



Adaptive neuro-fuzzy sliding mode control of the human upper limb during manual wheelchair propulsion: estimation of continuous joint movements using synergy-based extended Kalman filter

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Received: 19 October 2023 / Accepted: 9 May 2024 / Published online: 17 June 2024
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Abstract

Wheelchair upper limb exoskeletons can present a revolutionary approach to aid individuals with neuromuscular disorders in their daily tasks, which require two primary factors, i.e., estimating the human intention to decrease human–robot interactions and generating the adaptive optimal control signals. Therefore, firstly, this study aimed to propose an adaptive neuro-fuzzy sliding mode controller to generate the optimal control signals, in which and an adaptive optimal multi-critic-based neuro-fuzzy system was designed to tune the control gains of the sliding mode controller according to the changes in the joint torques and tracking errors. Secondly, a neural network model was designed as a measurement function in the structure of an extended Kalman filter to infer the human's continuous movement intention, which was trained to establish a comprehensive relationship between inputs, i.e., joints' kinematics and pushrim force, and outputs, i.e., electromyography features. Data acquisition relied on Biometrics Ltd.'s DataLink software and hardware, including surface electromyography and electrogoniometer sensors, while a force sensor system was designed for pushrim force acquisition. The features were extracted using the nonnegative matrix factorization method. The results of the proposed controller were compared with two of the newest control strategies for position-tracking in the wheelchair upper limb exoskeleton robotic system, i.e., proportional derivative-based fuzzy sliding mode control and a fuzzy-based nonsingular terminal sliding mode control structures, which both used the sliding mode control approach with different proposed sliding surfaces to generate the required control signals and also used the neuro-fuzzy system to improve the performance. For the proposed measurement model, the results were compared with the linear regression model and the adaptive neuro-fuzzy inference system, which are two of the most used classification methods. The results affirmed the efficacy of the proposed controller as a robust and accurate control structure for trajectory tracking, both in the absence and presence of disturbance, thereby underscoring its potential for practical applications in manual wheelchair propulsion. Furthermore, the findings underscored the proposed measurement model's robustness and adaptability, making it a promising tool for estimating continuous joint movements in rehabilitation and assistive applications.

Keywords Sliding mode controller · Neuro-fuzzy system · Extended Kalman filter · Neural network

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1 Introduction

Manual wheelchairs (MWs) are crucial assistive devices for over 90% of the 65 million manual wheelchair users (MWUs) worldwide [1]. However, the repetitive movements in manual wheelchair propulsion (MWP) can impose excessive loads on the upper limb muscles, reducing efficiency and causing musculoskeletal pain [2, 3]. Therefore, MWUs are always prone to upper limb pathology and clinical rehabilitation.

Neuro Fuzzy Manual

**Mufti Mahmud,M. Shamim
Kaiser,Nikola Kasabov,Khan
Iftexharuddin,Ning Zhong**

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Neuro-Fuzzy-Systeme Detlef Nauck, Christian Borgelt, Frank Klawonn, Rudolf Kruse, 2013-03-08 Eines der spannendsten Themen im Bereich intelligenter Systeme von namhaften Autoren geschrieben zum Lernen und Nachschlagen Das Buch führt in das Thema der Neuronalen Netze ein und weist darüber hinaus den Weg bis zum vollen Verständnis modernster Fuzzy Systeme Neuronale Netze sind ein wichtiges Werkzeug in den Bereichen der Datenanalyse und Mustererkennung Ursprünglich durch das biologische Vorbild inspiriert wurde eine Vielfalt neuronaler Netze für verschiedenste Anwendungen entwickelt Ihre Kopplung mit Fuzzy Systemen führt zu den sogenannten Neuro Fuzzy Systemen Diese weisen die Lernfähigkeit Neuronaler Netze auf und bieten gleichzeitig den Vorteil einer transparenten regelbasierten Struktur Sie sind daher besonders vorteilhaft für Anwendungsbereiche in denen verständliche Lösungen aus Daten erzeugt werden müssen *Soft Computing and Industry* Rajkumar Roy, Mario Köppen, Seppo Ovaska, Takeshi Furuhashi, Frank Hoffmann, 2012-12-06 Soft computing embraces various methodologies for the development of intelligent systems that have been successfully applied to a large number of real world problems Soft Computing in Industry contains a collection of papers that were presented at the 6th On line World Conference on Soft Computing in Industrial Applications that was held in September 2001 It provides a comprehensive overview of recent theoretical developments in soft computing as well as of successful industrial applications It is divided into seven parts covering material on keynote papers on various subjects ranging from computing with autopoietic systems to the effects of the Internet on education intelligent control classification clustering and optimization image and signal processing agents multimedia and Internet theoretical advances prediction design and diagnosis The book is aimed at researchers and professional engineers who develop and apply intelligent systems in computer engineering

