

**Problem 1.** (Transformation to controllable canonical form). Consider the following third-order SISO LTI system

$$\dot{x} = Ax + Bu, \quad x \in \mathbb{R}^3, u \in \mathbb{R}^1 \quad (\text{AB-CLTI})$$

Assume that the characteristic polynomial of  $A$  is given by

$$\det(sI - A) = s^3 + \alpha_1 s^2 + \alpha_2 s + \alpha_3$$

and consider the  $3 \times 3$  matrix

$$T := C \begin{bmatrix} 1 & \alpha_1 & \alpha_2 \\ 0 & 1 & \alpha_1 \\ 0 & 0 & 1 \end{bmatrix}$$

where  $C$  is the system's controllability matrix.

(a) Show that the following equality holds:

$$B = T \begin{bmatrix} 1 \\ 0 \\ 0 \end{bmatrix}$$

(b) Show that the following equality holds:

$$AT = T \begin{bmatrix} -\alpha_1 & -\alpha_2 & -\alpha_3 \\ 1 & 0 & 0 \\ 0 & 1 & 0 \end{bmatrix}$$

(c) Show that if the system (AB-CLTI) is controllable, then  $T$  is a nonsingular matrix.

(d) Combining parts (a)–(c), you showed that, if the system (AB-CLTI) is controllable, then the matrix  $T$  given above can be viewed as a similarity transformation that transforms the system into the controllable canonical form

$$T^{-1}AT = \begin{bmatrix} -\alpha_1 & -\alpha_2 & -\alpha_3 \\ 1 & 0 & 0 \\ 0 & 1 & 0 \end{bmatrix}, \quad T^{-1}B = \begin{bmatrix} 1 \\ 0 \\ 0 \end{bmatrix}.$$

Use this to find the similarity transformation that transforms the following pair into the controllable canonical form

$$A := \begin{bmatrix} 6 & 4 & 1 \\ -5 & -4 & 0 \\ -4 & -3 & -1 \end{bmatrix}, \quad B := \begin{bmatrix} 1 \\ -1 \\ -1 \end{bmatrix}.$$

# Linear Systems Theory Hespanha Solutions

**Chi-Tsong Chen**



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with solutions Based on typical problems these exercises guide students to succinct and precise answers helping to clarify issues and consolidate knowledge The book's balanced chapters can each be covered in approximately two hours of lecture time simplifying course planning and student review Easy to use textbook in unique lecture style format Sidebars explain topics in further detail Annotated proofs and discussions of MATLAB commands Balanced chapters can each be taught in two hours of course lecture New practice exercises with solutions included      **Solutions Manual for Linear Systems Theory** Dan Liu, Ferenc Szidarovszky, Terry Bahill, 1992-07-01      Hybrid Systems: Computation and Control Alberto Bemporad, Giorgio C Buttazzo, Antonio Bicchi, 2007-05-31 This book constitutes the refereed proceedings of the 10th International Conference on Hybrid Systems Computation and Control HSCC 2007 held in Pisa Italy in April 2007 Among the topics addressed are models of heterogeneous systems computability and complexity issues real time computing and control embedded and resource aware control control and estimation over wireless networks and programming languages support and implementation      Unsolved Problems in Mathematical Systems and Control Theory Vincent D. Blondel, Alexandre Megretski, 2009-04-11 This book provides clear presentations of more than sixty important unsolved problems in mathematical systems and control theory Each of the problems included here is proposed by a leading expert and set forth in an accessible manner Covering a wide range of areas the book will be an ideal reference for anyone interested in the latest developments in the field including specialists in applied mathematics engineering and computer science The book consists of ten parts representing various problem areas and each chapter sets forth a different problem presented by a researcher in the particular area and in the same way description of the problem motivation and history available results and bibliography It aims not only to encourage work on the included problems but also to suggest new ones and generate fresh research The reader will be able to submit solutions for possible inclusion on an online version of the book to be updated quarterly on the Princeton University Press website and thus also be able to access solutions updated information and partial solutions as they are developed      *Handbook of Reinforcement Learning and Control* Kyriakos G. Vamvoudakis, Yan Wan, Frank L. Lewis, Derya Cansever, 2021-06-23 This handbook presents state of the art research in reinforcement learning focusing on its applications in the control and game theory of dynamic systems and future directions for related research and technology The contributions gathered in this book deal with challenges faced when using learning and adaptation methods to solve academic and industrial problems such as optimization in dynamic environments with single and multiple agents convergence and performance analysis and online implementation They explore means by which these difficulties can be solved and cover a wide range of related topics including deep learning artificial intelligence applications of game theory mixed modality learning and multi agent reinforcement learning Practicing engineers and scholars in the field of machine learning game theory and autonomous control will find the Handbook of Reinforcement Learning and Control to be thought provoking instructive and informative      Discrete and Topological Models in Molecular Biology Nataša Jonoska, Masahico

