Preface

Computer Vision and *Computer Graphics* can be thought of as opposite sides of the same coin. In computer graphics we start, for example, with a three-dimensional model of a face, and we attempt to render or project this model onto a two-dimensional surface to create an image of the face. In computer vision we attempt to do the opposite — we start with a two-dimensional image of the face and we try to generate a computer model from a sequence of one or more such images. However, the two sides of the coin are by no means equal as far as the amount of research and development lavished upon them; computer graphics is a very advanced and developed field, whereas computer vision is still relatively in its infancy. This is largely because developments in computer graphics have been driven forwards by the multi-billion dollar markets for computer aided design, computer games, and the movie and advertising industry. It therefore makes a great deal of sense to try and exploit this powerful relationship between the two fields so that computer vision can benefit from the wealth of powerful techniques already developed for computer graphics.

In this book we apply this thinking to a field which whilst not exactly a sub-discipline of computer vision has a very great deal in common with it. This field is *Biometrics* where we attempt to generate computer models of the physical and behavioural characteristics of human beings with a view to reliable personal identification. It is not completely a sub-discipline of computer vision because the human characteristics of interest are not restricted to visual images, but also include other human phenomena such as odour, DNA, speech, and indeed anything at all which might help to uniquely identify the individual.

Although biometrics is at least as old as computer vision itself, research and development in this field has proceeded largely independently of computer graphics. We strongly believe that this has been a mistake in the past and we will attempt to redress this balance by developing the other side of the biometrics coin, namely *Biometric Synthesis* — rendering biometric phenomena from their corresponding computer models. For example, we could generate a synthetic face from its corresponding computer model. Such a model could include muscular dynamics to model the full gamut of human emotions conveyed by facial expressions.

We firmly believe that this will be a very fertile area of future research and development with many spin-offs. For example, much work has already been done on the information theory associated with computer graphics; just think of image and video compression — we can now fit a complete high quality $1\frac{1}{2}$ hour movie on a single 700MB CD using MPEG4 or DivX video compression. We should be able to exploit this valuable research to gain a much better understanding of the information theoretic aspects of biometrics which are not very well understood at present. This is just one example of how this powerful dual relationship between computer graphics and computer vision might be exploited.

This book is a collection of carefully selected chapters presenting the fundamental theory and practice of various aspects of biometric data processing in the context of pattern recognition. The traditional task of biometric technologies — human identification by analysis of biometric data is extended to include the new discipline, *Biometric Synthesis*— the generation of artificial biometric data from computer models of target biometrics. Some of new ideas were first presented at the

International Workshop on
"Biometric Technologies: Modeling and Simulation"

held in June 2004 in Calgary, Canada, and which was hosted by the research laboratory of the same name, from which the workshop took its title, "Biometric Technologies: Modeling and Simulation" at the University of Calgary.

The book is primarily intended for computer science, electrical engineering, and computer engineering students, and researchers and practitioners in these fields. However, individuals in other areas who are interested in these and related subjects will find it a most comprehensive source of relevant information.

Biometric technology may be defined as the automated use of physiological or behavioral characteristics to determine or verify an individual's identity. The word biometric also refers to any human physiological or behavioral characteristic[1] which possesses the requisite biometric properties. They are:

[1]A. Jain, R. Bolle, and S. Pankanti, Eds., *Biometrics: Personal Identification in a Networked Society*, Kluwer, 1999.

