Neural and Concurrent Real-Time Systems

The Sixth Generation

BRANKO SOUČEK

Sixth-Generation Computer Technology Series

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WILEY

A Wiley-Interscience Publication

JOHN WILEY & SONS

New York / Chichester / Brisbane / Toronto / Singapore

Library of Congress Cataloging in Publication Data:

Souček, Branko.
Neural and concurrent real-time systems: the sixth generation/
Branko Souček.
p. cm.
"A Wiley-Interscience publication."
Includes bibliographies and index.
ISBN 0-471-50889-6
1. Neural computers. 2. Real-time data processing. I. Title.
QA76.5.S6572 1989
006.3—dc19 89-5682
CIP

Printed in the United States of America

10 9 8 7 6 5 4 3 2 1

PREFACE

Thanks to advances in artificial neural networks, expert systems, and concurrent processors, it is now possible to build *intelligent* real-time systems, which belong to the sixth-generation technology. Intelligent real-time systems described in this book cover the following applications: intelligent instruments, data acquisition, signal and speech processing, computer vision and graphics, process control and manufacturing inspection, intelligent robots, decision-making systems, on-line simulators, transputer-based superclusters, flexible factory cells, and compter integrated manufacturing.

The built-in neural and concurrent processors and knowledge bases provide these systems with a set of new features: learning and self-organization, fuzzy reasoning, very high-speed signal processing and process control, real-time recognition and classification of patterns in signals and images, high reliability due to the dispersed storage, and a very high performance/price ratio. As a result, intelligent real-time systems present a rapidly growing technology.

The book is divided into two parts:

Part I: INTELLIGENT PROCESSES (Chapters 1 to 5)
Part II: INTELLIGENT SYSTEMS (Chapters 6 to 11)

Chapter 1 gives an overview of signal processing. Histogram measurement principles are reviewed first; different methods for the correlation analysis are explained next. Computer programs are shown to calculate power spectra for periodic and nonperiodic signals. Chapter 2 reviews the processes needed to understand real-time systems: sampling and quantizing theorems, analog-to-digital conversion, and servicing and queueing involving serial and parallel components.

Chapter 3 describes mapping, adaptation, and learning in neural networks. Neural networks of very fine and medium granularity are presented: field computers, back-propagation networks, high-order units, alternating projection networks, and stochastic cells. Chapter 4 gives concrete examples of neural networks in real-time applications. Examples cover signal processing, noise cancellation, EKG, sonar, speech, phonetic typewriter, image recognition, object classification, manufacturing inspection, feedback process control, and robot manipulators. Neural networks open the road toward new learning, control, and robots, avoiding analytical system design.

Chapter 5 deals with coarse grain intelligent processes: artificial genetic selection, forward-backward chaining of knowledge schemas, and frames. Examples include expert systems for fault diagnosis, factory cell simulation and knowledge-based robots and process control.

Chapter 6 gives an overview of computers in instrumentation and in-process control. The basic techniques explained are: input/output transfer, interrupts, direct-memory access, interfacing, real-time clock, channels, pools, and semaphores. Real-time operating systems, schedulers and monitors are also explained and widely used real-time computers, buses, and networks are illustrated.

Chapter 7 describes newly developed neural chips and systems. Structures realizing 20 billion multiply/adds per second equivalent to 40,000 MIPS are shown. Neurocomputers with 10 million processing elements are presented. Digital and analog neural chips are described and compared. The chapter ends with the description of high-speed neural coprocessors. Chapter 8 defines the concurrent system as a set of relatively independent processes, connected to each other through synchronized messages. Functional features of the transputer family of chips and the OCCAM language are described. Real-time programming is explained, including timers, scheduling, interrupts, and polling.

Chapter 9 concentrates on concurrent system design and applications. Concrete examples of parallel system design and real-time programming, based on transputers and OCCAM, are presented. Examples range from simple units, speech, vision and graphics, to multi-user flight simulators and flexible manufacturing cells.

Chapter 10 deals with the upper level transputer-based concurrent systems: computing surface, cluster and superclusters. These systems achieve the power of supercomputers for a tenth of the cost of other systems. Superclusters can expand infinitely, with overall throughput going up in proportion to the number of processors. Application specific topologies can be configured with the network configuration unit.

Chapter 11 outlines the market for neural, concurrent, and intelligent real-time systems. A whole new industry and business has been born. Intelligent systems and services represent the infrastructure for a highly efficient and clean economy of the 1990s. The suggestions of Nobel Laureates, devoting time and energy in intelligence research, are discussed.

The book has been written as a textbook for students, as well as a reference for practicing engineers and scientists. A minimal undergraduate-level background is assumed, although many fundamentals are reviewed. The treatment is kept as straightforward as possible emphasizing functions, systems, and applications. A comprehensive list of manufacturers at the end of the book includes addresses, products, and services (neural, concurrent, intelligent, real-time systems). Readers interested in other related topics of neural and concurrent processing should combine this book with B. Souček and M. Souček, *Neural and Massively Parallel Computers: The Sixth Generation,* Wiley, New York, 1988. These two books are independent volumes, with only a slight overlap.

