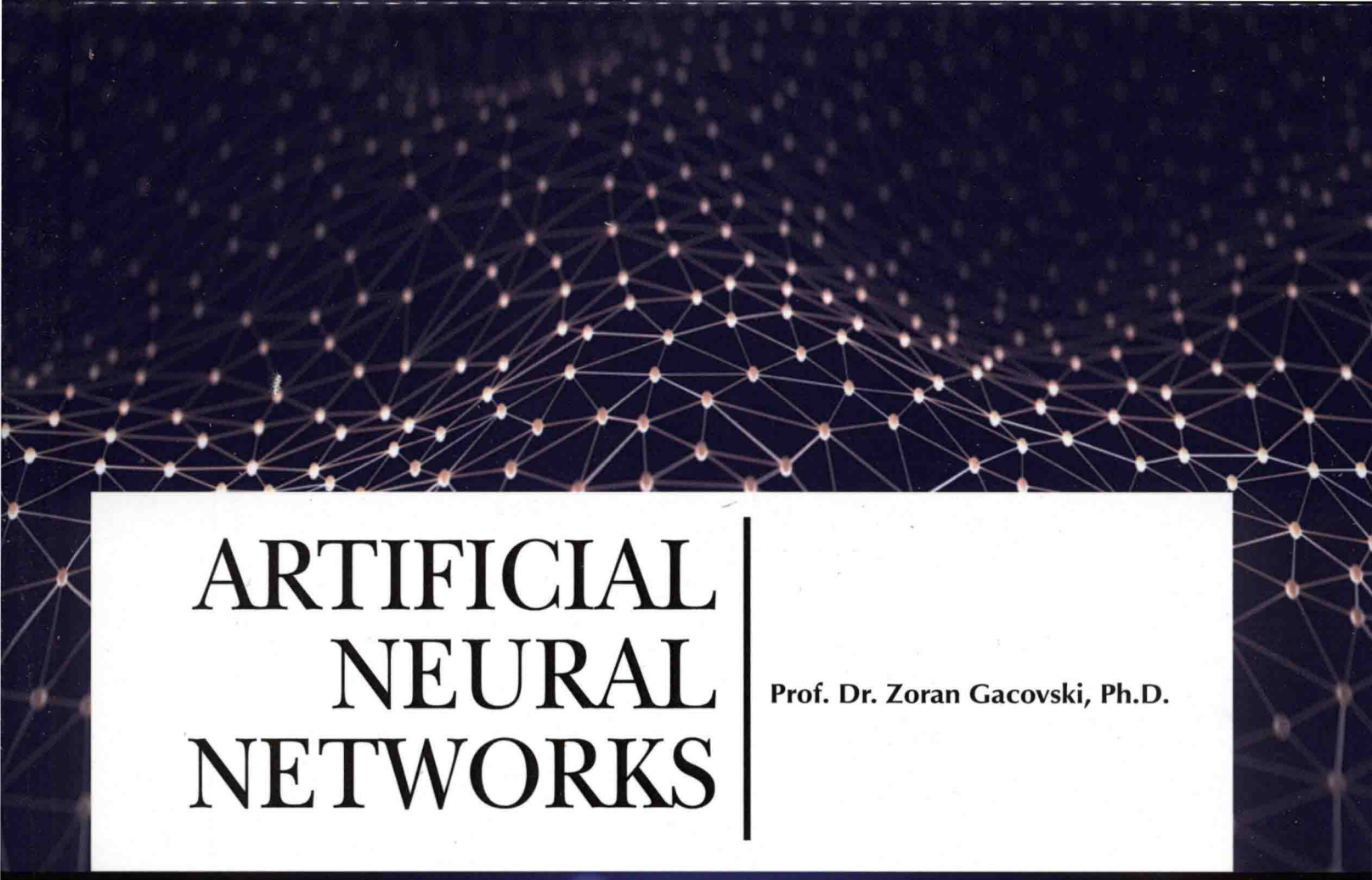
