

## SYNTHESIS AND INVESTIGATION OF THE CONTROL SYSTEMS WITH VARIABLE STRUCTURE

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**Abstract.** Variable structure control systems (VSCS) refer to automatic control systems operating in "special modes". These systems do not use adaptation algorithms. However, they have robust properties against some uncertainties. At present, the robust characteristics of VSPS have not been sufficiently studied. In this paper, new control algorithms have been developed to control dynamic objects with parametric and signal uncertainty. These algorithms operate in a sliding mode, implemented in systems with a variable structure. The structure of a robust regulator consists of relays with different static characteristics: a two-position relay without hysteresis; to reduce the switching frequency, a relay-linear regulator with a linearity zone. This design allows the system to be stabilized in a small vicinity of the equilibrium position without the occurrence of self-oscillations. As a result of simulation modeling on Matlab/Simulink under conditions of parametric uncertainty, dynamic characteristics were obtained that confirm the increase in robust indicators relative to known systems.

**Keywords:** special modes, systems with variable structure, adaptation, robustness, relay, sliding mode, Simulink.

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## 1 Introduction

In the paper a variable structure system (VSS) is understood as a control system that has several adjustable controllers.

The methodological basis for constructing such systems is the combination of various control structures in order to use the positive properties of each of them. Depending on the current operating mode of the system, a suitable structure is connected to the object (Kondratenko et al., 2022; Prasad et al., 2022; Wang et al., 2022).

Special control modes can mainly be divided into two types:

1. Sliding modes, implemented using relays with different static characteristics (Utkin, 1992; Mamedov & Rustamov, 2012; Rustamov, 2014).
2. Oscillatory mode with output feedback (Emelyanov, 1986; Dekarlo et al., 1988; Rustamov et al., 2011; Rustamov et al., 2015).

Positive features of the VSS:

- Allows one to control objects with parametric and signal uncertainties;
- Allows one to obtain the modes inaccessible to linear systems in a simple way;
- Simplicity of the system solution and high performance.

# Control Systems Of Variable Structure

**Zheng Xu, Saed Alrabaee, Octavio  
Loyola-González, Niken Dwi Wahyu  
Cahyani, Nurul Hidayah Ab Rahman**

## **Control Systems Of Variable Structure:**

**Variable Structure Systems** Asif Sabanovic, Leonid M. Fridman, Sarah K. Spurgeon, 2004-10-08 This unique book fulfils the definite need for an accessible book on variable structure systems and also provides the very latest results in research on this topic Divided into three parts basics of sliding mode control new trends in sliding mode control and applications of sliding mode control the book contains many numerical design examples so that readers can quickly understand the design methodologies and their applications to practical problems Primarily aimed at students and researchers in the field the book will also be useful for practising control engineers Control Systems of Variable Structure U. Itkis, 1976

*Variable-Structure Systems and Sliding-Mode Control* Martin Steinberger, Martin Horn, Leonid Fridman, 2020-02-10 The book covers the latest theoretical results and sophisticated applications in the field of variable structure systems and sliding mode control This book is divided into four parts Part I discusses new higher order sliding mode algorithms including new homogeneous controllers and differentiators Part II then explores properties of continuous sliding mode algorithms such as saturated feedback control reaching time and orbital stability Part III is focused on the usage of variable structure systems VSS controllers for solving other control problems for example unmatched disturbances Finally Part IV discusses applications of VSS these include applications within power electronics and vehicle platooning Variable structure Systems and Sliding Mode Control will be of interest to academic researchers students and practising engineers Variable Structure Systems, Sliding Mode and Nonlinear Control K.D. Young, Ü. Özgüner, 2014-03-12 This book comprises a selection of papers that were first presented at VSS98 5th International Workshop on Variable Structure Systems held in Sarasota Florida This workshop was the fifth in a series of VSS international workshops and the first to be held in the United States Work presented herein on theoretical developments and applications on VSS and Sliding Mode reflects how trends have advanced beyond the original ideas that are now well documented in a number of books and research monographs In particular the concepts of Sliding Sector and Second Order Sliding Mode introduced in this volume will stimulate discussions and invite further extensions Also the focus on Sampled Data systems represents a positive trend towards practical industrial implementations of sliding mode controllers *Safety of Computer Control Systems 1992 (SAFECOMP' 92)* H.H. Frey, 2014-05-23

