

## Chapter 7: CAPM

Some questions in this problem set are taken from the book *Investment Science* from Luenberger.

### Question 1 (Capital Market Line):

1. (Capital market line) Assume that the expected rate of return on the market portfolio is 23% and the rate of return on T-bills (the risk-free rate) is 7%. The standard deviation of the market is 32%. Assume that the market portfolio is efficient.
- (a) What is the equation of the capital market line?
  - (b) (i) If an expected return of 39% is desired, what is the standard deviation of this position? (ii) If you have \$1,000 to invest, how should you allocate it to achieve the above position?
  - (c) If you invest \$300 in the risk-free asset and \$700 in the market portfolio, how much money should you expect to have at the end of the year?

(a) The capital market line is defined by:

$$\tilde{r}_i = E(r_i) = r_F + \frac{E(r_M) - r_F}{\sigma_M} \sigma_i = 0.07 + \frac{0.23 - 0.07}{0.32} \sigma_i$$

(b) (i)

$$0.39 = 0.07 + \frac{0.23 - 0.07}{0.32} \sigma_i \implies \sigma_i = \frac{0.32^2}{0.23 - 0.07} = 0.64$$

(ii)

$$\omega \times 0.07 + (1 - \omega) \times 0.23 = 0.39 \implies \omega = -1$$

$\implies$  Borrow \$1000 at the risk-free rate and invest \$2000 into the market

(c)

$$300 \times (1.07) + 700 \times (1.23) = 1182$$

### Question 2 (A small world):

2. (A small world) Consider a world in which there are only two risky assets,  $A$  and  $B$ , and a risk-free asset  $F$ . The two risky assets are in equal supply in the market; that is,  $M = \frac{1}{2}(A + B)$ . The following information is known:  $r_F = 10$ ,  $\sigma_A^2 = 04$ ,  $\sigma_{AB} = 01$ ,  $\sigma_B^2 = 02$ , and  $\bar{r}_M = 18$ .
- (a) Find a general expression (without substituting values) for  $\sigma_M^2$ ,  $\beta_A$ , and  $\beta_B$ .
  - (b) According to the CAPM, what are the numerical values of  $\bar{r}_A$  and  $\bar{r}_B$ ?

(a) We use the calculation rules for the covariance of a sum of random variables (<https://en.wikipedia.org/wiki/Covariance>)

# Luenberger Chapter 7 Problem

**Ying Liu**



## **Luenberger Chapter 7 Problem:**

*Observer Design for Nonlinear Systems* Pauline Bernard, 2019-02-01 Observer Design for Nonlinear Systems deals with the design of observers for the large class of nonlinear continuous time models. It contains a unified overview of a broad range of general designs including the most recent results and their proofs such as the homogeneous and nonlinear Luenberger design techniques. The book starts from the observation that most observer designs consist in looking for a reversible change of coordinates transforming the expression of the system dynamics into some specific structures called normal forms for which an observer is known. Therefore the problem of observer design is broken down into three subproblems: What are the available normal forms and their associated observers? Under which conditions can a system be transformed into one of these forms and through which transformation? How can an inverse transformation that recovers an estimate in the given initial coordinates be achieved? This organisation allows the book to structure results within a united framework highlighting the importance of the choice of the observer coordinates for nonlinear systems. In particular the first part covers state affine forms with their Luenberger or Kalman designs and triangular forms with their homogeneous high gain designs. The second part addresses the transformation into linear forms through linearization by output injection or in the context of a nonlinear Luenberger design and into triangular forms under the well known uniform and differential observability assumptions. Finally the third part presents some recently developed methods for avoiding the numerically challenging inversion of the transformation. *Observer Design for Nonlinear Systems* addresses students and researchers looking for an introduction to or an overview of the state of the art in observer design for nonlinear continuous time dynamical systems. The book gathers the most important results focusing on a large and diffuse literature on general observer designs with global convergence and is a valuable source of information for academics and practitioners.