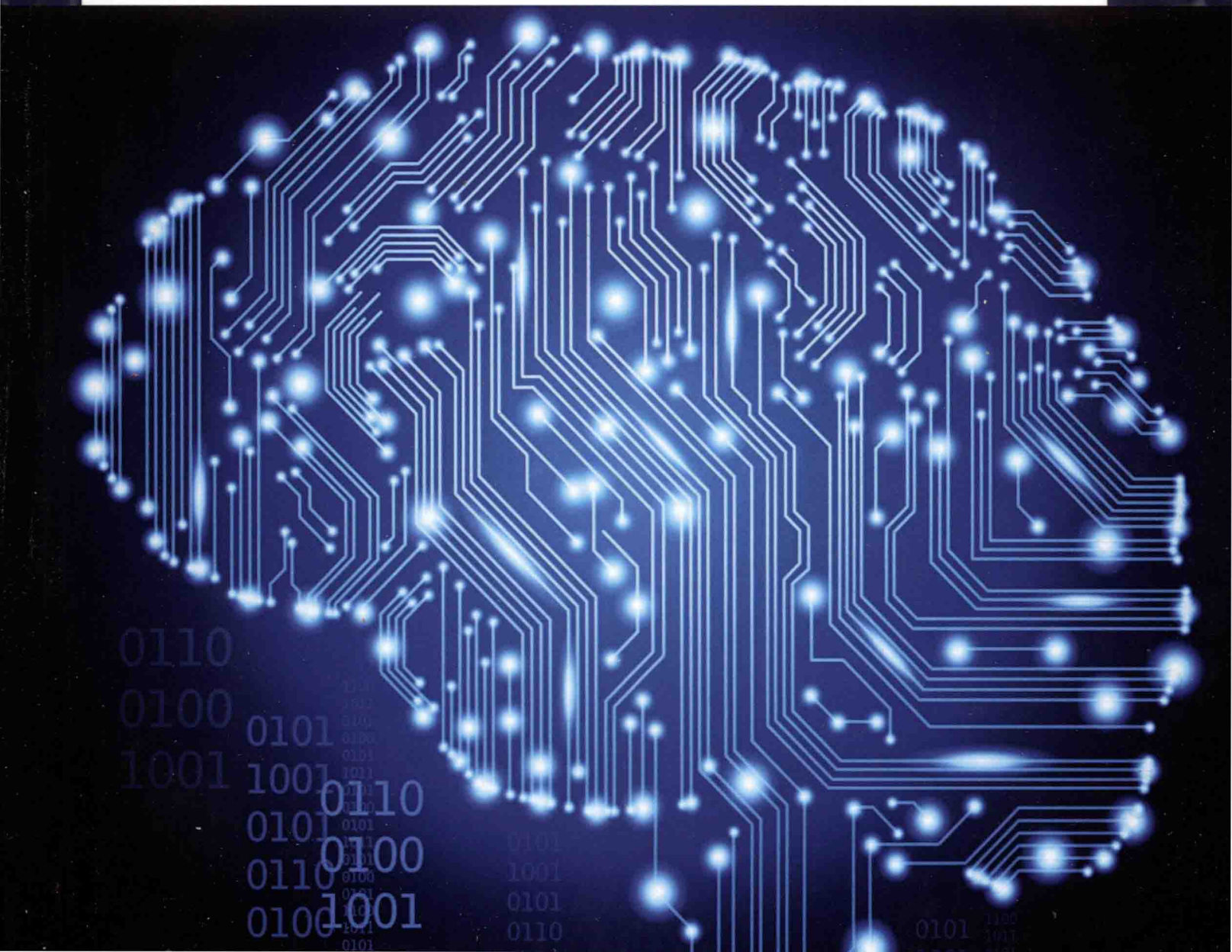


