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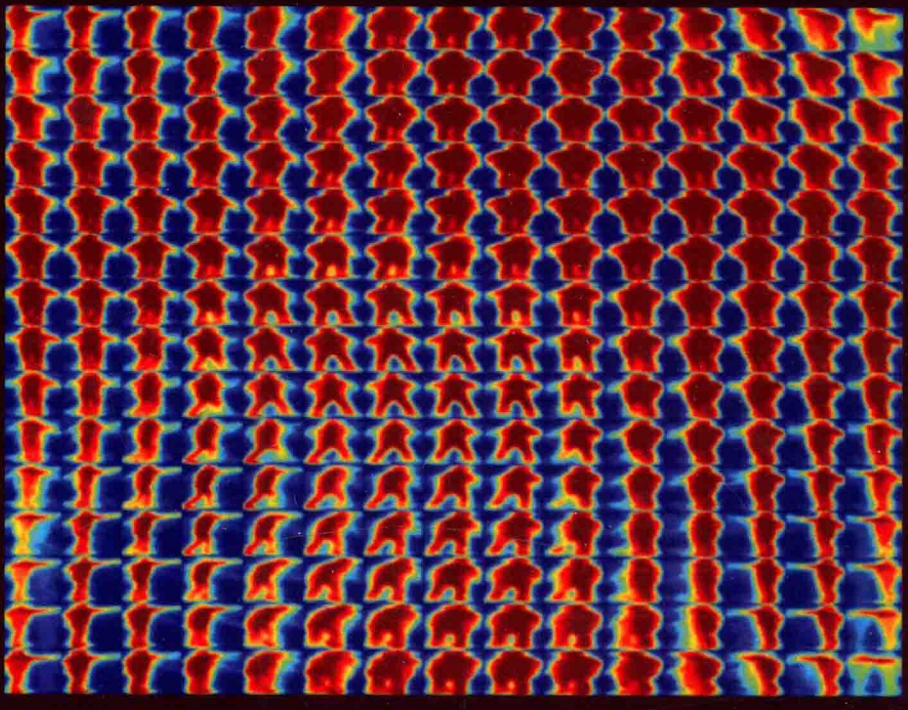
Handbook on Soft Computing for Video Surveillance



Edited by
Sankar K. Pal
Alfredo Petrosino
Lucia Maddalena

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Handbook on Soft Computing for Video Surveillance

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Preface

Video surveillance is the area of computer science devoted to real-time acquisition, processing, and management of videos coming from cameras installed in public and private areas, in order to automatically understand events happening at the monitored sites, eventually sending up an alarm. Because of the rapidly increasing number of surveillance cameras, it has become a key technology for security and safety, with applications ranging from the fight against terrorism and crime, to private and public safety (e.g., in private buildings, transport networks, town centers, schools, and hospitals), and to the efficient management of transport networks and public facilities (e.g., traffic lights and railroad crossings). Video surveillance is an extremely interdisciplinary area, embracing the study of methods and algorithms for computer vision and pattern recognition, but also hardware for sensors and acquisition tools, computer architectures, wired and wireless communication infrastructures, and middleware. From an algorithmic standpoint, the general problem can be broken down into several steps, including motion detection, object classification, tracking, activity understanding, and semantic description, each of which poses its own challenges and hurdles for system designers. Moreover, the scope of video surveillance is being extended to offline multimedia analysis systems related to security and safety, thus entailing disciplines such as content-based video retrieval for visual data similarity retrieval and video mining for knowledge extraction; typical applications are in forensic video analysis and human behavior analysis.

Soft computing is a consortium of methodologies (working synergistically, not competitively) that, in one form or another, reflects its guiding principle: exploit the tolerance for imprecision, uncertainty, approximate reasoning, and partial truth to achieve tractability, robustness, low-cost solution, and close resemblance to human-like decision making. This provides flexible information processing capability for representation and evaluation of various real-life ambiguous and uncertain situations, and therefore results in the foundation for the conception and design of high MIQ (Machine IQ) systems. At this juncture, the principal constituents of soft computing are fuzzy sets, neurocomputing, genetic algorithms, probabilistic reasoning, and rough sets.

