
ASE	Adaptive Signal Enhancer
BP	Back-Propagation
BSE	Blind Signal Extraction
BSP	Blind Signal Processing
BSS	Blind Source Separation
CMOS	Complimentary Metal-Oxide Semiconductor
CR	Conditioned Response
CS	Conditioned Stimuli
DASE	Dual Adaptive Signal Enhancer
DFT	Discrete Fourier Transform
DOA	Direction Of Arrival
ECG	ElectroCardioGraphy
EEG	ElectroEncephaloGraphy
EGO	Emotionally GrOunded
EMG	ElectroMyoGraphy
EVD	EigenValue Decomposition
FIR	Finite Impulse Response
FFT	Fast Fourier Transform
fMRI	functional Magnetic Resonance Imaging
GCM	Generalised Context Model
GMM	Gaussian Mixture Model
GRNN	Generalised Regression Neural Network
HA-GRNN	Hierarchically Arranged Generalised Regression
HMM	Hidden Markov Model

HRNN	Hopfield-type Recurrent Neural Network
ICA	Independent Component Analysis
i.i.d.	Independent Identically Distributed
KF	Kernel Function
KM	Kernel Memory
K-Line	Knowledge-Line
LAD	Language Acquisition Device
LIFO	Last-In-Fast-Out
LMS	Least Mean Square
LPC	Linear Predictive Coding
LTD	Long Term Depression
LTM	Long Term Memory
MDIMO	Multi-Domain Input Multi-Output
MEG	MagnetoEncephaloGraphy
MIMO	Multi-Input Multi-Output
MLP-NN	Multi-Layered Perceptron Neural Network
MORSEL	Multiple Object Recognition and Attentional Selection
M-SSP	Multi-stage Sliding Subspace Projection
NLMS	Normalised Least Mean Square
NM	Neural Memory
NN	Neural Network
NR	Noise Reduction
NSS	Nonlinear Spectral Subtraction
PET	Positron Emission Tomography
PNN	Probabilistic Neural Network
PRS	Perceptual Representation System
PSD	Power Spectral Density
QMF	Quadrature Mirror Filter
RBF	Radial Basis Function
SAD	Sound Activity Detection
SAIM	Selective Attention for Identification Model
SDIMO	Single-Domain-Input Single Output
SE	Signal Separation
SFS	Speech Filing System
SIMO	Single-Input Single Output
SLAM	SeLective Attention Model
SNR	Signal-to-Noise Ratio
SOBI	Second-Order Blind Identification
SOFM	Self-Organising Feature Map
SOKM	Self-Organising Kernel Memory
SPECT	Single-Photon Emission Computed Tomography
SRN	Simple Recurrent Network
SS	Signal Separation
SSP	Sliding Subspace Projection
STM	Short Term Memory

SVD	Singular Value Decomposition
SVM	Support Vector Machine
TDNN	Time Delay Neural Network
UR	Unconditioned Response
US	Unconditioned Stimuli
XOR	eXclusive OR