ARTIFICIAL NEURAL NETWORKS

Prof. Dr. Zoran Gacovski, Ph.D.



Artificial Neural Networks

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" Dr. Zoran Gacovski has earned his PhD degree at Faculty of Electrical engineering, Skopje. His research interests include Intelligent systems and Software engineering, fuzzy systems, graphical models (Petri, Neural and Bayesian networks), and IT security. He has published over 50 journal and conference papers, and he has been reviewer of renowned Journals. In his career he was awarded by Fulbright postdoctoral fellowship (2002) for research stay at Rutgers University, USA. He has also earned best-paper award at the Baltic Olympiad for Automation control (2002), US NSF grant for conducting a specific research in the field of human-computer interaction at Rutgers University, USA (2003), and DAAD grant for research stay at University of Bremen, Germany (2008). Currently, he is a professor in Computer Engineering at European University, Skopje, Macedonia."

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Artificial Neural Nerworks

About the Editor

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List of Contributors

Tielin Zhang
Institute of Automation, Chinese Academy of Sciences, Beijing, China
University of Chinese Academy of Sciences, Beijing, China

Yi Zeng
Institute of Automation, Chinese Academy of Sciences, Beijing, China

Bo Xu
Institute of Automation, Chinese Academy of Sciences, Beijing, China

Ning Ning
Data Storage Institute, Agency for Science, Technology and Research, Singapore

Guoqi Li
Department of Precision Instrument, Tsinghua University, Beijing, China
Center for Brain-Inspired Computing Research (CBICR), Tsinghua University, Beijing, China

Wei He
Data Storage Institute, Agency for Science, Technology and Research, Singapore

Kejie Huang
Singapore University of Technology and Design, Dover, Singapore

Li Pan
Data Storage Institute, Agency for Science, Technology and Research, Singapore

Kiruthika Ramanathan
Data Storage Institute, Agency for Science, Technology and Research, Singapore

Rong Zhao
Singapore University of Technology and Design, Dover, Singapore

Luping Shi
Department of Precision Instrument, Tsinghua University, Beijing, China
Center for Brain-Inspired Computing Research (CBICR), Tsinghua University, Beijing, China

Shinichi Tamura
NBL Technovator Co., Ltd., 631 Shindachimakino, Sennan 590-0522, Japan

Yoshi Nishitani
Department of Radiology, Graduate School of Medicine, Osaka University, Suita 565-0871, Japan

Chie Hosokawa
Biomedical Research Institute, AIST, Ikeda, Osaka 563-8577, Japan

Tomomitsu Miyoshi
Department of Integrative Physiology, Graduate School of Medicine, Osaka University, Suita 565-0871, Japan

Hajime Sawai
College of Health and Human Sciences, Osaka Prefecture University, Habikino, Osaka 583-8555, Japan

Wei Li,
College of Automation, Huazhong University of Science and Technology, Wuhan 430074, China
Image Processing and Intelligent Control Key Laboratory of Education Ministry of China, Wuhan 430074, China

Miao Wang
College of Automation, Huazhong University of Science and Technology, Wuhan 430074, China
Image Processing and Intelligent Control Key Laboratory of Education Ministry of China, Wuhan 430074, China

Yapeng Li
College of Automation, Huazhong University of Science and Technology, Wuhan 430074, China
Image Processing and Intelligent Control Key Laboratory of Education Ministry of China, Wuhan 430074, China

Yue Huang
College of Automation, Huazhong University of Science and Technology, Wuhan 430074, China
School of Electrical and Electronic Engineering, East China Jiaotong University, Nanchang 330013, China

Xi Chen
College of Automation, Huazhong University of Science and Technology, Wuhan 430074, China
Image Processing and Intelligent Control Key Laboratory of Education Ministry of China, Wuhan 430074, China

Hani Omar
Institute of Information Management, National Chiao Tung University, Hsinchu 300, Taiwan
Computational Intelligence Technology Center, Industrial Technology Research Institute, Chutung, Hsinchu 310, Taiwan

Van Hai Hoang
The University of Danang, Campus in Kon Tum, No. 129 Phan Dinh Phung Street, Kon Tum 580000, Vietnam