Saito,2013-12-23 Theoretical tools and insights from discrete mathematics theoretical computer science and topology now play essential roles in our understanding of vital biomolecular processes The related methods are now employed in various fields of mathematical biology as instruments to zoom in on processes at a molecular level This book contains expository chapters on how contemporary models from discrete mathematics in domains such as algebra combinatorics and graph and knot theories can provide perspective on biomolecular problems ranging from data analysis molecular and gene arrangements and structures and knotted DNA embeddings via spatial graph models to the dynamics and kinetics of molecular interactions The contributing authors are among the leading scientists in this field and the book is a reference for researchers in mathematics and theoretical computer science who are engaged with modeling molecular and biological phenomena using discrete methods It may also serve as a guide and supplement for graduate courses in mathematical biology or bioinformatics introducing nontraditional aspects of mathematical biology *Hybrid Systems with Constraints*

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*Linear System* Ferenc Szidarovszky, 1997-11 **Hybrid Systems: Computation and Control** Joao Hespanha, 2006-03-20 This book constitutes the refereed proceedings of the 9th International Workshop on Hybrid Systems Computation and Control HSCC 2006 held in Santa Barbara CA USA in March 2006 The 39 revised full papers presented together with the abstracts of 3 invited talks were carefully reviewed and selected from 79 submissions Among the topics addressed are tools for analysis and verification control and optimization modeling engineering applications and emerging directions in programming language support and implementation The papers focus on modeling analysis and implementation of dynamic and reactive systems involving both discrete and continuous behaviors *Handbook of Hybrid Systems Control* Jan Lunze, Françoise Lamnabhi-Lagarrigue, 2009-10-15 Sets out core theory and reviews new methods and applications to show how hybrid systems can be modelled and understood **Advances in Distributed Parameter Systems** Jean Auriol, Joachim Deutscher, Guilherme Mazanti, Giorgio Valmorbida, 2022-04-24 The proposed book presents recent breakthroughs for the control of distributed parameter systems and follows on from a workshop devoted to this topic It introduces new and unified visions of the challenging control problems raised by distributed parameter systems The book collects contributions written by prominent international experts in the control community addressing a wide variety of topics It spans the full range from theoretical research to practical implementation and follows three traverse axes emerging ideas in terms of control strategies energy shaping prediction based control numerical control input saturation theoretical concepts for interconnected systems with potential non linear actuation dynamics advanced applications cable operated elevators traffic networks and numerical aspects Cutting edge experts in the field contributed in this volume making it a valuable reference source for control practitioners graduate students and scientists researching practical and theoretical solutions to the challenging problems raised by distributed parameter systems Constructions of Strict Lyapunov Functions Michael Malisoff, Frédéric Mazenc, 2009-06-13 Converse Lyapunov function theory guarantees the existence of strict Lyapunov functions in many situations but the functions it provides are often abstract and nonexplicit and therefore may not lend themselves to engineering applications Often even when a system is known to be stable one still needs explicit Lyapunov functions however once an appropriate strict Lyapunov function has been constructed many robustness and stabilization problems can be solved through standard feedback designs or robustness arguments Non strict Lyapunov

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Linear Systems Theory João P. Hespanha, 2009-09-13 Linear systems theory is the cornerstone of control theory and a well established discipline that focuses on linear differential equations from the perspective of control and estimation In this textbook João Hespanha covers the key topics of the field in a unique lecture style format making the book easy to use for instructors and students He looks at system representation stability controllability and state feedback observability and state estimation and realization theory He provides the background for advanced modern control design techniques and feedback linearization and examines advanced foundational topics such as multivariable poles and zeros and LQG LQR The textbook presents only the most essential mathematical derivations and places comments discussion and terminology in sidebars so that readers can follow the core material easily and without distraction Annotated proofs with sidebars explain the techniques of proof construction including contradiction contraposition cycles of implications to prove equivalence and the difference between necessity and sufficiency Annotated theoretical developments also use sidebars to discuss relevant commands available in MATLAB allowing students to understand these important tools The balanced chapters can each be covered in approximately two

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