Artificial Intelligence for Multimedia Information Processing Xavier Savarimuthu, Sivakannan Subramani, Alex Noel Joseph Raj, 2024-06-14 Advances in artificial intelligence AI widespread mobile devices internet technologies multimedia data sources and information processing have led to the emergence of multimedia processing Multimedia processing is the application of signal processing tools to multimedia data text audio images and video to allow the interpretation of these data particularly in urban and smart city environments This book discusses the new standards of multimedia and information processing from several technological perspectives including analytics empowered by AI streaming on the intelligent edge multimedia edge caching and AI services for edge AI and hardware and devices for multimedia on edge intelligence FEATURES Covers a wide spectrum of enabling technologies for AI and machine learning for multimedia and information processing Includes many applications using AI from robotics and driverless cars to environmental human health and remote sensing Presents an overview of the fundamentals of AI and multimedia processing imaging signal and speech Explains new models and architectures for multimedia streaming services and caching for AI Discusses the emerging paradigms of the deployment of hardware and devices for multimedia on edge intelligence Gives recommendations for future research in

multimedia and AI This book is written for engineers and graduate students in image and signal processing information processing environmental engineering medical and public health etc who are interested in machine learning deep learning and multimedia processing **Fuzzy Logic and NeuroFuzzy Applications Explained** Constantin Von Altrock,1995 Disks contain simulation edition of fuzzyTECH development software from Inform Software corporation *Soft Computing for Control of Non-Linear Dynamical Systems* Oscar Castillo,Patricia Melin,2012-12-06 This book presents a unified view of modelling simulation and control of non linear dynamical systems using soft computing techniques and fractal theory Our particular point of view is that modelling simulation and control are problems that cannot be considered apart because they are intrinsically related in real world applications Control of non linear dynamical systems cannot be achieved if we don't have the appropriate model for the system On the other hand we know that complex non linear dynamical systems can exhibit a wide range of dynamic behaviors ranging from simple periodic orbits to chaotic strange attractors so the problem of simulation and behavior identification is a very important one Also we want to automate each of these tasks because in this way it is more easy to solve a particular problem A real world problem may require that we use modelling simulation and control to achieve the desired level of performance needed for the particular application **Applied Intelligence and Informatics** Mufti Mahmud,M. Shamim Kaiser,Nikola Kasabov,Khan Iftekharuddin,Ning Zhong,2021-07-27 This book constitutes the refereed proceedings of the First International Conference on Applied Intelligence and Informatics AII 2021 held in Nottingham UK in July 2021 Due to the COVID 19 pandemic the conference was held in a fully virtual mode The 26 full papers and 4 short papers presented were thoroughly reviewed and selected from the total 107 submissions They are organized in the following topical sections application of AI and informatics in disease detection application of AI and informatics in healthcare application of AI and informatics in pattern recognition application of AI and informatics in network security and analytics emerging applications of AI and informatics **Modelling Dynamics in Processes and Systems** Wojciech Mitkowski,2009-06-01 Dynamics is what characterizes virtually all phenomenae we face in the real world and processes that proceed in practically all kinds of inanimate and animate systems notably social systems For our purposes dynamics is viewed as time evolution of some characteristic features of the phenomenae or processes under consideration It is obvious that in virtually all non trivial problems dynamics can not be neglected and should be taken into account in the analyses to first get insight into the problem consider and second to be able to obtain meaningful results A convenient tool to deal with dynamics and its related evolution over time is to use the concept of a dynamic system which for the purposes of this volume can be characterized by the input control state and output spaces and a state transition equation Then starting from an initial state we can find a sequence of consecutive states outputs under consecutive inputs controls That is we obtain a trajectory The state transition equation may be given in various forms exemplified by differential and difference equations linear or nonlinear deterministic or stochastic or even fuzzy imprecisely specified fully or partially known etc These features

can give rise to various problems the analysts may encounter like numerical difficulties instability strange forms of behavior e g chaotic etc This volume is concerned with some modern tools and techniques which can be useful for the modeling of dynamics We focus our attention on two important areas which play a key role nowadays namely automation and robotics and biological systems We also add some new applications which can greatly benefit from the availability of effective and efficient tools for modeling dynamics exemplified by some applications in security systems

Fuzzy Modeling and Control: Theory and Applications Fernando Matía,G. Nicolás Marichal,Emilio Jiménez,2014-08-14 Much work on fuzzy control covering research development and applications has been developed in Europe since the 90 s Nevertheless the existing books in the field are compilations of articles without interconnection or logical structure or they express the personal point of view of the author This book compiles the developments of researchers with demonstrated experience in the field of fuzzy control following a logic structure and a unified the style The first chapters of the book are dedicated to the introduction of the main fuzzy logic techniques where the following chapters focus on concrete applications This book is supported by the EUSFLAT and CEA IFAC societies which include a large number of researchers in the field of fuzzy logic and control The central topic of the book Fuzzy Control is one of the main research and development lines covered by these associations

Smart Manufacturing Innovation and Transformation: Interconnection and Intelligence Luo, ZongWei,2014-03-31 Fast advances in information technology have led to a smarter world vision with ubiquitous interconnection and intelligence Smart Manufacturing Innovation and Transformation Interconnection and Intelligence covers both theoretical perspectives and practical approaches to smart manufacturing research and development triggered by ubiquitous interconnection and intelligence This reference work discusses the transformation of manufacturing the latest developments in smart manufacturing innovation current and emerging technology opportunities and market imperatives that enable manufacturing innovation and transformation useful tools for readers in industry academia and government

