Nonlinear System Analysis
Practice Problems

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1. Let $y(t)$ be the population of fish at a lake and it is governed by the equation $\dot{y} = y(4 - y) - k$ where $k > 0$ is the rate of fishing.
   Find the critical rate of harvesting above which the entire fish population becomes extinct. Find the type of bifurcation at that critical harvest rate.

Solution:
The fixed points occur when $y(4 - y) = k$. It is given by intersection of the line $y = k$ with the curve $f(y) = y(4 - y)$ as shown in Figure 1. We see that at low values of k, say k_1, there are two fixed points,
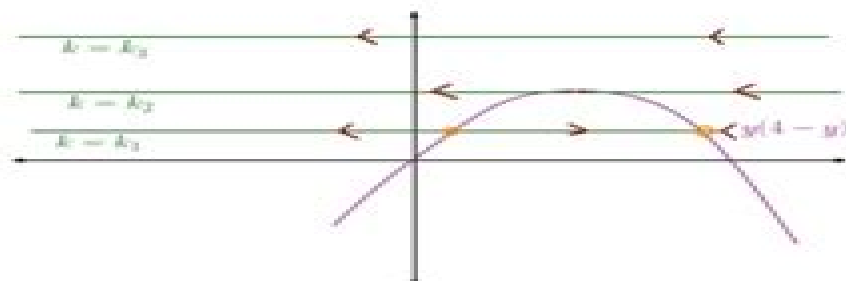

Figure 1

(marked in orange) and there is a stable steady state (stable equilibrium point in the right) of population if it initially were above a threshold (given by the unstable equilibrium point in the left). But they merge at $k = k_2$ and disappear. So, there is a saddle node bifurcation happening at k_2 as a stable and an unstable fixed point collide and disappear. The precise value is when $y = k_2 =$ maximum value of the parabola. The parabolic function $f(y) = y(4 - y) = 4y - y^2$ attains its maximum at y where $f'(y) = 4 - 2y = 0$ and hence at $y = 2$, at which $f(2) = 4$. So, $k_2 = 4$.

2. Sketch the bifurcation diagram and phase portrait for $\dot{x} = \mu x + x^3 - x^5$. What would happen if the parameter μ is slowly increased from $-\infty$ to ∞?

Solution:
The equilibria satisfy $x(\mu + x^2 - x^4) = 0$ and hence the equilibria are,

$$x = 0$$
$$x^2 = \frac{1 \pm \sqrt{1 + 4\mu}}{2}$$

These roots x^2 are both complex if $\mu < -\frac{1}{4}$ (hence no roots for x), both real and positive if $-\frac{1}{4} < \mu < 0$ (hence four roots for x), and one is real and positive the other real and negative if $\mu > 0$ (hence only two roots for x). It follows that there are no equilibria in addition to $x = 0$ if $\mu < -\frac{1}{4}$, four additional equilibria if $-\frac{1}{4} < \mu < 0$, and only two equilibria if $\mu > 0$.

μ	Equilibria and type
$\mu < -\frac{1}{4}$	$x = 0$
$-\frac{1}{4} < \mu < 0$	$x = 0$, four additional equilibria
$\mu > 0$	$x = 0$ and two other equilibria

Nonlinear System Analysis

J. Karl Hedrick,Henry Martyn Paynter

Nonlinear System Analysis:

   Nonlinear Systems Analysis Mathukumalli Vidyasagar,1993   **Nonlinear Systems Analysis** M. Vidyasagar,2002-10-01 This text provides a rigorous mathematical analysis of the behavior of nonlinear control systems under a variety of situations   Nonlinear Systems Shankar Sastry,2013-04-18 There has been a great deal of excitement in the last ten years over the emer gence of new mathematical techniques for the analysis and control of nonlinear systems Witness the emergence of a set of simplified tools for the analysis of bifurcations chaos and other complicated dynamical behavior and the develop ment of a comprehensive theory of geometric nonlinear control Coupled with this set of analytic advances has been the vast increase in computational power available for both the simulation and visualization of nonlinear systems as well as for the implementation in real time of sophisticated real time nonlinear control laws Thus technological advances havebolstered the impact of analytic advances and produced a tremendous variety of new problems and applications that are nonlinear in an essential way Nonlinear controllaws have been implemented for sophisticated flight control systems on board helicopters and vertical take offand landing aircraft adaptive nonlinearcontrollaws havebeen implementedfor robot manipulators operating either singly or in cooperation on a multi fingered robot hand adaptive control laws have been implemented forjetengines andautomotive fuel injection systems as well as for automated highway systems and air traffic management systems to mention a few examples Bifurcation theory has been used to explain and understand the onset of fiutterin the dynamics of aircraft wing structures the onset of oscillations in nonlinear circuits surge and stall in aircraft engines voltage collapse in a power transmission network   Nonlinear System Analysis and Identification from Random Data Julius S. Bendat,1990-03-16 Describes procedures to identify and analyze the properties of many types of nonlinear systems from random data measured at the input and output points of physical systems Improvements are offered in applying older techniques and problems that traditionally have been difficult to analyze are solved by new simpler procedures Formulas are stated for optimum nonlinear system identification in both general models consisting of parallel linear bilinear and trilinear systems and special models consisting of parallel linear finite memory square law systems and finite memory cubic systems New results obtained here show when and how to replace complicated single input output nonlinear models with simpler alternative multiple input single output linear models New error analysis formulas are presented to design experiments and to evaluate estimates obtained from measured data Includes many illustrative examples

