

## Sliding Mode Neurocontrol with Applications

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**Abstract**—In this study the tracking problem for a class of nonlinear uncertain systems is tackled. A new sliding mode neurocontroller is suggested to solve this problem. The designing of this controller includes the construction of on-line state estimates and the corresponding tracking control based on sliding mode approach using obtained state estimates. We apply a special sliding mode technique during the “off-line training” to estimate the right-hand side of the given dynamics in finite-time and then to use these estimates for the best (in LQ-sense) nominal weights selection in the designed neuro observer. A switching (sign) type term is incorporated in to the observer structure to correct the current state estimates using only available and on-line measurable output data supplied with a new learning procedure with a relay term. The illustrative example dealing with a real water sanitation process is presented.

### I. INTRODUCTION

Over the past decades, considerable research efforts had been undertaken on control design for uncertain nonlinear dynamic systems. Uncertainties in dynamic systems, commonly occurred in actual applications, provoke considerable troubles in any control realization being a source of instability or poor performance. Several approaches are known to synthesize a control in this situation. Two most effective of them, as it is widely recognized, are the Neural Network Approach and the Sliding Mode technique. Practically, there are few publications considering the application of both of them simultaneously [13], [10]. Such combinations of basic ideas of both methods seems to be very promising providing a new instrument for identification and control of a wide class of systems with uncertainties. This paper presents the realization of this idea and suggests the control design based on both *Dynamic Neural Network Observation* and *Sliding Mode Technique*, applied to the obtained neural network model. Below this approach is referred to as *Sliding Mode Neurocontrol*.

Research on *adaptive output feedback control of uncertain nonlinear dynamic systems* is of paramount importance today, particularly considering the growing interest in the use of unconventional control devices such as chemical sensors, piezoelectric actuators, etc. In a large number of practical problems there are important disturbances, uncertainties or several parameter variations. In these situations a solution of the control problem is given by the, so-called, unconventional adaptive control supplied by a mechanism for

adjusting the parameters of controllers [1]. A solution of the output feedback stabilization problem for systems in which nonlinearities depend only upon the available measurement, is given in [14]. In [8], backstepping -based approach is used and its extension is in [6], [7] and [17].

There exists another effective approach to identify and control a wide class of unknown systems: it is *Sliding Mode Control* (SMC) [18] which applies the relay (discontinuous) feedback to reach and maintain the closed-loop dynamics on a certain manifold (in the state space) with a corresponding desired properties. This control offers significant potential advantages comparing to other identification and control techniques: good transient behavior, global exponential stability of a small estimation error, no modeled disturbance rejection capability, insensitivity to plant nonlinearities or parameter variations and remarkable stability and performance robustness [16], [18]. In this study we suggest a dynamic neuro observer (see the subsection below), which incorporates switching type term to correct current state estimates using only available measurable output data.

Artificial Neural Networks (NN) have shown good identification properties in the presence of some uncertainties or external disturbances. There are known two type of NN: *static* one, using the, so-called, back-propagation technique [5] and *dynamic* neural networks (DNN), [15]. The first one deal with the class of global optimization problems trying to adjust the weights of such NN to minimize an identification error. The second approach, exploiting the feedback properties of the applied DNN, permits to avoid many problems related to global extremum search converting the learning process to an adequate feedback design, [10], [9]. Several approaches dealing with state estimation problem are widely used in practical applications. Among them there are the Lie-algebraic method [7], Lyapunov-like observers [16], high gain observation [4], the reduced-order nonlinear observers [3] and others. Dynamic neuro-observers are studied in [10], [12] and [13].