Soft Computing and Fractal Theory for Intelligent Manufacturing Oscar Castillo,Patricia Melin,2012-08-11 We describe in this book new methods for intelligent manufacturing using soft computing techniques and fractal theory Soft Computing SC consists of several computing paradigms including fuzzy logic neural networks and genetic algorithms which can be used to produce powerful hybrid intelligent systems Fractal theory provides us with the mathematical tools to understand the geometrical complexity of natural objects and can be used for identification and modeling purposes Combining SC techniques with fractal theory we can take advantage of the intelligence provided by the computer methods and also take advantage of the descriptive power of the fractal mathematical tools Industrial manufacturing systems can be considered as non linear dynamical systems and as a consequence can have highly complex dynamic behaviors For this reason the need for computational intelligence in these manufacturing systems has now been well recognized We consider in this book the concept of intelligent manufacturing as the application of soft computing techniques and fractal theory for achieving the

goals of manufacturing which are production planning and control monitoring and diagnosis of faults and automated quality control As a prelude we provide a brief overview of the existing methodologies in Soft Computing We then describe our own approach in dealing with the problems in achieving intelligent manufacturing Our particular point of view is that to really achieve intelligent manufacturing in real world applications we need to use SC techniques and fractal theory

GIS and Geocomputation for Water Resource Science and Engineering Barnali Dixon,Venkatesh Uddameri,2016-02-08 GIS and Geocomputation for Water Resource Science and Engineering not only provides a comprehensive introduction to the fundamentals of geographic information systems but also demonstrates how GIS and mathematical models can be integrated to develop spatial decision support systems to support water resources planning management and engineering The book uses a hands on active learning approach to introduce fundamental concepts and numerous case studies are provided to reinforce learning and demonstrate practical aspects The benefits and challenges of using GIS in environmental and water resources fields are clearly tackled in this book demonstrating how these technologies can be used to harness increasingly available digital data to develop spatially oriented sustainable solutions In addition to providing a strong grounding on fundamentals the book also demonstrates how GIS can be combined with traditional physics based and statistical models as well as information theoretic tools like neural networks and fuzzy set theory

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Neural Nets WIRN10 Bruno Apolloni,2011

Modelling, Simulation and Intelligent Computing Nilesh Goel,Shazia Hasan,V. Kalaichelvi,2020-07-28 This book presents articles from the International Conference on Modelling Simulation and Intelligent Computing MoSICom 2020 held at Birla Institute of Technology and Science Pilani Dubai Campus Dubai UAE in January 2020 Modelling and simulation are becoming increasingly important in a wide variety of fields from Signal Image and Speech Processing and Microelectronic Devices and Circuits to Intelligent Techniques Control and Energy Systems and Power Electronics Further Intelligent Computational techniques are gaining significance in interdisciplinary engineering applications such as Robotics and Automation Healthcare Technologies IoT and its Applications Featuring the latest advances in the field of engineering applications this book serves as a definitive reference resource for researchers professors and practitioners interested in exploring advanced techniques in the field of modelling simulation and computing

Advances in Natural Computation Ke Chen,2005-08-17 This book and its sister volumes i e LNCS vols 3610 3611 and 3612 are the proceedings of the 1st International Conference on Natural Computation ICNC 2005 jointly held with the 2nd International Conference on Fuzzy Systems and Knowledge Discovery FSKD 2005 LNAI vols 3613 and 3614 from 27 to 29 August 2005 in Changsha Hunan China

Handbook of Human Factors and Ergonomics Gavriel Salvendy,2012-05-24 The fourth edition of the

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Fei Chen,Jose De Jesus Rubio,Mu-Yen Chen,2023-01-20 **Intelligent Computing in Engineering and Architecture** Ian F.C. Smith,2006-10-02 This book constitutes the thoroughly refereed proceedings of the 13th Workshop of the European Group for Intelligent Computing in Engineering and Architecture EG ICE 2006 held in Ascona Switzerland in June 2006 The 59 revised full papers were carefully reviewed and selected from numerous submissions for inclusion in the book All issues of advanced informatics are covered including a range of techniques *Handbook of Digital Human Modeling* Vincent G. Duffy,2016-04-19 The rapid introduction of sophisticated computers services telecommunications systems and manufacturing systems has caused a major shift in the way people use and work with technology It is not surprising that computer aided modeling has emerged as a promising method for ensuring products meet the requirements of the consumer The Handbook of D [Intelligent Computational Paradigms in Earthquake Engineering](#) Nikos D. Lagaros,Yiannis Tsompanakis,2007-01-01 This book contains contributions that cover a wide spectrum of very important real world engineering problems and explores the implementation of neural networks for the representation of structural responses in earthquake engineering It assesses the efficiency of seismic design procedures and describes the latest findings in intelligent optimal control systems and their applications in structural engineering Provided by publisher

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