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# Human Motion Sensing and Recognition

A Fuzzy Qualitative Approach

 Springer

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# Preface

Human motion sensing and recognition are currently one of the most important and active research topics because of the strongly growing interests driven by a wide spectrum of promising applications in many areas such as surveillance and security, human computer interactions/interfaces, human skill transfer, human robot corporation, animation and gaming, sport analysis, *etc.* With recent advances in sensing techniques, various motion capture devices have been developed and applied to the above applications, including high-resolution cameras, depth cameras, marker-based motion capture devices, data gloves, biosignal sensors, *etc.* The major challenges for recognising human motion stem mainly from first the dynamic environment where there exist some unpredicted lighting conditions, concurrent body structures or motion occlusions, second from multi-modal data which requires refined sensor integration and fusion algorithms, third from uncertain sensory information with inaccuracy, noise or fault, and finally from the limited response time required in real-time systems. Therefore, the sensing and recognition systems need to not only extract the most useful sensory information from single or multiple sources, but also avoid heavy computational cost.

This book aims to introduce readers to the latest progresses made on human motion sensing and recognition, including 2D and 3D vision-based human motion analysis, hand motion analysis and view-invariant motion recognition, from the perspective of Fuzzy Qualitative (FQ) techniques, which provide practical solutions to the above challenges by properly balancing the system's effectiveness and efficiency. Chapters in this book are deliberately arranged to cover both the theories of the fuzzy approaches and their applications in motion analysis. The book is primarily intended to be used as a valuable reference for related researchers and engineers, who are seeking practical solutions to human motion sensing and recognition. It can also be useful to practitioners for advanced knowledge, and university undergraduates and postgraduates with interest in fuzzy techniques and their applications in motion recognition.

Twelve chapters are carefully selected and arranged from our recent research work. Research background is discussed in Chap. 1. Chapters 2, 3, 5 and 6 focus on the important theory concept development of fuzzy techniques, including FQ

trigonometry, FQ robot kinematic, Fuzzy Empirical Copula (FEC) and Fuzzy Gaussian Mixture Models (FGMMs), while Chaps. 4, 7, 8 and 9 explore their applications in human motion analysis. Chapters 10, 11 and 12 are self-contained ones providing practical solutions particularly to 3D and view-invariant motion recognition using novel approaches.

Chapter 1 gives a general introduction of the human motion sensing techniques, including vision-based sensing, wearable sensing and multimodal sensing, and recent recognition methods, such as probabilistic graphical models, support vector machines, neural networks and fuzzy approaches, and then highlights the motivation of this book with discussion on the current challenges in the human motion analysis.

Chapter 2 presents a novel FQ representation of conventional trigonometry to effectively bridge the gap between symbolic cognitive functions and numerical sensing and control tasks in physical systems and intelligent robotics. Fuzzy logic and qualitative reasoning techniques are employed to convert conventional trigonometric functions, rules and their extensions to triangles in Euclidean space into their counterparts in FQ coordinates. This proposed approach provides a promising representation transformation interface to easily communicate between the numeric world and qualitative world in general trigonometry-related physical systems from an artificial intelligence perspective.

Chapter 3 extends the FQ trigonometry to FQ robot kinematics by replacing the trigonometry role in robot kinematics. FQ robot kinematics have been explored and discussed in terms of FQ transformation, position and velocity of a serial kinematics. An aggregation operator is proposed to extract robot behaviour giving prominence to the impact of FQ Robot Kinematics to intelligent robotics. The proposed two versions of FQ approaches have been integrated into XTRIG MATLAB toolbox with a case study on a PUMA robot.

Chapter 4 combines the FQ robot kinematics with human motion tracking and recognition algorithms to analyse vision-based human motion analysis, especially to recognise human motions. A data quantisation process is proposed with the aim of saving computational cost and Qualitative Normalised Template (QNT) is developed by adapting the FQ robot kinematics to represent human motions. Comparative experimental results have been reported to support the effectiveness of the proposed method.

Chapter 5 presents a novel fuzzy approach, FEC, to reduce the computational cost of empirical copula, which is a non-parametric algorithm to estimate the dependence structure of high-dimensional arbitrarily distributed data, with a new version of Fuzzy Clustering by Local Approximation of Memberships (FLAME). Two case studies demonstrate the efficiency of the proposed method.

Chapter 6 introduces a fuzzy version of Gaussian Mixture Models (GMMs) with a fast convergence speed by using a degree of fuzziness onto the dissimilarity function based on distances or probabilities. The FGMMs outperform traditional GMMs because they not only suit for nonlinear datasets but also saves half of computational cost.