Recently, soft computing tools have shown enormous promise in many different tasks of video surveillance. For example, fuzzy logic has proved to be a powerful tool that allows one to handle the imprecision and uncertainty inherent in the background subtraction approach to moving object detection, as well as in the tracking process, and in visual sensor networks; approximate reasoning has proved beneficial for action recognition; fuzzy-rough interpretation of video data can help in dealing with the approximate, incomplete, and vague characteristics of surveillance videos for the analysis of usual and

unusual events; neural networks allow self-organizing learning of a scene background model for moving object detection, tracking of image features in video image sequences, and learning of usual and unusual human behaviors. Several conference papers and journal articles on integrating soft computing techniques into video surveillance have been published in the past decade. Articles describing the challenging issues of soft computing, namely synergistically integrating the constituting components to achieve application specific merits, have also been reported. However, this scattering of information causes inconvenience for researchers, applied scientists, and practitioners.

With this volume we aim to bring together research work concerning the application of soft computing techniques to different tasks of video surveillance, investigating novel solutions, and discussing future trends of existing literature in this field. It includes both review and new material written by worldwide experts describing, in a unified way, the basic concepts, theories, algorithms, and applications that demonstrate why and how soft computing methodologies can be used in different video surveillance problems.

The book consists of eleven chapters. Chapter 1 presents an introduction to video surveillance systems, providing a nice reference for beginners in this area. It includes a fairly extensive and updated survey on such systems, tracing a brief history of their evolution and the actual state of the art. It also highlights the challenges that modern-day systems still face despite achieving significant advancements, and covers several sub-topics concerning video sensors, data fusion, and artificial intelligence techniques.

For the convenience of readers, a brief description of different soft computing tools is provided in Chapter 2, covering the basics of fuzzy sets, rough sets, neural networks, genetic algorithms, and probabilistic reasoning. Special focus is provided on the combination and the hybridization of rough and fuzzy sets, and their role for several image processing tasks, which represent the starting point of many algorithms employed in video surveillance.

Chapter 3 presents some examples of neural network–based approaches to the solution of video surveillance tasks provided in the literature, including moving object detection and tracking, crowd and traffic density estimation, anomaly detection, and behavior understanding. A specific neural-based approach is further described in order to give evidence of the advantages of its adoption for moving object detection, also showing possible uses in the context of other video surveillance tasks, such as stopped object detection, activity recognition, and anomaly detection.

Chapter 4 focuses on summarization, which helps generate movie trailers, sports and news video highlights, and keeps the records of interesting events for future inspection, playing an important role in the context of video surveillance, where processing huge chunks of video data for potential risk demands a huge amount of resources. It reviews existing summarization techniques in the context of their relation to significant content identification, and addresses the suitability of these techniques for surveillance video summarization along with the issue of personalization. Relevance of soft computing is also mentioned.

Chapters 5 through 11 cover a broad spectrum of video surveillance topics that adopt soft computing techniques. They are organized following the usual articulation of a video surveillance system, starting with the task of moving object detection, to tracking, to classification and the recognition of target objects.

Chapter 5 concerns the detection of moving objects in video streams, which is the first relevant step in information extraction in many computer vision applications, and specifically in video surveillance applications. It presents a fairly extensive and updated survey of research on background subtraction that exploits fuzzy techniques in order to handle imprecision and uncertainty inherent in all the steps for problem solution, ranging from background modeling, to foreground detection, to background maintenance. Some of the existing methods are thoroughly compared and future research directions are envisaged.

The problem of fusion of data acquired from multiple sensors, together with related methods and challenges, is considered in Chapter 6, with some applications to tracking objects in video sequences. Dempster–Shafer and Bayesian inference–based data fusion algorithms are considered, and the impact of the fusion of video sequences from different sensors for enhancing the tracking process in the presence of changeable illumination, shadows, and other ambiguous conditions, is specifically addressed. Open issues and other possible applications are also briefly mentioned.

Chapter 7 tackles the problem of human action modeling and recognition from video sequences of human silhouettes independent of the viewpoint. The modeling step relies on Kohonen self-organizing maps, trained from 2D motion templates recorded in different viewpoints and velocities, thus integrating spatial and temporal templates into a common framework and reducing their high dimensionality. Efficacy of the corresponding recognition system, adopting resampling to increase the number of training sequences, is evaluated both on virtual and real datasets.

The task of multi-perspective automated analysis of video data for learning usual event patterns, as well as detecting unusual events, is addressed in Chapter 8, based on clustering using both individual attributes and combination of several attributes, such as time, size, shape, and position of objects. A fuzzy–rough interpretation of the video data for automated video analysis is provided for the analysis of events from surveillance videos, which is helpful in dealing with the approximate, incomplete, and vague characteristics of the video data.

