HUMAN-MACHINE INTERACTION BY TRACKING HAND MOVEMENTS

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Dedicated to my parents

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LIST OF ABBREVIATIONS

HMI	Human-Machine Interaction
CNC	Computer Numerical Controls
PCA	Principal Component Analysis
PDM	Point Distribution Model
MRI	Magnetic Resonance Image
ID	Identification
SIFT	Scale Invariant Feature Transform
CoM	Centre of Mass
HD	Hausdorff Distance
M_E	Hausdorff Distance Under Rigid Motion
MMM	Model-Matching Methods
UPAO	Unknown Partially Appeared Objects
LIL	Low Intensity of Light
FD's	Fourier's Descriptors
NN	Neural Network
BPNN	Back Propagation Neural Network
C_m	Fourier's Series Coefficients
FFT	Fast Fourier Transform
Q	Number of Weights in Neural Network
SSE	Sum of the Squared Errors
MC	Momentum Constant
MER	Maximum Error Ratio
LRI	Learning Rate Increase
LRD	Learning Rate Decrease

HCI	Human-Computer Interaction
HMM	Hidden Markov Models
GRF	Gibbs Random Field
HSV	Hue, Saturation and Value
RGB	Red, Green, Blue
SE	Structuring Element
DH	Denavit and Hartenberg
M_y	Moment of the Detected Gesture about Y axis
GMD	Gesture Movement's Direction
DFT	Discrete Fourier Transform

LIST OF SYMBOLS

V	Vector
T	Translation Factor
S	Scaling Factor
R	Rotational Matrix
b	Biases Matrix
θ	Phase Angle
P	Probability Density Function
a_n	Fourier's Coefficient
τ	Delay of Time or Distance
C	Covariance
W^{new}	New Weight Matrix
W^{old}	Old Weight Matrix
α	Learning Rate
δ	Difference Between Two Vectors / Change in Weight
∇w	The Derivative of the Activation Function
μ_s	Mean Vector
Σ_s	Covariance Matrix
p	Conditional Probability
c	Chrominance Vector
φ	Skin Probability Image

R	2D Rotation Matrix
G	Gradient Magnitude
L_p	Distance from position
L_N	Distance to the new position
**	Convolution Operator
ϕ	Orientation Angle

Pergesanan Interaksi Manusia-Mesin Melalui Pergerakan Tangan

ABSTRAK

Pengesanan berasaskan pemerhatian pergerakan dan isyarat tangan merupakan satu masalah yang sangat mencabar kerana sifat rumit gerakan tangan, ini adalah mengapa algorithma pengesanan imej mempunyai pengiraan yang kompleks. Dalam penyelidikan ini satu teknik pengesan dan pengenalan pergerakan dan isyarat tangan dalam bentuk tiga dimensi (3D) diperkenalkan. Ianya boleh digunakan untuk interaksi manusia dan komputer serta dalam lain-lain aplikasi sistem robotik. Teknik yang diperkenalkan bagi menyelesaikan masalah pengesanan dan pengenalan pergerakan dan isyarat tangan adalah berdasarkan keperihalan Fourier, Neural Network dan secara pendekatan morfologi dalam isyarat objek 3D daripada satu imej bayangan. Walaubagaimanapun terdapat banyak halangan dan cabaran untuk mengenalpasti sesuatu objek seperti perubahan saiz, translasi, putaran pada tiga paksi, akulasi separa, kekurangan pengcahayaan dan juga kecacatan bentuk objek yang terlibat. Bagi mengatasi segala masalah ini, dalam kajian kami menggunakan perihalan berubah Fourier dan teknik rambatan balik Neural Network untuk pengesanan objek 3D daripada corak bayang 2D. Pendekatan yang dicadangkan ini adalah menggunakan koefisien keperihalan Fourier dan teknik rembatan balik Neural Network dengan jumlah lapisan tersembunyi yang berbeza untuk membina pengkelasan optimum objek 3D daripada satu imej bayangan. Selain daripada itu, kaedah menggunakan pemprosesan imej dan teknik morfologi yang digabungkan dengan pelbagai kaedah formula matematik bagi mengira kedudukan dan orientasi tangan juga dicadangkan. Objek yang telah dikenalpasti didedahkan kepada keamatan cahaya yang berbeza, disepara aklusikan, diubah saiznya, ditanslasi, diputarkkan pada semua tiga paksi dan juga menggunakan kecacatan struktur bentuk dalam kaedah pengkajian. Teknik yang telah dicadangkan ini diaplikasikan dan diuji ke atas Sistem Simulasi Manipulasi Robotik UniMAP (UniMAP Robot Manipulator Simulation System). Teknik ini membolehkan sistem robotik bertindak sebagai sistem pintar bagi mengesan kedudukan tangan manusia dalam ruang 3D dan menganggarkan pelbagai orientasi dan kedudukan tangan manusia dalam masa sebenar. Matlamat akhir adalah membolehkan algoritma yang dicadangkan ini digunakan dalam dalam sistem pergelangan tangan sfera robotik. Dalam kaedah ujian ini, keperluan untuk kalibrasi kamera yang berterusan tidak diperlukan. Ianya hanya memerlukan sekali sahaja proses kalibrasi pada peringkat awal bagi mengesan kedudukan awal tangan. Dengan menggunakan teknik yang telah dicadangkan ini pelbagai pergerakan dan isyarat tangan dapat dikenalpasti dengan tepat. Keputusan eksperimen ini menunjukkan teknik ini merupakan satu teknik yang mantap, tidak seperti teknik-teknik lain yang menggunakan fungsi pembelajaran atau teknik menyeluruh yang mahal. Pengesanan pergerakan tangan yang tepat dan beban komputasi yang ringan menyebabkan kelajuan pemprosesan yang tinggi dan ini membolehkan kami mencapai kemajuan tinggi dalam eperimentasi ini. Teknik yang diperkenalkan ini boleh digunakan dengan pelbagai jenis teleoperasi manipulator robotik atau lain-lain aplikasi interaksi manusia-komputer yang mengutamakan kelajuan pemprosesan.