Chapter 7 proposes a unified fuzzy framework of a set of recognition algorithms: Time Clustering (TC), FGMMs and FEC, from numerical clustering to data dependency structure in the context of optimally real-time human hand motion recognition. TC is a fuzzy time modelling approach based on fuzzy clustering and Takagi-Sugeno (TS) modelling with numerical value as output; FGMMs efficiently extract abstract Gaussian pattern to represent components of hand gestures; FEC utilises the dependence structure among the finger joint angles to recognise motion types. Various tests have been reported to evaluate this framework's performance.

Chapter 8 develops a generalised framework to study and analyse multimodal data of human hand motions, with modules of sensor integration, signal preprocessing, correlation study of sensory information and motion identification. Fuzzy approaches have been utilised, *e.g.* FEC is used to reveal significant relationships among the sensory data; and FGMMs are employed to identify different hand grasps and manipulations based on the forearm electromyography (EMG) signals.

Chapter 9 shows a new approach to extract human hand gesture features in real-time from RGB-D images by the earth mover's distance and Lasso algorithms. A modified finger earth mover's distance algorithm is employed to locate the palm image and then a Lasso algorithm is proposed to effectively extract the fingertip feature from a hand contour curve.

Chapter 10 focuses on the problem of recognising occluded 3D human motion assisted by the recognition context. Fuzzy Quantile Generation (FQG) is proposed by using metrics derived from the probabilistic quantile function to represent uncertainties via a fuzzy membership function. Time-dependent and context-aware rules are then generated to smooth the qualitative outputs represented by fuzzy membership functions. Feature selection and reconstruction are also discussed to deal with the motion occlusion.

Chapter 11 improves 3D human motion recognition by combining a local spatiotemporal feature with a global Positional Distribution Information (PDI) of interest points. For each interest point, 3D Scale-Invariant Feature Transform (SIFT) descriptors are extracted and then integrated with the computed PDI. The combined feature is evaluated and compared on the public KTH dataset using the Support Vector Machine (SVM) recognition algorithm.

Chapter 12 addresses the issue of view-invariant action recognition by presenting a multi-view space Hidden Markov Models (HMMs). A view-insensitive feature is proposed by combining the bag-of-words of interest point with the amplitude histogram of optical flow. Based on the above combined feature, HMMs are then used to recognise unknown viewpoint by analysing the derived similarity in each sub-view space. Experimental results on multi-view action dataset IXMAS are discussed.

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# Acronyms

AcaGMMs	Active Curve Axis Gaussian Mixture Models
CCA	Curvilinear Component Analysis
CRF	Conditional Random Fields
CSO	Cluster Supporting Object
DSP	Digital Signal Processor
EM	Expectation–Maximization
EMG	Electromyography
FA	Factor Analysis
FCMs	Fuzzy C-means
FEC	Fuzzy Empirical Copula
FGMMs	Fuzzy Gaussian Mixture Models
FHMM	Fuzzy Hidden Markov Model
FLAME	Fuzzy Clustering by Local Approximation of Memberships
FPF	False Positive Fraction
FQ	Fuzzy Qualitative
FQG	Fuzzy Quantile Generation
FQT	Fuzzy Qualitative Trigonometry
FSM	Finite State Machine
GMMs	Gaussian Mixture Models
GMR	Gaussian Mixture Regression
HMMs	Hidden Markov Models
ICA	Independent Component Analysis
KL	Kullback–Leibler
KNN	K-Nearest Neighbours
MEMM	Maximum Entropy Markov Models
MEI	Motion Energy Image
MHI	Motion History Image
MR	Midpoint-Radius
NP	Normal Points
PC	Principal Curves

PCA	Principal Component Analysis
PDI	Positional Distribution Information
PMK	Pyramid Match Kernel
PP	Projection Pursuit
QNT	Qualitative Normalised Template
RMS	Root Mean Square
ROC	Receiver Operating Characteristic
RVM	Relevance Vector Machines
SIFT	Scale-Invariant Feature Transform
SMC	Sequential Monte Carlo
SOM	Self-Organizing Maps
SSM	Self-Similarity Matrix
SVM	Support Vector Machine
TC	Time Clustering
TDNN	Time Delay Neural Network
TPF	True Positive Fraction
TS	Takagi–Sugeno
TSK	Takagi–Sugeno–Kang