SAFECOMP 92 advances the state of the art reviews experiences of the past years considers the guidance now available and identifies the skills methods tools and techniques required for the safety of computer control systems **Design Methods of Control Systems** D. Franke, F. Kraus, 2014-05-23 These Proceedings contain a selection of papers presented at the first IFAC Symposium on Design Methods of Control Systems The volume contains three plenary papers and 97 technical papers the latter classified under 15 section headings as listed in the contents **Variable Structure Systems, Sliding Mode and Nonlinear Control** K.D. Young, Ü. Özgüner, 1999-08-18 This book comprises a selection of papers that were first presented at VSS98 5th International Workshop on Variable Structure Systems held in Sarasota Florida This workshop was

the fifth in a series of VSS international workshops and the first to be held in the United States Work presented herein on theoretical developments and applications on VSS and Sliding Mode reflects how trends have advanced beyond the original ideas that are now well documented in a number of books and research monographs In particular the concepts of Sliding Sector and Second Order Sliding Mode introduced in this volume will stimulate discussions and invite further extensions Also the focus on Sampled Data systems represents a positive trend towards practical industrial implementations of sliding mode controllers

*Variable Structure Control Systems* David Wayne Ginsberg,1989      **A New Design Procedure for Variable Structure Control Systems** Tarek M. M. Nassab,1995      **Nonlinear Control Systems Design 1989 A.**

Isidori,2014-05-23 In the last two decades the development of specific methodologies for the control of systems described by nonlinear mathematical models has attracted an ever increasing interest New breakthroughs have occurred which have aided the design of nonlinear control systems However there are still limitations which must be understood some of which were addressed at the IFAC Symposium in Capri The emphasis was on the methodological developments although a number of the papers were concerned with the presentation of applications of nonlinear design philosophies to actual control problems in chemical electrical and mechanical engineering

**Adaptive Systems in Control and Signal Processing 1989** T.S. Durrani,D.H. Owens,M.A. Johnson,M.J. Grimble,2014-06-28 The Symposium covered three major areas adaptive control identification and signal processing In all three new developments were discussed covering both theoretical and applications research Within the subject area of adaptive control the discussion centred around the challenges of robust control design to unmodelled dynamics robust parameter estimation and enhanced performance from the estimator while the papers on identification took the theme of it being a bridge between adaptive control and signal processing The final area looked at two aspects of signal processing recursive estimation and adaptive filters

Scientific and Technical Aerospace Reports ,1964 Lists citations with abstracts for aerospace related reports obtained from world wide sources and announces documents that have recently been entered into the NASA Scientific and Technical Information Database

*Power Systems and Power Plant Control 1989* U. Ahn,2014-06-05 The control of power systems and power plants is a subject of growing interest which continues to sustain a high level of research development and application in many diverse yet complementary areas such as maintaining a high quality but economical service and coping with environmental constraints The papers included within this volume provide the most up to date developments in this field of research

*Cyber Security Intelligence and Analytics* Zheng Xu,Saed Alrabaei,Octavio Loyola-González,Niken Dwi Wahyu Cahyani,Nurul Hidayah Ab Rahman,2023-04-29 This book provides the proceedings of the 5th International Conference on Cyber Security Intelligence and Analytics The 5th International Conference on Cyber Security Intelligence and Analytics CSIA 2023 is an international conference dedicated to promoting novel theoretical and applied research advances in the interdisciplinary agenda of cyber security particularly focusing on threat intelligence and analytics and countering cybercrime Cyber security experts

including those in data analytics incident response and digital forensics need to be able to rapidly detect analyze and defend against a diverse range of cyber threats in near real time conditions We are organizing the CSIA 2023 at Radisson Blu Shanghai Pudong Jinqiao Hotel It will feature a technical program of refereed papers selected by the international program committee keynote address *Comparative Study of Variable Structure Control Systems* Gregory V. Murphy, 1986