**H-infinity Control and Estimation of State-multiplicative Linear Systems** Eli Gershon, Uri Shaked, Isaac Yaesh, 2005-06-24 Multiplicative noise appears in systems where the process or measurement noise levels depend on the system state vector. Such systems are relevant for example in radar measurements where larger ranges involve higher noise level. This monograph embodies a comprehensive survey of the relevant literature with basic problems being formulated and solved by applying various techniques including game theory, linear matrix inequalities and Lyapunov parameter dependent functions. Topics covered include convex  $H_2$  and  $H_\infty$  norms analysis of systems with multiplicative noise, state feedback control and state estimation of systems with multiplicative noise, dynamic and static output feedback of stochastic bilinear systems, tracking controllers for stochastic bilinear systems utilizing preview information. Various examples which demonstrate the applicability of the theory to practical control engineering problems are considered; two such examples are taken from the aerospace and guidance control areas. *Linear and Nonlinear Programming* David G. Luenberger, Yinyu Ye, 2021-10-31 The 5th edition of this classic textbook covers the central concepts of practical optimization techniques with

an emphasis on methods that are both state of the art and popular One major insight is the connection between the purely analytical character of an optimization problem and the behavior of algorithms used to solve that problem End of chapter exercises are provided for all chapters The material is organized into three separate parts Part I offers a self contained introduction to linear programming The presentation in this part is fairly conventional covering the main elements of the underlying theory of linear programming many of the most effective numerical algorithms and many of its important special applications Part II which is independent of Part I covers the theory of unconstrained optimization including both derivations of the appropriate optimality conditions and an introduction to basic algorithms This part of the book explores the general properties of algorithms and defines various notions of convergence In turn Part III extends the concepts developed in the second part to constrained optimization problems Except for a few isolated sections this part is also independent of Part I As such Parts II and III can easily be used without reading Part I and in fact the book has been used in this way at many universities New to this edition are popular topics in data science and machine learning such as the Markov Decision Process Farkas lemma convergence speed analysis duality theories and applications various first order methods stochastic gradient method mirror descent method Frank Wolf method ALM ADMM method interior trust region method for non convex optimization distributionally robust optimization online linear programming semidefinite programming for sensor network localization and infeasibility detection for nonlinear optimization     Geophysical Inverse Theory Robert L.

Parker,1994-06-05 In many physical sciences the most natural description of a system is with a function of position or time In principle infinitely many numbers are needed to specify that function but in practice only finitely many measurements can be made Inverse theory concerns the mathematical techniques that enable researchers to use the available information to build a model of the unknown system or to determine its essential properties In Geophysical Inverse Theory Robert Parker provides a systematic development of inverse theory at the graduate and professional level that emphasizes a rigorous yet practical solution of inverse problems with examples from experimental observations in geomagnetism seismology gravity electromagnetic sounding and interpolation Although illustrated with examples from geophysics this book has broad implications for researchers in applied disciplines from materials science and engineering to astrophysics oceanography and meteorology Parker s approach is to avoid artificial statistical constructs and to emphasize instead the reasonable assumptions researchers must make to reduce the ambiguity that inevitably arises in complex problems The structure of the book follows a natural division in the subject into linear theory in which the measured quantities are linear functionals of the unknown models and nonlinear theory which covers all other systems but is not nearly so well understood The book covers model selection as well as techniques for drawing firm conclusions about the earth independent of any particular model

Data Transportation and Protection John E. Hershey,Rao K. Yarlagadda,2012-12-06 A new breed of engineer is developing in our contemporary society These engineers are concerned with communications and computers economics and

regulation These new engineers apply themselves to data to its packing transmission and protection They are data engineers Formal curricula do not yet exist for their dedicated development Rather they learn most of their tools on the job and their roots are in computer engineering communications engineering and applied mathematics There is a need to draw relevant material together and present it so that those who wish to become data engineers can do so for the betterment of themselves their employer their country and ultimately the world for we share the belief that the most effective tool for world peace and stability is neither politics nor armaments but rather the open and timely exchange of information This book has been written with that goal in mind Today numerous signs encourage us to expect broader information exchange in the years to come The movement toward a true Integrated Services Digital Network ISDN is perhaps the clearest of these Also the development of formal protocol layers reflects both a great deal of brilliance and compromise and also the desire for a common language among data engineers