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Universal (every person should have that
      characteristic),
Unique (no two people should be exactly the same in
      terms of that characteristic),
Permanent (invariant with time),
Collectable (can be measured quantitatively),
Reliable (must be safe and operate at a satisfactory
      performance level),
Acceptable (non-invasive and socially tolerable), and
Non-circumventable (how easily the system is fooled
      into granting access to impostors).
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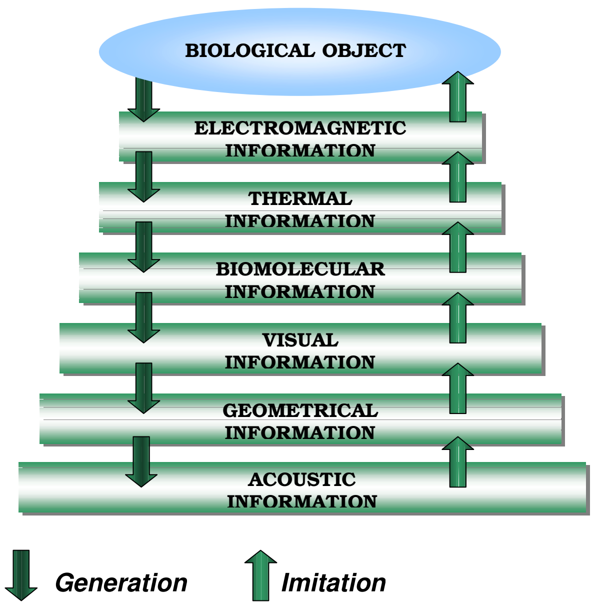

Fig. 1. A biological object as a generator of different types of information. Imitation of biometric data is the solution of the inverse problem.

Research and development in advanced biometrics techniques is currently proceeding in both directions simultaneously: analysis for identification or recognition of humans (direct problems), and synthesis of biometric information (inverse problems), see Fig. 1. The problem of analysis of biometric information has long been investigated. Many researchers have provided efficient solutions for human authentication based on signature, fingerprints, facial characteristics, hand geometry, keystroke analysis, ear, gait, iris and retina scanning. Active research is being conducted using both traditional and emerging technologies, to find better solutions to the problems of verification where claimants are checked against their specific biometric records in a database, and identification where a biometric database is searched to see if a particular candidate can be matched to any record. However, development of biometric simulators for generating synthetic biometric data has not yet been well investigated, except for the particular area of modeling of signature forgery, and voice synthesis, see Fig. 2.

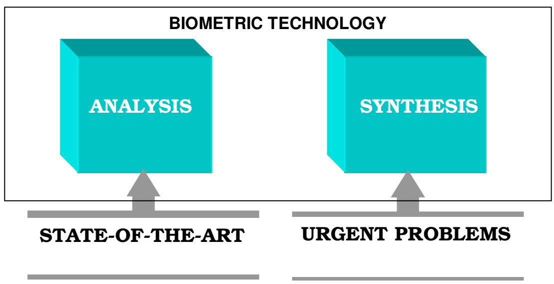

Fig. 2. Direct and inverse problems of biometric technology.

Imitation of biometric information is the inverse problem to the analysis of biometric information. In the area of graphical image processing, for instance, synthesis serves as a source for many innovative technologies such as virtual simulation. The objects in the virtual world are modeled through a virtual reality modeling language. Similarly, the solution to the inverse problem in biometrics will foster pioneering applications, such as biometric imitators that reflect both psychological (mood, tiredness) and physical (normal vs. ultra-red light) characteristics. It will also alleviate the well known backlog problems in traditional biometric research, for example, by providing a novel approach to decision making based on the paradigm of relevance of information. Synthetic biometric data has been the focus of numerous previous studies, but these attempts were limited in that the synthesis was either not automated or semi-automated. Some examples are given in Table 1

Our aim has been to make this book both a comprehensive review and a suitable starting point for developing modeling and simulation techniques

Table 1. Synthetic biometrics.

BIOMETRIC	COMMENTS
Synthetic fingerprints	*Today's interest in automatic fingerprint synthesis addresses the urgent problem of testing fingerprint identification systems, training security personnel, biometric database security, and protecting intellectual property.*
Synthetic signatures	*Current interest in signature analysis and synthesis is motivated by the development of improved devices for human-computer interaction, which enable input of handwriting and signatures. The focus of this study is the formal modeling of this interaction.*
Synthetic irises	*The ocularist's approach to iris synthesis is based on the composition of painted primitives, and utilizes layering of semi-transparent textures built from topological and optic models. Vanity contact lenses are available with fake iris patterns printed onto them (designed for people who want to change eye colors). Colored lenses, i.e., synthetic irises, cause trouble for current identification systems based on iris recognition.*
Synthetic speech	*Synthetic speech has evolved considerably since the first experiments in the 1960s. New targets in speech synthesis include improving the audio quality and the naturalness of speech, developing techniques for emotional "coloring", and combining it with other technologies, for example, facial expressions and lip movement. Synthetic voice should carry information about age, gender, emotion, personality, physical fitness, and social upbringing. The synthesis of an individual's voice will be possible too, the imitation based upon the actual physiology of the person.*
Synthetic emotions and expressions	*Synthetic emotions and expressions are more sophisticated real world examples of synthesis. People often use their smile to mask sorrow, or mask gladness with a neutral facial expression. Such facial expressions can be thought of as artificial or synthetic in a social sense. In contrast to synthetic fingerprints and irises, the carrier of this synthetic facial information is a person's physical face rather than an image on the computer. The carrier of information can be thought of as facial topologies, indicative of emotions. To investigate the above problems, techniques for modeling facial expressions, i.e., the generation of synthetic emotions, must be developed. These results can be used, in particular, in a new generation of lie detectors. A related problem is how music or an instrument expresses emotions. To examine whether music produces emotions, a measuring methodology might be developed.*
Humanoid robots	*Humanoid robots are artificial intelligence machines that include challenging direct and inverse biometrics: language technologies, such as voice recognition and synthesis, speech-to-text and text-to-speech; face and gesture recognition of the "moods" of the instructor, following of cues; dialog and logical reasoning; vision, hearing, olfaction, tactile, and other sensing (artificial retinas, e-nose, e-tongue).*

in biometrics. To achieve this goal, the presentation is organized in three parts:

Part 1: Synthesis in Biometrics,
Part 2: Analysis in Biometrics, and
Part 3: Biometric Systems and Applications.

PART 1: SYNTHESIS IN BIOMETRICS

The first part is devoted to the inverse problems of biometrics — synthesis of biometric data. It includes four chapters and overviews existing and currently being developed approaches to synthesis of various biometric data.

Chapter 1 by Drs. *Yanushkevich, Shmerko, Stoica, Wang*, and *Srihari* "Introduction to Synthesis in Biometrics" introduces the inverse problems of biometrics — synthesis of biometric data. Synthetic biometric data provides for detailed and controlled modeling of a wide range of training skills, strategies, and tactics for forgeries of biometrics, thus enabling a better approach to enhancing system performance.

Chapter 2 by Dr *Popel*, "Signature Analysis, Verification and Synthesis in Pervasive Environments" introduces a system developed to identify and authenticate individuals based on their signatures or handwriting, or both. The issues of pervasive services are addressed by integrating unique data acquisition and processing techniques which are capable of communicating with a variety of off-the-shelf devices such as pressure sensitive pens, mice, and touch pads; by using sequence processing techniques (like matching, alignment or filtering) for signature analysis techniques and comparison; by using self-learning database solutions for achieving accurate results, and by utilizing signature synthesis techniques for benchmarking and testing.

Chapter 3 by Drs. *Samavati* and *Bartels*, and their student *Luke Olsen* "Local B-Spline Multiresolution with Examples in Iris Synthesis and Volumetric Rendering" studies B-splines and filtering techniques for image synthesis and reconstruction allowing high resolution of data.

Chapter 4 by Dr. *Gavrilova* "Computational Geometry and Image Processing Techniques in Biometrics: on the Path to Convergence" examines a unique aspect of the problem — the development of new approaches and methodologies for biometric identification, verification and synthesis, utilizing the notion of proximity and topological properties of biometric identifiers. The use of recently developed advanced techniques in computational geometry and image processing is examined with the purpose of finding the common characteristics between different biometric problems, and identifying the most promising methodologies. In particular, this chapter discusses applications of computational geometry methods such as constructing medial axis transforms, distance distribution computation, Voronoi diagrams and Delaunay triangulation, and topology-based approaches for feature extraction and pattern matching.

We also recommend the books by *S. Yanushkevich*, *A. Stoica*, *V. Shmerko* and *D. Popel* "Biometric Inverse Problems", Taylor & Francis/CRC Press 2005, and the book by *Z. Wen*, by *T. S. Huang* "3D Face Processing: Modeling, Analysis and Synthesis", Kluwer, 2004, and by *W. Zhao* and *R. Chellappa,* Eds., "Face Processing: Advanced Modeling and Methods", Elsevier, 2006, as an introduction to the problem of biometric data design.

PART 2: ANALYSIS IN BIOMETRICS

The second part includes six chapters on general methodology used in the traditional applications of biometric technologies — identification and verification of individuals. These methods are classified as image analysis and pattern recognition.

Chapter 5 by Dr. *Srihari* and his PhD student *Harish Srinivasan* "A Statistical Model for Biometric Verification", introduces a statistical learning methodology for determining whether a pair of biometric samples belong to the same individual. The proposed approach is applied to friction ridge prints (physical biometric) and and handwriting (behavioral biometric) and advantages over conventional methods are demonstrated (improved accuracy and a natural provision for combining with other biometric modalities).

Chapter 6 by Dr. *Parker* "Composite Systems for Handwritten Signature Recognition", introduces a simple way to reliably compare signatures in a quite direct fashion. Comparisons are made to other methods, and a four algorithm voting scheme is used to achieve over 99% success.

Chapter 7 by Dr. *Hurley* "Force Field Feature Extraction for Ear Biometrics", presents a new transformation and feature extraction technique using a force field model in the context of ear biometrics. This method automatically locates the potential wells and channels of an energy surface produced by the transform, which then forms the basis of characteristic ear features, which are subsequently used for ear recognition.

Chapter 8 by Drs. *You*, *Wang*, and their colleagues *Q. Chen* and *D. Zhang* "Nontensor-Product-Wavelet - Based Facial Feature Representation", introduces a method for facial feature representation by using a non-tensor product bivariate wavelet transform. Nontensor product bivariate wavelet filter banks with linear phase are constructed from the centrally symmetric matrices.

Chapter 9 by Drs. *Lu, Zhang, Kong*, and *Liao*, "Palmprint Identification by Fused Wavelet Characteristics" presents a novel method of feature extraction for palmprint identification based on the wavelet transform. This method is used to handle the textural characteristics of palmprint images at low resolution. The extraction of four sets of statistical features (the mean, energy, variance, and kurtosis), allows the achievement of high accuracy in identification.

Chapter 10 by Dr. *Traoré* and his PhD student *Ahmed Awad E. Ahmed* "Behavioral Biometrics for Online Computer User Monitoring" introduces an artificial neural network based techniques for analyzing and processing keystroke and mouse dynamics to achieve passive user monitoring. Keystroke dynamics recognition systems measure the dwell time and flight time for keyboard actions. Mouse dynamics are described as the characteristics of the actions received from the mouse input device for a specific user, while interacting with a specific graphical user interface.

We also recommend the book by R. C. Gonzalez, R. E. Woods, and S. L. Eddins *Digital Image Processing Using MATLAB*, Pearson Prentice Hall, 2004, as the basis of analysis of biometric data.

PART 3: BIOMETRIC SYSTEMS AND APPLICATIONS

The third part of the book includes five chapters in the broader context of systems and applications.

Chapter 11 by Drs. *Ratha*, *Bolle*, and *Pankanti*, "Large-Scale Biometric Identification: Challenges and Solutions" reviews the tools, terminology and methods used in large-scale biometrics identification applications. In large-scale biometrics, the performance of the identification algorithms need to be significantly improved, to successfully handle millions of persons in the biometrics database, matching thousands of transactions per day.

Chapter 12 by Dr. *Coello Coello*, "Evolutionary Algorithms: Basic Concepts and Applications in Biometrics" provides a short introduction to the main concepts related to evolutionary algorithms and several case studies on the use of evolutionary algorithms in both physiological and behavioral biometrics. The case studies include fingerprint compression, facial modeling, hand-based feature selection, handwritten character recognition, keystroke dynamics and speaker verification.

Chapter 13 by Dr. *Wang* "Some Concerns on the Measurement for Biometric Analysis and Applications", reexamines the "measurement" techniques essential for comparing the "similarity" of patterns. The chapter focuses on the concepts of "segmentation" and "disambiguation" from global semantic point of view, which are important in the context of pattern recognition and biometric-based applications.

Chapter 14 by Dr *Elliott* and his students *Eric Kukula*, and *Shimon Modi*, "Issues Involving The Human Biometric Sensor Interface", examines topics such as ergonomics, the environment, biometric sample quality, and device selection, and how these factors influence the successful implementation of a biometric system.

Chapter 15 by Drs. *Yanushkevich, Stoica*, and *Shmerko*, "Fundamentals of Biometrics-Based Training System Design", introduces the concept of biometric-based training for a wide spectrum of applications in the social sphere (airports and seaports, immigration service, border control, important public events, hospitals, banking, etc.). The goal of such training is to assist the officers in developing their skills for decision making, based on two types of information about an individual: biometric information collected during pre-screening or surveillance, and information collected during the authorization check itself.

We also recommend the book by A. Jain, S. Pankanti, and Bolle, R. Eds. *Biometrics: Personal Identification in Networked Society*, Kluwer, 1999.

There are a lot of new approaches that are not included in this book, for example, gait biometrics. The book by Dr *Nixon* et al. “Human ID based on Gait”, Springer, 2006, can help the reader to get familiar with this biometric. Note that gait biometrics are very useful in security systems which use screening and the early warning paradigm (see Chapter 15).

This collection of selected papers introduces the activity of several internationally recognized research centres:

Analytical Engines Ltd., UK, represented by Dr. *D. J. Hurley*

Biometric Research Center directed by Dr. *D Zhang*, Hong Kong Polytechnic University, Hong Kong

Biometrics Standards, Performance, and Assurance Laboratory directed by Dr. *S. J. Elliott*, Purdue University, U.S.A.

Biometric Technology Group directed by Dr. *D. V. Popel*, Baker University U.S.A.

Biometric Technology Laboratory: Modeling and Simulation directed by Dr. *S. N. Yanushkevich* and Dr. *M. L. Gavrilova*, University of Calgary, Canada

Center of Excellence for Document Analysis and Recognition (CEDAR) directed by Dr.*S. N. Srihari*, State University of New York at Buffalo, U.S.A.

Department of Information Security, Office of National Statistics, UK, directed by Eur. Ing. *Phil Phillips*

Digital Media Laboratory directed by Dr. *J. Parker*, University of Calgary, Canada

European Center for Secure Information and Systems, Iasi, Romania, represented by Drs. *A. Stoica*, *S. Yanushkevich*, and *V. Shmerko*.

Humanoid Robotics Laboratory directed by Dr. *A. Stoica*, California Institute of Technology, Jet Propulsion Laboratory, National Aeronautics and Space Agency (NASA), U.S.A.

Evolutionary Computation Group, directed by Dr. *Carlos A. Coello Coello*, CINVESTAV-IPN, Mexico

IBM Thomas J. Watson Research Center, Exploratory Computer Vision Group, IBM, N.Y. U.S.A., represented by Drs. *N. K. Ratha, R. M. Bolle,* and *S. Pankanti*

Image Processing Group directed by Dr. *P. S. Wang*, Northeastern University, U.S.A.

Information: Signals, Images, System Research Group, School of Electronics and Computer Science at the University of Southampton, UK, represented by Dr. *M. S. Nixon*

Information Security and Object Technology Laboratory, directed by Dr. *I. Traoré*, University of Victoria, Canada

Visual Information Processing Laboratory directed by Dr. *Q. M. Liao*, Graduate School at Shenzhen, Tsinghua University, China