Automatic Control Systems with Variable Structure S. V. Emelyanov, FOREIGN TECHNOLOGY DIV WRIGHT-PATTERSON AFB OHIO., 1970 The book examines principles of construction of one class of nonlinear automatic control systems with variable structure Basic attention is allotted to different problems of control of linear objects with constant and variable parameters both for free and for forced motions It is shown that the principle of changeability of structure permits ensuring high quality control of free motion of an object and in the case of change of parameters in a wide range permits constructing a system insensitive to these changes Methods of synthesis of control for objects working under conditions of continuously acting external perturbing forces are given It is shown that for a broad class of disturbances it is possible to ensure independence of quality indicators of the control process by using executing devices with variable structure A very important peculiarity of the examined class of systems from the practical point of view is that for realization of offered laws of control required is information neither about the value of variable parameters of the object nor on disturbances applied to it The offered methods of control of objects with one adjustable value are generalized in case of multiconnected objects with several adjustable coordinates Author *Variable Structure Systems: Towards the 21st Century* Xinghuo Yu, Jian-Xin Xu, 2002-01-11 The book is a collection of contributions concerning the theories applications and perspectives of Variable Structure Systems VSS Variable Structure Systems have been a major control design methodology for many decades The term Variable Structure Systems was introduced in the late 1950 s and the fundamental concepts were developed for its main branch Sliding Mode Control by Russian researchers Emelyanov and Utkin The 20th Century has seen the formation and consolidation of VSS theory and its applications It has also seen an emerging trend of cross fertilization and integration of VSS with other control and non control techniques such as feedback linearization atness passivity based control adaptive and learning control system identification pulse width modulation H geometric and algebraic methods artificial intelligence modeling and optimization neural networks fuzzy logic to name just a few This trend will continue and flourish in the new millennium To reflect these major developments in the 20th Century this book includes 16 specially invited contributions from well known experts in VSS theory and applications covering a wide range of topics The first chapter First Stage of VSS People and Events written by Vadim Utkin the founder of VSS overviews and documents the historical developments of VSS in the 20th Century including many interesting events not known to the West until now The second chapter An Integrated Learning Variable Structure Control Method written by Jian Xin Xu addresses an important issue regarding control integration between variable structure control and learning control Advances in Variable Structure Systems and Sliding Mode

Control—Theory and Applications Shihua Li,Xinghuo Yu,Leonid Fridman,Zhihong Man,Xiangyu Wang,2017-08-10 This book reflects the latest developments in variable structure systems VSS and sliding mode control SMC highlighting advances in various branches of the VSS SMC field e g from conventional SMC to high order SMC from the continuous time domain to the discrete time domain from theories to applications etc The book consists of three parts and 16 chapters in the first part new VSS SMC algorithms are proposed and their properties are analyzed while the second focuses on the use of VSS SMC techniques to solve a variety of control problems the third part examines the applications of VSS SMC to real time systems The book introduces postgraduates and researchers to the state of the art in VSS SMC field including the theory methodology and applications Relative academic disciplines include Automation Mathematics Electrical Engineering Mechanical Engineering Instrument Science and Engineering Electronic Engineering Computer Science and Technology Transportation Engineering Energy and Power Engineering etc

A Minimum Function-Based Discrete Sliding Mode Control: Theory and Applications Shyam Kamal,Parijat Prasun,2025-12-12 This monograph is driven by the ambition to thoroughly investigate and advance the field of discrete time sliding mode design based on difference equations with minima for dynamical systems The motivation behind this exploration lies in the recognition of limitations inherent in classical and conventional control techniques prompting a quest for methodologies that can effectively address the evolving demands of modern applications The overarching objective of this monograph is to introduce innovative approaches capable of enabling timely and precise control even in the presence of uncertainties and exogenous perturbations Through the development of sophisticated discrete control strategies designed to ensure finite time convergence this research aims to enhance the capabilities and operational efficiency of diverse engineering systems thereby contributing to the ongoing evolution of control methodologies in response to contemporary challenges

**Advances In Variable Structure Systems: Analysis, Integration And Application - Proceedings Of The 6th Ieee International Workshop On Variable Structure**

**Systems** Jian-xin Xu,Xing Huo Yu,2000-11-14 The last of such a workshop in the 20th Century this workshop aims not only to summarize the state of the art developments in VSS theory and applications but also identify new promising directions perceived as being important for VSS in the 21st century The 20th Century has witnessed the formation and consolidation of VSS theory and its applications It has also witnessed an emerging trend of cross fertilization and integration of VSS with other control and non control areas such as feedback linearization flatness passivity based control adaptive control system identification pulse width modulation Hinf geometric and algebraic methods artificial intelligence modelling and optimisation neural networks fuzzy logic etc This trend will continue and flourish in the new millennium Special features of the book include a survey paper entitled VSS Premise of XX Century Evidences of a Witness by the father of VSS theory Professor Vadim Utkin and other articles by many authoritative experts in VSS

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