Kata Kunci Pengenalan Corak Tiga Dimensi, Manipulator Pintar, Replika Tangan Tiga Dimensi, Interaksi Manusia-Komputer, Morfologi.

Human-Machine Interaction by Tracking Hand Movements

ABSTRACT

The vision-based hand tracking and gesture recognition is an extremely challenging problem due to the intricate nature of hand gestures this is a reason that available computer vision algorithms are computationally complex. In this research work a new methodology for 3D human hand gestures detection and recognition is proposed, which can be used for natural and intuitive human-computer interaction and other robotic systems. The proposed method based on Fourier's descriptors, neural networks and morphology approaches to solve the problem of human hand tracking and gesture recognition of 3D objects from a single silhouette image. There are many constrains and challenges are there for the recognition of an object, like size change, translation, rotation around the three axes, partial occlusion, low intensity of light as well as the deformation of the shape. In this research work we used invariant Fourier's descriptors and back propagation neural networks techniques for 3D objects recognitions from their 2D silhouette pattern to solve above mentioned challenges. The proposed approach used Fourier's descriptors coefficients and back propagation neural network with different numbers of hidden layers to build the optimal classifier of 3D pattern from a single silhouette image. Besides that, another method is proposed using image processing and morphology technique in conjunction with various mathematical formulas to calculate hand position and orientation. The recognised objects are exposed to different intensities of light, are partially occluded, with size change, translation, rotation about all the axes and we used also deformed shapes. This new proposed method was applied and tested on the simulated Manipulated Robotic System (UniMAP Robot Manipulator Simulation System) that allows this robotic system to act as an intelligent system to track a human hand in 3D space and estimate its orientation and position in real time with the goal of ultimately using the algorithm with a robotic spherical wrist system. During experiment, there was no need for continuous camera calibration, and it required only once at the beginning for the registration of the hand and using proposed technique large number of hand movements and orientations are correctly identify. Experimental result shows that proposed method is a robust technique, unlike other approaches that use costly leaning functions or generalization methods. The high performance was achieved during experiments because of the accurate hand movement identification and the low computational load that results in a fast processing time. The proposed method could therefore be used with different types of teleoperated robotic manipulators or in other human-computer interaction applications in which a fast processing time was important.

Keywords 3D Pattern Recognition, Intelligent manipulator, 3D Hand Replication, Human Computer Interaction, Morphology.

CHAPTER ONE

INTRODUCTION

1.1 Introduction to Human-Machine Interaction

Human-machine interaction (HMI) is a field of study of the interaction between humans (applicants or users) and actual machines Ravani, (2011). The purpose of research in this field leads towards better human-machine systems analysis, design and implementation to perform tasks collaboratively with human activities. Modern technologies of manufacturing and assembly lines, devices production, everyday appliances needs, advanced control in such auto pilot and in- railways trains or vehicle systems, and software systems (e.g. computer-aided design software system, CNC (Computer Numerical Controls), etc.) are all the result of the growing interest of both industry needs and academic researchers in the field of HMI. It is an interdisciplinary field of human factors and ergonomics, computer engineering, engineering design, mechatronic engineering, applications in most fields and interface design.