#### A. Motivation

One of the most attractive feature of the SMC approach is its finite-time convergence for controlled trajectories to a desired sliding surface [18]. The realization of such control demands the complete knowledge of all current states of the system to be controlled. Obviously when dealing with SMC and only output (no state) information is available for a designer, it turns out to be useless when it's applied directly. Thus SMC application demands state observer designing to keep all its attractive features. When a nonlinear model of a controlled system is a priori unknown exactly, the state

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# Neurocontrol And Its Applications

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Khalid,Rubiyah Yusof**



## **Neurocontrol And Its Applications:**

Neuro-Control and its Applications Sigeru Omatu, Marzuki B. Khalid, Rubiyah Yusof, 2012-12-06 The series *Advances in Industrial Control* aims to report and encourage technology transfer in control engineering The rapid development of control technology impacts all areas of the control discipline New theory new controllers actuators sensors new industrial processes computer methods new applications new philosophies new challenges Much of this development work resides in industrial reports feasibility study papers and the reports of advance collaborative projects The series offers an opportunity for researchers to present an extended exposition of such new work in all aspects of industrial control for wider and rapid dissemination Sigeru Omatu Marzuki Khalid and Rubiyah Yusof have pursued the new developments of fuzzy logic and neural networks to present a series volume on neuro control methods As they demonstrate in the opening pages of their book there is an explosion of interest in this field Publication and patent activity in these areas are ever growing according to international is timely databases and hence this volume The presentation of the material follows a complementary pattern Reviews of existing control techniques are given along side an exposition of the theoretical constructions of fuzzy logic controllers and controllers based on neural networks This is an extremely useful methodology which yields rewards in the applications chapters The series of applications includes one very thorough experimental sequence for the control of a hot water bath

**Advances in Instrumentation and Control**, 1993 **Neural Networks and Their Applications** John G. Taylor, John Gerald Taylor, 1996 Neural networks are one of the fast growing paradigms for learning systems with a wide variety of potential applications in industry In particular there are general results which prove the universal applicability of neural networks to many problems There is also an ever greater understanding of the underlying manner in which tasks such as classification can be solved optimally by this host of techniques Through the application of ideas of statistics dynamical systems theory and information theory the methods are likely to become ever more effective for solving problems previously found to be difficult to tackle using standard techniques This book compares and contrasts the academic theory and the industrial reality with case studies and latest research findings from international experts The contributions describe application areas including finance digital data transmission hybrid systems automotive and aerospace industries pattern analysis in clinical psychiatry time series prediction and genetic and neural algorithms This book demonstrates the vigour and strength of the subject in solving hard problems and as such will be of great interest to all researchers and professionals with an interest in neural networks

Water Industry Systems Dragan Savic, Godfrey Walters, 1999 These conference proceedings reflect the current and future roles of modeling and optimization in the description and management of water industry systems Balanced views of academic and industry experts from around the world are included in the two volumes of papers Insights are provided into the experiences of leading researchers and practitioners in applying modelling and optimization to the management of water quantity and quality The topics covered are advanced modelling techniques risk

