Preface

Control techniques are indispensable in the design of robots and modern vehicles. Using feedback control the safety and efficiency of these mechanical systems can considerably be improved. In order to achieve good control performances, the mathematical model of the controlled mechanical system has to be taken into consideration during control algorithm design. The dynamic model of vehicles and robots are nonlinear.

First the book briefly outlines the most important nonlinear control algorithms that can be applied for the control of mechanical systems. The very first requirement of each control system is the closed loop stability. It is why the stability analysis methods for nonlinear systems are presented in detail. Basic nonlinear control methods (feedback linearization, backstepping, sliding control, receding horizon control) that can be applied for mechanical systems are also reviewed.

For efficient controller design it is inevitable the knowledge of the dynamic model of controlled mechanical system. A framework for the modeling of vehicles and robots are introduced. Staring from the dynamic model of rigid bodies, the mechanical model of robotic manipulators, ground, aerial and marine vehicles are presented. The nonlinear effects that appear in the model of different mechanical systems are discussed.

The control of robots and different type of vehicles are discussed in separate chapters. The model based tracking control of robotic manipulators is addressed in different approaches. Firstly it is assumed that the parameters of the mathematical model of the robotic system are known. For such systems the classical robot control methods are presented such as cascade control, nonlinear decoupling and hybrid position/force control. For the control of robots with unknown parameters selftuning adaptive control is proposed. If the robot prescribed path include sharp corners, backstepping control techniques are suggested.

The ground vehicles generally move in unknown environment with stationary or moving obstacles. Some control algorithms are proposed for these systems that take into consideration the static and dynamic obstacles based on input–output linearization and receding horizon control techniques.

Receding horizon control is also applied for the control of aircrafts. This control algorithm is extended with a robust disturbance observer. For the control of a quadrotor helicopter, backstepping control techniques are applied.

For nonlinear ship control the acceleration feedback can be combined with nonlinear PID control. Adaptive control techniques can be applied for ships with unknown parameters. The control of 6 degree of freedom ships is solved using backstepping control techniques.

For simultaneous control of a group of vehicles, formation control techniques can to be applied. In this work two approaches are suggested for vehicles that move on a surface: potential field method and passivity theory.

Non-smooth nonlinearities such as friction and backlash severely influence the control performances of mechanical systems. To solve the problem of friction compensation and identification in robotic systems, efficient friction modeling techniques are necessary. A piecewise linearly parameterized model is introduced to describe the frictional phenomenon in mechanical control system. The behavior of the control systems with Stribeck friction and backlash is analyzed in a hybrid system approach. Prediction and analysis methods for friction and backlash generated limit cycles are also presented. A friction identification method is introduced that can be applied for robotic manipulators driven by electrical motors and for hydraulic actuators as well. The piecewise linear friction model is also applied for robust adaptive friction and payload compensation in robotic manipulators.

The appendixes of the book are important for understanding other chapters. The kinematic and dynamic foundations of physical systems and the basis of differential geometry for control problems are presented. Readers who are familiar with these fundamentals may overstep the appendixes.

The reader of this book will become familiar with the modern control algorithms and advanced modeling techniques of the most common mechatronic systems: vehicles and robots. The examples that are included in the book will help the reader to apply the presented control and modeling techniques in their research and development work.

Budapest Béla Lantos
Târgu Mureş (Marosvásárhely) Lőrinc Márton

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