1.2 Problem Statements

Human machine interaction system is getting more and more attractive in the field of robotic and intelligent systems in most of life applications now a days. Recently, the interactions of hand or eye movements are most applicable in some critical applications such as nuclear reactor controls or for purposes of disasters recoveries. The human hand interaction using a simple webcam without any needs of calibration or extra expensive requirements e.g. specific gloves fitted with sensor or colouring parts for human hands while natural hand or fingers are very preferable. The limitation factors to the system performance are the kind of technique to be used; heavy computational processes, huge looping or iterations are not preferable. Therefore in well-designed ones are the most wanted.

Recently, there are several issues raised by applicants and users across disciplines that need to be focused upon for future advances in HMI in terms of speed, intelligent level and complex issues that can be handled while keeping the cost at normal or even to a cheaper level. One major issue is regarding the fundamental things that need to be considered by designers in the process of development of machines and other automated systems with which humans' interaction. For example, currently intelligent teleguided robot manipulator systems for solving configuration, calibration or external support to eliminate the humans decision making Hussain et al. (2013). The process is becoming a totally automated process that essentially eliminates the human out of the loop.

In this process human designers loose an opportunity of exhibiting their creativity. Another problem with the current HMI systems is that communication between the human and the machine is very primitive and primarily is a monologue of information exchange. It is crucial, as a first step towards building better human-machine systems, to understand the core capabilities that are to be expected of machines in interaction with humans. Therefore the question in this thesis study is what are the basic requirements to be addressed when building human interaction systems for better HMI and how to implement such a system for human hand tracking and replication. Within the context of human-machine systems, there is a new paradigm for better interaction, which is to develop adaptive machines that can sense the user's state and act accordingly. For example, by means of sensors "planted" on the hand or fingers of a human hand to drive an intelligent manipulator robot, an on-board computer could recognize the state of the human hand and take actions to put influence over the manipulator robot to change it properly according to Chiri (2011).

Research reports in literature seem to bring the future closer to reality by the day. However, a major issue remains that the state of the human hand cannot be accurately sensed. The main objective is that if a machine takes action based on an incorrectly identified state of the human hand, it may lead to huge problems. There are several algorithms reported in literature to infer the human hand. All these differ from technique to another of inference and this effect their power of accuracy. The problem is that each of these algorithms gives a so-called "opinion" about the state, which is only an estimate of the actual state. Hence, the other question raised in this thesis are Is there a way to integrate various techniques of inference of the human's activities state for better accuracy of inference? And would representation of human hand state in a 'natural' way significantly affect the user's actions in doing a task done by manipulator robot?

In general, the contemporary literature in HMI has not provided sufficient knowledge to answer the above questions; a detailed review of literature is provided in the next chapter. The motivation of this thesis is to generate knowledge to answer these questions and is to advance technologies for better HMI.

1.3 Research Objectives

There are three challenging objectives defined for the work been presented on this thesis study:

Objective 1 Explore the core capabilities in human-machine systems for good interactions between humans and machines by means of a case study about human hand tracking and replication. However, the outcome can be easily adapted to any so-called intelligent hardware machine system according to Oborski (2004).

Objective 2 Develop a framework that allows the integration of various algorithms / techniques for object recognition based in 3D. An investigation of 3D objects recognition from their 2D patterns based on invariant Fourier's descriptors and using back propagation neural networks. The development of hybrid morphology based algorithm for recognition of hand orientation and position. The hybridization and integration of various types of algorithms on multiple cues should result in a more accurate result than a single algorithm according to Hussain et al. (2005) & Elhachloufi (2011).

Objective 3 Build a simulated test-bed model in which the machine can be guided by a human hand movements that affect the machine's state in a natural way; design and conduct experiments to generate knowledge about the effect of such a natural human hand movements activities, that a machine's state can follow user's actions (all the possible changes in orientations, translation and size of 3D hand about the three axes x, y & z; which leads to millions of hand states) NOT like other applications of recognising few tens of hand signs or states. The experimental procedure and results are also discussed to understand the specific effects in terms of tracking and replication of hand movements by intelligent manipulator robot according to Kosuge (1998), Hussain et al. (2012) & Hussain et al. (2013).