Chapter 9 concerns the task of detecting video shot boundaries to identify subsequences consisting of different video contexts, which is a prerequisite in several applications, including video surveillance, target tracking, and robotic maneuvering. The significance of a fuzzy entropy measure in determining the change in video context is highlighted, leading to an automatic unsupervised detection method.

Although many of the aforesaid chapters present specific applications

of the reported methods, the last two chapters are mainly devoted to present comprehensive application settings, providing descriptions of advanced surveillance systems under development.

Chapter 10 presents a multi-camera platform to monitor the environment, integrated to a multi-robot platform, to enhance situation awareness. Two different vision methods are applied to monitor the environment in real-time, one based on a maximally stable detection and tracking algorithm, and the other using stereo depth. These lead to two different systems comprising the multi-camera platform, whose results are sent to the multi-robot system, which, on alarm, dispatches a robot to monitor the region of interest. The system has been tested in a number of real-world activity recognition tasks.

A surveillance system using multiple audio and video sensors is presented in Chapter 11, where the audio subsystem is used to cover large portions of the monitored area and exploited to guide the video subsystem toward the area of interest for further analysis. An approach for optimal coverage reconfiguration is also considered to reconfigure the sensors to maximize the coverage of the environment. Experimental results in real scenarios show the efficiency of the proposed framework.

A color insert gathers sixteen figures from different chapters, for the convenience of better understanding their color-related content.

The book is intended to be a reference for researchers and professionals, as well as graduate students, interested in the application of soft computing techniques to video surveillance and other related areas, including ambient intelligence, security and safety, civilian and military remote sensing, management of transport networks, and biometrics. It can also be considered as a suggested reading text to be adopted for teaching graduate courses in subjects like computer vision and pattern recognition, image processing, soft computing, and computational intelligence.

The editors of this volume extend their profound gratitude to the reviewers for their generosity and helpful comments concerning the chapters in this volume, which were extensively reviewed and revised before final acceptance. We also received useful suggestions from the reviewers of the original book proposal. In addition, we are very grateful for the help that we have received from Bob Stern and others at CRC Press during the preparation of this volume.

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He worked at the University of California, Berkeley and the University of Maryland, College Park in 1986–1987; the NASA Johnson Space Center, Houston, Texas in 1990–1992 & 1994; and in the US Naval Research Laboratory, Washington DC in 2004. Since 1997 he has served as a distinguished visitor of the IEEE Computer Society (USA) for the Asia-Pacific Region, and held several visiting positions in Italy, Poland, Hong Kong, and Australian universities.

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He received the 1990 S.S. Bhatnagar Prize (which is the most coveted award for a scientist in India), and many prestigious awards in India and abroad, including the 1999 G.D. Birla Award, 1998 Om Bhasin Award, 1993 Jawaharlal Nehru Fellowship, 2000 Khwarizmi International Award from the Islamic Republic of Iran, 2000–2001 FICCI Award, 1993 Vikram Sarabhai Research Award, 1993 NASA Tech Brief Award (USA), 1994 IEEE Trans. Neural Networks Outstanding Paper Award (USA), 1995 NASA Patent Application Award (USA), 1997 IETE-R.L. Wadhwa Gold Medal, the 2001 INSA-S.H. Zaheer Medal, 2005–2006 Indian Science Congress-P.C. Mahalanobis Birth Centenary Award (Gold Medal) for Lifetime Achievement, 2007 J.C. Bose Fellowship of the Government of India and the 2008 Vigyan Ratna Award from Science & Culture Organization, West Bengal.

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Initial research dealt with parallel computing algorithms, methodologies and techniques, and their application to computer graphics. Subsequent research is devoted to methods, algorithms and software for image processing and multimedia systems in high-performance computational environments, with application to real-world problems, mainly digital film restoration and video surveillance.

She taught at the University of Naples Federico II (1999–2006) and at the University of Naples Parthenope (2006–today). She is an associate editor of the *International Journal of Biomedical Data Mining*, serves as a reviewer for several international journals, and is a member of the IEEE and of the International Association for Pattern Recognition.

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A surveillance system can be defined as an implementation that serves as an extension or expansion to awareness. This service is provided to human users to facilitate and assist in the perception and detection of events in the purvey of interest. The capacity of human senses and minds has its limits in areas of cognizance and perspicacity. A wide range of diverse data will succumb rapidly to the most apt individuals. The rapidity and complexity of the received information will only further aggravate the predicament [28].

Currently well-known and modern surveillance systems include the elements of data collection and information analysis. Surveillance systems obtain data, such as video and audio, from their environment. Then the collected