Duen-Ren Liu
Institute of Information Management, National Chiao Tung University, Hsinchu 300, Taiwan

Elizabeth Martinez-Zeron
Facultad de Informática, Universidad Autónoma de Querétaro, Querétaro, México

Marco A. Aceves-Fernandez
Facultad de Informática, Universidad Autónoma de Querétaro, Querétaro, México

Efren Gorrostieta-Hurtado
Facultad de Informática, Universidad Autónoma de Querétaro, Querétaro, México

Artemio Sotomayor-Olmedo
Laboratory of Artificial Intelligence, Faculty of Engineering, Universidad Autónoma de Querétaro, Querétaro, México

Juan Manuel Ramos-Arreguín
Facultad de Informática, Universidad Autónoma de Querétaro, Querétaro, México

Itedal Sabri Hashim Bahia
Ministry of Higher Education and Scientific Research, Baghdad, Iraq

Jie Wang
School of Science, Beijing Jiaotong University, Beijing 100044, China

Jun Wang
School of Science, Beijing Jiaotong University, Beijing 100044, China

Wen Fang
School of Economics and Management, Beijing Jiaotong University, Beijing 100044, China

Hongli Niu
School of Science, Beijing Jiaotong University, Beijing 100044, China

Deepti Moyi Sahoo
Department of Mathematics, National Institute of Technology Rourkela, Rourkela, Odisha 769 008, India

S. Chakraverty
Department of Mathematics, National Institute of Technology Rourkela, Rourkela, Odisha 769 008, India

Fahed Awad

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Depatment of Network Engineering & Security, Jordan University of Science & Technology, Irbid, Jordan

Rufaida Shamroukh
Depatment of Computer Engineering, Jordan University of Science & Technology, Irbid, Jordan

Yongtae Do
Electronic Control Major, Division of Electronic & Electrical Engineering, Daegu University, 712-714, South Korea

Xiaoqing Luo
School of IoT Engineering, Jiangnan University, Wuxi, China

Xiaojun Wu
School of IoT Engineering, Jiangnan University, Wuxi, China

Gulshan Kumar
Department of Computer Application, Shahed Bhagat Singh State Technical Campus, Punjab, India

Krishan Kumar
Department of Computer Science & Engineering, Punjab Institute of Technology, Punjab, India

Manar Maraqa
Department of Management Information Systems, Al-Isra' Private University, Amman, Jordan;

Farid Al-Zboun
College of Information Technology, Ajloun National University, Ajloun, Jordan;

Mufleh Dhyabat
College of Information Technology, AL al-Bayt University, Mafraq, Jordan;

Raed Abu Zitar

School of Engineering and Technology, New York Institute of Technology, Amman, Jordan.

Jamal Salahaldeen Majeed Alneamy
Software Engineering Department, Computer and Mathematics Science College, University of Mosul, Mosul, Iraq

Rahma Abdulwahid Hameed Alnaish
Software Engineering Department, Computer and Mathematics Science College, University of Mosul, Mosul, Iraq

Yuhua Chen
Department of Electrical and Computer Engineering, University of Houston, Houston, USA

Subhash Kak
Department of Computer Science, Oklahoma State University, Stillwater, USA

Lei Wang
Department of Electrical and Computer Engineering, University of Houston, Houston, USA

Junjia Yuan,
College of Automation, Harbin Engineering University, Harbin 150001, China

Hao Meng
College of Automation, Harbin Engineering University, Harbin 150001, China

Qidan Zhu
College of Automation, Harbin Engineering University, Harbin 150001, China

Jiajia Zhou
College of Automation, Harbin Engineering University, Harbin 150001, China

Wei-Bo Chen
National Science and Technology Center for Disaster Reduction, New Taipei City 23143, Taiwan

Wen-Cheng Liu
Department of Civil and Disaster Prevention Engineering, National United University, Miaoli 36063, Taiwan
Taiwan Typhoon and Flood Research Institute, National Applied Research Laboratories, Taipei 10093, Taiwan

B. Krishna
Deltaic Regional Center, National Institute of Hydrology Kakinada, Andhra Pradesh, India

Y. R. Satyaji Rao
Deltaic Regional Center, National Institute of Hydrology Kakinada, Andhra Pradesh, India

P. C. Nayak
Deltaic Regional Center, National Institute of Hydrology Kakinada, Andhra Pradesh, India

Jafar Keighobadi
Faculty of Mechanical Engineering, University of Tabriz, Tabriz, Iran.

Khadijeh Alioghli Fazeli
Faculty of Mechanical Engineering, University of Tabriz, Tabriz, Iran.

Mohammad Sadeghi Shahidi
Faculty of Mechanical Engineering, University of Tabriz, Tabriz, Iran.

Preface

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INTRODUCTION

Artificial Neural Networks are relatively crude electronic models based on the neural structure of the brain. The brain basically learns from experience. It is natural proof that some problems that are beyond the scope of current computers are indeed solvable by small energy efficient packages. This brain modeling also promises a less technical way to develop machine solutions. This new approach to computing also provides a more graceful degradation during system overload than its more traditional counterparts.

These biologically inspired methods of computing are thought to be the next major advancement in the computing industry. Even simple animal brains are capable of functions that are currently impossible for computers. Computers do rote things well, like keeping ledgers or performing complex math. But computers have trouble recognizing even simple patterns much less generalizing those patterns of the past into actions of the future.

Now, advances in biological research promise an initial understanding of the natural thinking mechanism. This research shows that brains store information as patterns. Some of these patterns are very complicated and allow us the ability to recognize individual faces from many different angles. This process of storing information as patterns, utilizing those patterns, and then solving problems encompasses a new field in computing. This field, as mentioned before, does not utilize traditional programming but involves the creation of massively parallel networks and the training of those networks to solve specific problems. This field also utilizes words very different from traditional computing, words like behave, react, self-organize, learn, generalize, and forget.

Analogy to the Brain

The exact workings of the human brain are still a mystery. Yet, some aspects of this amazing processor are known. In particular, the most basic element of the human brain is a specific type of cell which, unlike the rest of the body, doesn't appear to regenerate. Because this type of cell is the only part of the body that isn't slowly replaced, it is assumed that these cells are what provide us with our abilities to remember, think, and apply previous experiences to our every action. These cells, all 100 billion of them, are known as neurons. Each of these neurons can connect with up to 200,000 other neurons, although 1,000 to 10,000 is typical.

The power of the human mind comes from the sheer numbers of these basic components and the multiple connections between them. It also comes from genetic programming and learning.

The individual neurons are complicated. They have a myriad of parts, sub-systems, and control mechanisms. They convey information via a host of electrochemical pathways. There are over one hundred different classes of neurons, depending on the classification method used. Together these neurons and their connections form a process which is not binary, not stable, and not synchronous. In short, it is nothing like the currently available electronic computers, or even artificial neural networks.

These artificial neural networks try to replicate only the most basic elements of this complicated, versatile, and powerful organism. They do it in a primitive way. But for the software engineer who is trying to solve problems, neural computing was never about replicating human brains. It is about machines and a new way to solve problems.

Artificial Neurons and How They Work

The fundamental processing element of a neural network is a neuron. This building block of human awareness encompasses a

few general capabilities. Basically, a biological neuron receives inputs from other sources, combines them in some way, performs a generally nonlinear operation on the result, and then outputs the final result. Figure 1 shows the relationship of these four parts.