Zagreb, Yugoslavia
September 1989

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ACKNOWLEDGMENTS

I acknowledge the encouragement, stimulating atmosphere, discussions, and support received from my teachers, friends, and colleagues. Here, I can only name a few:

P. Brajak, I. Bratko, A. D. Carlson, F. Cellier, B. Furht, S. R. Hameroff, F. J. Hill, F. Jović, G. A. Korn, D. Koruga, H. Kraljević, R. H. Mattson, V. Milutinović, B. Ostojić, P. Papić, G. R. Peterson, M. Petrinović, S. Prešern, J. W. Rozenblit, A. Scott, P. Šuhel, T. Triffet, D. Vrsalović, B. P. Zeigler, A. Železnikar.

I thank the following institutions where I performed the experiments with neural, concurrent, and real time systems:

Department of Mathematics, University of Zagreb
Department of Electrical and Computer Engineering, University of Arizona
Department of Neurobiology and Behavior, State University of New York at Stony Brook
Brookhaven National Laboratory
Institute Rudjer Bošković

To write a book like this one, it was necessary to borrow some data from the manuals of computer/system manufacturers. I should like to thank the following companies for giving permission to adapt material from their publications:

AI Wave, Inc.
Global Holonetic Corporation
Hecht-Nielsen Neurocomputer Corporation
INMOS Group of Companies
Intellicorp
Nestor, Inc.
Oxford Computer
Paracom
Parsytec
Syntonic Systems, Inc.
TRW

Special thanks to John Wiley's editors and reviewers and to Mrs. B. Grdović and Mrs. V. Zlatić for assistance during preparation of the manuscript for the publisher. I am grateful to Mrs. L. Van Horn for an outstanding job in supervising the copyediting of the manuscript.

CONTENTS

PART I

Intelligent Processes

CHAPTER 1

Signal Processing

INTRODUCTION AND SURVEY

A substantial increase in data collection efficiency can be achieved if data can be sorted on the basis of some parameter. In this case, hundreds or thousands of pieces of data, instead of being individually recorded, can be accumulated into one counting location. Each value of the parameter should have its own counting location. A histogram accumulated in this way presents the probability distribution function of the measured parameter. This kind of data collection is used in numerous experiments and can be readily done with a laboratory computer. Data collecting and sorting systems are usually called *analyzers*.

This chapter describes basic data analysis techniques. Probability distribution measurement principles are reviewed first, and the most important analysis techniques are described next. Different kinds of data analyzers are widely used in physics, chemistry, biomedicine, and engineering (pulse-height analyzers, time-of-flight analyzers, Mossbauer-effect analyzers, neuron activity analysis, industrial product testing, communication signal analysis, etc.).

A simple yet efficient tool for analyzing random data through statistical averaging is the correlation function, which describes the time dependencies of a random data record. The correlation function can be measured with special instruments or a laboratory computer. In this chapter, we describe the basic definition and properties of the correlation function and explain two methods for calculating it. It is shown that the classical method, although good for analysis of random amplitudes, produces meaningless results if used to analyze random intervals. Both computer-simulated and experimental data have been used to check the correlation algorithms. A modified method for interval analysis is explained, and computer programs for both methods are discussed.

The most obvious presentation of the signal is in the time domain: the amplitude of the signal is displayed as a function of time. Another important presentation of the signal is in the frequency domain. For this purpose a Fourier series is used. The signal waveform may be expanded into a series of sine waves. By finding the amplitudes of these sine waves, we form the power spectra. The power spectral density function describes the general frequency composition of the data. The frequency composition of the data, in turn, bears important relationships to the basic characteristics of the physical or biomedical system involved.

In this chapter the Fourier series expansion is explained. Computer programs are used to calculate Fourier coefficients for a periodic signal and the power spectra for a nonperiodic signal. Also, some typical, frequently occurring waveforms are analyzed, and their power spectra are displayed and discussed. The chapter concludes with a discussion of special machines for measuring the power spectra and their variation with time. Such sonograms are widely used in acoustic communication for speech study and for animal communication study.

1.1. AMPLITUDE AND LATENCY HISTOGRAMS

In analyzing nature, one finds that many results indicate that the subjects of measurements belong to the class of random physical phenomena. *Randomness* means that the data are nonperiodic, exhibit no explicit time trend, bias, or regularity, and cannot be precisely defined for all time by any simple analytic function. Many random processes belong to the class of stationary processes. *Stationary* means that certain statistical properties of the data do not change with time.

Three main types of statistical analyses should be carried out for random and stationary data:

1. Amplitude probability density functions,
2. Correlation functions, and
3. Power spectral density functions.

These functions describe a random process, much like the amplitude, waveform, and Fourier frequency spectrum describe a deterministic process. This chapter deals with methods for measuring the amplitude probability density function (pdf).

Five important examples of processes that could occur in practice, singly or in combinations, will now be considered: