

The book "Attractive Ellipsoids in Robust Control" introduces a newly developed robust control design technique for a wide class of continuous-time dynamical systems.

- **Preface** gives a general look at the book.
- **Chapter 1 (Introduction)** presenting the motivation and intuitive concepts.
- **Chapter 2 (MATHEMATICAL BACKGROUNDS)** contains a short collection of necessary mathematical facts from the classic analysis and related areas, namely, the description of the class of nonlinear uncertain models (Quasi-Lipschitz Dynamic Systems and their examples), Differential Inclusions and their general solution concept, the Filippov regularization procedure, the Lyapunov approach to Quasi-Lipschitz Dynamic Systems, Elements of the Linear Matrix Inequalities including the existence of solutions and some numerical approaches, the duality for LMIs constrained problems, the  $S$ -Lemma and more.
- **Chapter 3 (ROBUST STATE FEEDBACK CONTROL)** establishes the main concepts of the linear (proportional to the current state) feedback design using the  $S$ -procedure based approach, discusses the Storage Function Method providing the boundedness of all possible trajectories of the controlled system from a given class and presents the technique of the minimization of the attractive ellipsoid containing all bounded trajectories, the aspects of the practical stabilization are also discussed.
- **Chapter 4 (ROBUST OUTPUT FEEDBACK CONTROL)** is devoted to the direct feedback control designing and considers two feedback structures:
  - the observer-based feedback,
  - the full order linear dynamic controller,and for both of them the Attractive Ellipsoid Method is applied and analyzed.
- In **Chapter 5 (CONTROL WITH SAMPLE - DATA MEASUREMENTS)** the main problem is formulated and there are discussed some necessary mathematical concepts related with the feedback control design for nonlinear systems under sample-data output measurements. Then we present the theoretical analysis of the extended version of the invariant ellipsoid method. Then two feedbacks are analyzed:- a linear feedback proportional the current state estimate obtained by a Luenberger - type estimator,
  - a full order linear dynamic controller governed by a linear ODE with available sample - data as input.

Then we construct a minimal attractive ellipsoid that guarantees stability of the system in a practical sense varying all parameters of the suggested

feedbacks. The associated numerical techniques is also presented. An implementable algorithms for the constructive treatment of the robust control design problem are proposed.

- **Chapter 6 (SAMPLE DATA AND QUANTIFYING OUTPUT CONTROL)** considers the analysis and design of an output feedback controller for a perturbed nonlinear system in which the output is sampled and quantized. Using the invariant ellipsoid method, which is based on Lyapunov analysis techniques, together with the relaxation of a nonlinear optimization problem, sufficient conditions for the design of a robust control law are obtained. Since the original conditions result in nonlinear matrix inequalities, a numerical algorithm to obtain the solution is presented. The obtained control ensures that the trajectories of the closed-loop system will converge to a minimal (in a sense to be made specific) ellipsoidal region. Finally, numerical examples are presented in order to illustrate the applicability of the proposed design method.
- **Chapter 7 (ROBUST CONTROL OF IMPLICIT SYSTEMS)** focuses on the analysis and synthesis of the robust feedback for a class of implicit systems which state derivatives can not be expressed analytically as functions of its state coordinates, the transformation to Differential - Algebraic form is presented and the Attractive Ellipsoid Method is designed for such systems, the reduction of bilinear matrix inequalities in to linear ones is presented in details, some specific numerical aspects are also discussed.
- **Chapter 8 (ATTRACTIVE ELLIPSOIDS IN SLIDING MODE CONTROL)** deals with minimization of unmatched uncertainties effect in Sliding Mode Control, in particular, LMI - based Sliding Mode Control design is considered and the optimal sliding surface is constructed, also the gain matrix tuning in dynamic actuators is analyzed as well as the sliding mode control of time-delay systems with a predictive control is discussed in details.
- **Chapter 9 (TIME-DELAY SYSTEM ROBUST CONTROL)** considers the class of uncertain time delay affine - controlled systems where a delay is admitted to be in state variables as well as in its derivatives (neutral systems), and shows that the Attractive Ellipsoid Method application permits to create a feedback which provides the convergence of any state trajectory of the controlled system from a given class to an ellipsoid which "size" depends on the parameters of the applied feedback. Finally, we present a method for numerical calculation of these parameters providing the "smallest" zone-convergence for controlled trajectories.
- **Chapter 10 (SWITCHED AND HYBRID SYSTEMS ROBUST CONTROL)** deals with robust control problems where a structure of the controlled dynamics may vary in time according to some fixed program - strategy or when the controlled trajectories cross some given surfaces. All

nonlinearities of each structure are admitted to be uncertain but belonging a wide class of quasi-Lipschitz functions. The corresponding switching of the applied feedback is shown to be much more effective than a "solid-structure" of the feedback providing a smaller convergence zone.

- **Chapter 11 (BOUNDED ROBUST CONTROL)** describes the application of the Attractive Ellipsoid Method to the controlled systems where the control actions are a priori bounded, so that a current control at each time is the projection of a linear function of the state or its estimate. Certainly, this constraint makes the convergence zone a little bit larger being compared with the unconstrained case, but our approach provides the instrument how to obtain this zone as small as possible.
- **Chapter 12 (ATTRACTIVE ELLIPSOID METHOD WITH ADAPTATION)** deals with the designing a state estimator and adaptive controller for a class of uncertain nonlinear systems having "quasi-Lipschitz" nonlinearities as well as external perturbations. The set of stabilizing feedback matrices is given by a specific matrix inequality including also the characteristic matrix of the attractive ellipsoid which contains all possible bounded trajectories around the origin. Here we present two modifications of the AEM, which permits
  - to use on-line information obtained during the process,
  - and to adjust a matrix parameters participating in some constrain which characterizes the class of adaptive stabilizing feedbacks.

The proposed approach guarantees that, under a specific persistent excitation condition, the controlled system trajectories converge to an ellipsoid of a "minimal size" having a minimal trace of the corresponding inverse ellipsoidal matrix which turns out to be significantly smaller than one without adaptation.