Introduction to Optimization Methods P. Adby, 2013-03-09 During the last decade the techniques of non linear optimization have emerged as an important subject for study and research The increasingly widespread application of optimization has been stimulated by the availability of digital computers and the necessity of using them in the investigation of large systems This book is an introduction to non linear methods of optimization and is suitable for undergraduate and post graduate courses in mathematics the physical and social sciences and engineering The first half of the book covers the basic optimization techniques including linear search methods steepest descent least squares and the Newton Raphson method These are described in detail with worked numerical examples since they form the basis from which advanced methods are derived Since 1965 advanced methods of unconstrained and constrained optimization have been developed to utilise the computational power of the digital computer The second half of the book describes fully important algorithms in current use such as variable metric methods for unconstrained problems and penalty function methods for constrained problems Recent work much of which has not yet been widely applied is reviewed and compared with currently popular techniques under a few generic main headings vi PREFACE Chapter I describes the optimization problem in mathematical form and defines the terminology used in the remainder of the book Chapter 2 is concerned with single variable optimization The main algorithms of both search and approximation methods are developed in detail since they are an essential part of many multi variable methods

*Financial Economics, Risk and Information* Marcelo Bianconi, 2011-08-23 Financial Economics Risk and Information presents the fundamentals of finance in static and dynamic frameworks with focus on risk and information The objective of this book is to introduce undergraduate and first year graduate students to the methods and solutions of the main problems in finance theory relating to the economics of uncertainty and information The main goal of the second edition is to make the materials more accessible to a wider audience of students and finance professionals The focus is on developing a core body of theory that will provide the student with a solid intellectual foundation for more advanced topics and methods The new edition has streamlined chapters and topics with

new sections on portfolio choice under alternative information structures The starting point is the traditional mean variance approach followed by portfolio choice from first principles The topics are extended to alternative market structures alternative contractual arrangements and agency dynamic stochastic general equilibrium in discrete and continuous time attitudes towards risk and towards inter temporal substitution in discrete and continuous time and option pricing In general the book presents a balanced introduction to the use of stochastic methods in discrete and continuous time in the field of financial economics

*Control and Filtering for Semi-Markovian Jump Systems* Fanbiao Li, Peng Shi, Ligang Wu, 2016-11-04

This book presents up to date research developments and novel methodologies on semi Markovian jump systems S MJS It presents solutions to a series of problems with new approaches for the control and filtering of S MJS including stability analysis sliding mode control dynamic output feedback control robust filter design and fault detection A set of newly developed techniques such as piecewise analysis method positively invariant set approach event triggered method and cone complementary linearization approaches are presented Control and Filtering for Semi Markovian Jump Systems is a comprehensive reference for researcher and practitioners working in control engineering system sciences and applied mathematics and is also a useful source of information for senior undergraduates and graduates in these areas The readers will benefit from some new concepts new models and new methodologies with practical significance in control engineering and signal processing

**Optimal Control for Chemical Engineers** Simant Ranjan Upreti, 2016-04-19

This self contained book gives a detailed treatment of optimal control theory that enables readers to formulate and solve optimal control problems With a strong emphasis on problem solving it provides all the necessary mathematical analyses and derivations of important results including multiplier theorems and Pontryagin's principle The text presents various examples and basic concepts of optimal control and describes important numerical methods and computational algorithms for solving a wide range of optimal control problems including periodic processes

**Theory of Stabilization for Linear Boundary Control**

**Systems** Takao Nambu, 2017-03-03 This book presents a unified algebraic approach to stabilization problems of linear boundary control systems with no assumption on finite dimensional approximations to the original systems such as the existence of the associated Riesz basis A new proof of the stabilization result for linear systems of finite dimension is also presented leading to an explicit design of the feedback scheme The problem of output stabilization is discussed and some interesting results are developed when the observability or the controllability conditions are not satisfied