management process control and optimization with particular emphasis on the development and implementation of emerging technologies Application areas include both water supply and waste water disposal **Intelligent Control Systems** IEEE Neural Networks Council,1996 *Proceedings of the ... International Florida AI Research Society Conference* ,1999 *IJCNN, International Joint Conference on Neural Networks* ,1989 Neurocontrol H. Tolle,E. Ersü,1992-03-05 Since heavily non linear and or very complex processes still pose a problem for automatic control they can often be handled easily by human operators The book describes re sults from ten years of research on learning control loops which imitate these abilities After discussing the diffe rencesto adaptive control some background on human informa tion processing and behaviour is put forward and some lear ning control loop structure related to these ideas is shown The ability to learn is due to memories which are able to interpolate for multi dimensional input spaces between scat tered output values A neuronally and mathematically inspi red memory lay out are compared and it is shown that they learn much faster thanbackpropagation neural networks which can also be used For the learning control loop diffe rent architectures are given Their usefulness is demonstra ted by simulation and results from applications to real pi lot plants The book should be of interest for control engi neers as well as researchers in neural net applications and or artificial intelligence The usual mathematical back ground of engineers is sufficient *Conference Proceedings* ,1993 *Neural Networks Applications* Patrick K. Simpson,1996 This volume builds on and continues the excellent coverage of the subject established in the first volume with a special focus on cutting edge applications This book provides practicing engineers with a snapshot of the latest applications supported by the most recent developments in neural networks theory and technology You ll find state of the art coverage of applications in control power systems medical systems information processing signal processing manufacturing production and inspection vehicular technology and more **Applications and Science of Artificial Neural Networks** Steven K. Rogers,Dennis W. Ruck,1995 **The Proceedings of the Third IEEE Conference on Control Applications, August 24th-26th, 1994, Venue, the University of Strathclyde, Glasgow, Scotland, UK** IEEE Control Systems Society,1994 **Artificial Neural Networks, 2** Igor Aleksander,John Taylor,1992 This two volume proceedings compilation is a selection of research papers presented at the ICANN 92 The scope of the volumes is interdisciplinary ranging from the minutiae of VLSI hardware to new discoveries in neurobiology through to the workings of the human mind USA and European research is well represented including not only new thoughts from old masters but also a large number of first time authors who are ensuring the continued development of the field Workshops on Virtual Intelligence ,1994 **1991 IEEE International Conference on Systems, Man, and Cybernetics** ,1991 **Adaptive Systems in Control and Signal Processing, 1998** Robert R. Bitmead,Michael A. Johnson,Michael J. Grimble,2000 Adaptive Systems have been studied for a substantial period as the logical intersection between modelling and design in control and signal processing Because of this adaptive systems studies need to live in these two worlds while introducing concepts of their own These reflect the requirements to track significant

system variations or to eliminate initial parameter uncertainty all the while maintaining satisfactory transient performance Historically Adaptive Systems and notably Adaptive Control have been the subject of takeover bids by neighbouring tribes from fields such as gain scheduling identification robust design or nonlinear systems The response to this has been to add impetus to the understanding of the connections between these disciplines and adaptation leading in turn to improvements of theory and practice We would appear to be currently in a period where there are increasing contacts being made with fields such as Learning Systems Computer Architectures and Identification Rather than hostile takeovers these have helped to expand the capability of Adaptive systems dramatically In this IFAC Workshop on Adaptive control and Signal Processing a wide range of papers expressing the large number of fronts on which adaptive systems are developing has been drawn together *Proceedings of the ... Workshop on Neural Networks*, 1991 *Knowledge for Sustainable Development* Unesco, 2002 This three volume set presents a multidisciplinary examination of the global life support systems on which we depend by providing a selection of articles on sustainable development issues written by international experts Volume 1 focuses on the earth and atmospheric sciences mathematical biological and medical sciences social sciences and humanities physical sciences engineering and technology resources Volume 2 covers chemical sciences energy science and water engineering as well as the main issues related to environmental sciences and ecological resources Volume 3 offers a comprehensive view of food and agricultural engineering resources the management of human and natural resources economic and institutional resources information technology and systems management as well as a regional overview of sustainable development issues Each article includes a bibliography a glossary and a guide to further information available as part of the on line Encyclopedia version <http://www.eolss.net> [The Second IEEE Conference on Control Applications](#), 1993 **Proceedings, Sixth, Seventh, and Eighth Workshops on Virtual Intelligence** Society for Computer Simulation, 1996

## Reviewing **Neurocontrol And Its Applications**: Unlocking the Spellbinding Force of Linguistics

In a fast-paced world fueled by information and interconnectivity, the spellbinding force of linguistics has acquired newfound prominence. Its capacity to evoke emotions, stimulate contemplation, and stimulate metamorphosis is actually astonishing. Within the pages of "**Neurocontrol And Its Applications**," an enthralling opus penned by a highly acclaimed wordsmith, readers set about an immersive expedition to unravel the intricate significance of language and its indelible imprint on our lives. Throughout this assessment, we shall delve into the book's central motifs, appraise its distinctive narrative style, and gauge its overarching influence on the minds of its readers.

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