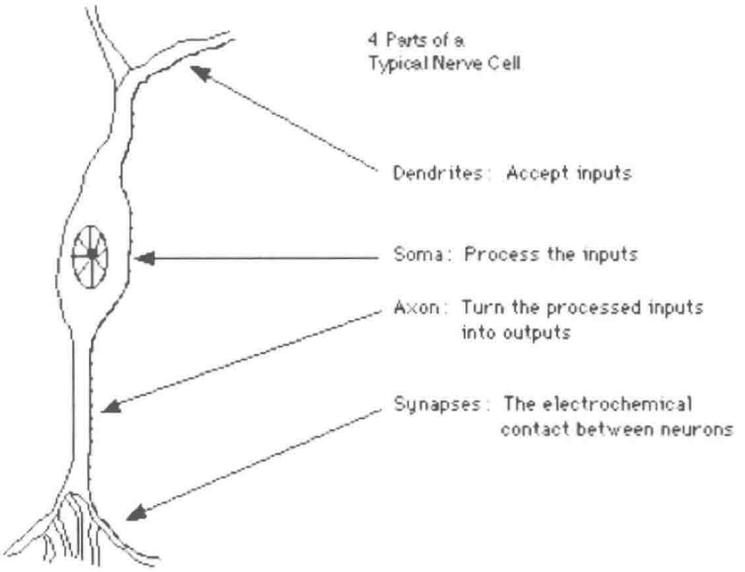

Figure 1: A Simple Neuron.

Within humans there are many variations on this basic type of neuron, further complicating man's attempts at electrically replicating the process of thinking. Yet, all natural neurons have the same four basic components. These components are known by their biological names - dendrites, soma, axon, and synapses. Dendrites are hair-like extensions of the soma which act like input channels. These input channels receive their input through the synapses of other neurons. The soma then processes these incoming signals over time. The soma then turns that processed value into an output which is sent out to other neurons through the axon and the synapses.

Recent experimental data has provided further evidence that biological neurons are structurally more complex than the simplistic explanation above. They are significantly more complex than the existing artificial neurons that are built into today's artificial neural networks. As biology provides a better understanding of neurons, and as technology advances, network designers can continue to improve their systems by building upon man's understanding of the biological brain.

But currently, the goal of artificial neural networks is not the grandiose recreation of the brain. On the contrary, neural network researchers are seeking an understanding of nature's capabilities for which people can engineer solutions to problems that have not been solved by traditional computing.

To do this, the basic unit of neural networks, the artificial neurons, simulates the four basic functions of natural neurons. Figure 2 shows a fundamental representation of an artificial neuron.

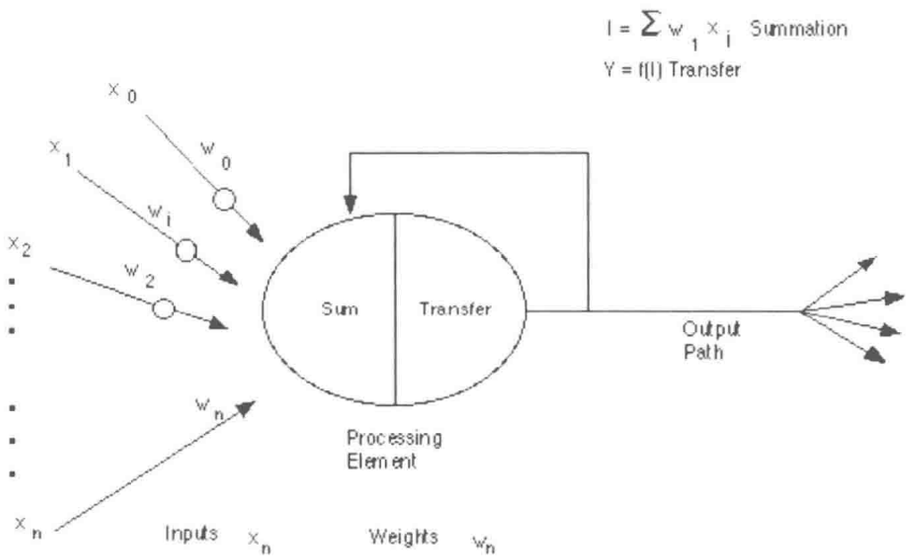

Figure 2: A Basic Artificial Neuron.

In Figure 2, various inputs to the network are represented by the mathematical symbol, x(n). Each of these inputs are multiplied by a connection weight. These weights are represented by w(n). In the simplest case, these products are simply

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