*Introduction to Mathematical Economics* M.C. Kemp, Y. Kimura, 2012-12-06 Our objectives may be briefly stated They are two First we have sought to provide a compact and digestible exposition of some sub branches of mathematics which are of interest to economists but which are underplayed in mathematical texts and dispersed in the journal literature Second we have sought to demonstrate the usefulness of the mathematics by providing a systematic account of modern neoclassical economics that is of those parts of economics from which jointness in production has been excluded The book is introductory not in the sense

that it can be read by any high school graduate but in the sense that it provides some of the mathematics needed to appreciate modern general equilibrium economic theory It is aimed primarily at first year graduate students and final year honors students in economics who have studied mathematics at the university level for two years and who in particular have mastered a full year course in analysis and calculus The book is the outcome of a long correspondence punctuated by periodic visits by Kimura to the University of New South Wales Without those visits we would never have finished They were made possible by generous grants from the Leverhulme Foundation Nagoya City University and the University of New South Wales Equally indispensable were the expert advice and generous encouragement of our friends Martin Beckmann Takashi Negishi Ryuzo Sato and Yasuo Uekawa

**Analysis and Design of Descriptor Linear Systems** Guang-Ren

Duan,2010-09-14 Descriptor linear systems theory is an important part in the general field of control systems theory and has attracted much attention in the last two decades In spite of the fact that descriptor linear systems theory has been a topic very rich in content there have been only a few books on this topic This book provides a systematic introduction to the theory of continuous time descriptor linear systems and aims to provide a relatively systematic introduction to the basic results in descriptor linear systems theory The clear representation of materials and a large number of examples make this book easy to understand by a large audience General readers will find in this book a comprehensive introduction to the theory of descriptive linear systems Researchers will find a comprehensive description of the most recent results in this theory and students will find a good introduction to some important problems in linear systems theory

*Parimutuel Applications In Finance* Ken Baron,Jeffrey Lange,2006-11-28 Financial intermediaries typically offer derivatives to their customers only when they can hedge the exposures from these transactions Baron and Lange show that parimutuel auctions can be used by financial intermediaries to offer derivatives without exposing themselves to risk

**Foundations of Deterministic and Stochastic Control** Jon H. Davis,2012-12-06

Control theory has applications to a number of areas in engineering and communication theory This introductory text on the subject is fairly self contained and consists of a wide range of topics that include realization problems linear quadratic optimal control stability theory stochastic modeling and recursive estimation algorithms in communications and control and distributed system modeling In the early chapters methods based on Wiener Hopf integral equations are utilized The fundamentals of both linear control systems as well as stochastic control are presented in a unique way so that the methods generalize to a useful class of distributed parameter and nonlinear system models The control of distributed parameter systems systems governed by PDEs is based on the framework of linear quadratic Gaussian optimization problems Additionally the important notion of state space modeling of distributed systems is examined Basic results due to Gohberg and Krein on convolution are given and many results are illustrated with some examples that carry throughout the text The standard linear regulator problem is studied in the continuous and discrete time cases followed by a discussion of dual filtering problems Later chapters treat the stationary regulator and filtering problems

using a Wiener Hopf approach This leads to spectral factorization problems and useful iterative algorithms that follow naturally from the methods employed The interplay between time and frequency domain approaches is emphasized Foundations of Deterministic and Stochastic Control is geared primarily towards advanced mathematics and engineering students in various disciplines

**Linearization of Nonlinear Control Systems** Hong-Gi Lee,2022-09-02 This textbook helps graduate level student to understand easily the linearization of nonlinear control system Differential geometry is essential to understand the linearization problems of the control nonlinear systems In this book the basics of differential geometry needed in linearization are explained on the Euclidean space instead of the manifold for students who are not accustomed to differential geometry Many Lie algebra formulas used often in linearization are also provided with proof The conditions in the linearization problems are complicated to check because the Lie bracket calculation of vector fields by hand needs much concentration and time This book provides MATLAB programs for most of the theorems The book also includes end of chapter problems and other pedagogical aids to help understanding and self study

**Computational Inelasticity** J.C. Simo,T.J.R. Hughes,2006-05-07 A description of the theoretical foundations of inelasticity its numerical formulation and implementation constituting a representative sample of state of the art methodology currently used in inelastic calculations Among the numerous topics covered are small deformation plasticity and viscoplasticity convex optimisation theory integration algorithms for the constitutive equation of plasticity and viscoplasticity the variational setting of boundary value problems and discretization by finite element methods Also addressed are the generalisation of the theory to non smooth yield surface mathematical numerical analysis issues of general return mapping algorithms the generalisation to finite strain inelasticity theory objective integration algorithms for rate constitutive equations the theory of hyperelastic based plasticity models and small and large deformation viscoelasticity Of great interest to researchers and graduate students in various branches of engineering especially civil aeronautical and mechanical and applied mathematics

**Mathematical Control Theory I** M. Kanat Camlibel,A. Agung Julius,Ramkrishna Pasumathy,Jacquelien M.A. Scherpen,2015-07-15 This treatment of modern topics related to mathematical systems theory forms the proceedings of a workshop Mathematical Systems Theory From Behaviors to Nonlinear Control held at the University of Groningen in July 2015 The workshop celebrated the work of Professors Arjan van der Schaft and Harry Trentelman honouring their 60th Birthdays The first volume of this two volume work covers a variety of topics related to nonlinear and hybrid control systems After giving a detailed account of the state of the art in the related topic each chapter presents new results and discusses new directions As such this volume provides a broad picture of the theory of nonlinear and hybrid control systems for scientists and engineers with an interest in the interdisciplinary field of systems and control theory The reader will benefit from the expert participants ideas on exciting new approaches to control and system theory and their predictions of future directions for the subject that were discussed at the workshop

**Journal of Applied Mechanics** ,1975 Publishes original research in all branches of mechanics including



aerodynamics aeroelasticity boundary layers computational mechanics constitutive modeling of materials dynamics elasticity flow and fracture heat transfer hydraulics impact internal flow mechanical properties of materials micromechanics plasticity stress analysis structures thermodynamics turbulence vibration and wave propagation      *Observers in Control Systems* George Ellis, 2002-10-16 Observers are digital algorithms that combine sensor outputs with knowledge of the system to provide results superior to traditional structures which rely wholly on sensors Observers have been used in selected industries for years but most books explain them with complex mathematics Observers in Control Systems uses intuitive discussion software experiments and supporting analysis to explain the advantages and disadvantages of observers If you are working in controls and want to improve your control systems observers could be the technology you need and this book will give you a clear thorough explanation of how they work and how to use them Control systems and devices have become the most essential part of nearly all mechanical systems machines devices and manufacturing systems throughout the world Increasingly the efficiency of production the reliability of output and increased energy savings are a direct result of the quality and deployment of the control system A modern and essential tool within the engineer's kit is the Observer which helps improve the performance and reduce the cost of these systems George Ellis is the author of the highly successful Control System Design Guide Second Edition Unlike most controls books which are written by control theorists and academics Ellis is a leading engineer designer author and lecturer working in industry directly with the users of industrial motion control systems Observers in Control Systems is written for all professional engineers and is designed to be utilized without an in depth background in control theory This is a real world book which will demonstrate how observers work and how they can improve your control system It also shows how observers operate when conditions are not ideal and teaches the reader how to quickly tune an observer in a working system Software Available online A free updated and enhanced version of the author's popular Visual ModelQ allows the reader to practice the concepts with Visual ModelQ models on a PC Based on a virtual laboratory all key topics are demonstrated with more than twenty control system models The models are written in Visual ModelQ and are available on the Internet to every reader with a PC Teaches observers and Kalman filters from an intuitive perspective Explains how to reduce control system susceptibility to noise Shows how to design an adaptive controller based on estimating parameter variation using observers Shows how to improve a control system's ability to reject disturbances Key topics are demonstrated with PC based models of control systems The models are written in both MatLab and ModelQ models are available free of charge      *Portfolio Theory and Performance Analysis* Noel Amenc, Veronique Le Sourd, 2005-01-21 For many years asset management was considered to be a marginal activity but today it is central to the development of financial industry throughout the world Asset management's transition from an art and craft to an industry has inevitably called integrated business models into question favouring specialisation strategies based on cost optimisation and learning curve objectives This book connects each of these major categories of techniques and practices to the unifying

and seminal conceptual developments of modern portfolio theory In these bear market times performance evaluation of portfolio managers is of central focus This book will be one of very few on the market and is by a respected member of the profession Allows the professionals whether managers or investors to take a step back and clearly separate true innovations from mere improvements to well known existing techniques Puts into context the importance of innovations with regard to the fundamental portfolio management questions which are the evolution of the investment management process risk analysis and performance measurement Takes the explicit or implicit assumptions contained in the promoted tools into account and by so doing evaluate the inherent interpretative or practical limits

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