   Nonlinear Systems: Analysis and Design Hazel Johnson,2021-11-16 A system where the changes in the output and input are not proportional is called a nonlinear system Most systems are inherently nonlinear in nature and hence nonlinear problems are studied in various fields such as engineering biology physics mathematics etc Unlike simple linear systems nonlinear dynamical systems that describe changes in variables over time may appear chaotic unpredictable or counterintuitive Nonlinear systems are commonly approximated by linear equations since nonlinear dynamical equations are

difficult to solve This process of approximation is called linearization This book provides significant information of this discipline to help develop a good understanding of nonlinear systems and related fields From theories to research to practical applications case studies related to all contemporary topics of relevance to this field have been included herein This book is a vital tool for all researching or studying nonlinear systems as it gives incredible insights into emerging trends and concepts

   Nonlinear System Analysis Austin Blaquiere,2012-12-02 Nonlinear System Analysis focuses on the study of systems whose behavior is governed by nonlinear differential equations This book is composed of nine chapters that cover some problems that play a major role in engineering and physics The opening chapter briefly introduces the difference between linear and nonlinear systems Considerable chapters are devoted to engineering and physics related problems and their applications to particle accelerators frequency measurements and masers Included in these chapters are important practical problems such as synchronization stability of systems with periodic coefficients and effect of random disturbances The remaining chapters examine random fluctuations of the motion and self oscillators This book is intended primarily for engineers and physicists   *Analysis and Design of Nonlinear Control Systems* Daizhan Cheng,Xiaoming Hu,Tielong Shen,2011-03-28 Analysis and Design of Nonlinear Control Systems provides a comprehensive and up to date introduction to nonlinear control systems including system analysis and major control design techniques The book is self contained providing sufficient mathematical foundations for understanding the contents of each chapter Scientists and engineers engaged in the field of Nonlinear Control Systems will find it an extremely useful handy reference book Dr Daizhan Cheng a professor at Institute of Systems Science Chinese Academy of Sciences has been working on the control of nonlinear systems for over 30 years and is currently a Fellow of IEEE and a Fellow of IFAC he is also the chairman of Technical Committee on Control Theory Chinese Association of Automation   Nonlinear Systems Dongbin Lee,Christos Volos,Timothy Burg,2016-10-19 The book consists mainly of two parts Chapter 1 Chapter 7 and Chapter 8 Chapter 14 Chapter 1 and Chapter 2 treat design techniques based on linearization of nonlinear systems An analysis of nonlinear system over quantum mechanics is discussed in Chapter 3 Chapter 4 to Chapter 7 are estimation methods using Kalman filtering while solving nonlinear control systems using iterative approach Optimal approaches are discussed in Chapter 8 with retarded control of nonlinear system in singular situation and Chapter 9 extends optimal theory to H infinity control for a nonlinear control system Chapters 10 and 11 present the control of nonlinear dynamic systems twin rotor helicopter and 3D crane system which are both underactuated cascaded dynamic systems Chapter 12 applies controls to antisynchronization synchronization in the chaotic models based on Lyapunov exponent theorem and Chapter 13 discusses developed stability analytic approaches in terms of Lyapunov stability The analysis of economic activities especially the relationship between stock return and economic growth is presented in Chapter 14   *Nonlinear Systems Analysis* Prentice Hall PTR,1993-07-01   **The Electrical Engineering Handbook,Second Edition** Richard C. Dorf,1997-09-26 In 1993 the first edition of The Electrical Engineering Handbook set

a new standard for breadth and depth of coverage in an engineering reference work Now this classic has been substantially revised and updated to include the latest information on all the important topics in electrical engineering today Every electrical engineer should have an opportunity to expand his expertise with this definitive guide In a single volume this handbook provides a complete reference to answer the questions encountered by practicing engineers in industry government or academia This well organized book is divided into 12 major sections that encompass the entire field of electrical engineering including circuits signal processing electronics electromagnetics electrical effects and devices and energy and the emerging trends in the fields of communications digital devices computer engineering systems and biomedical engineering A compendium of physical chemical material and mathematical data completes this comprehensive resource Every major topic is thoroughly covered and every important concept is defined described and illustrated Conceptually challenging but carefully explained articles are equally valuable to the practicing engineer researchers and students A distinguished advisory board and contributors including many of the leading authors professors and researchers in the field today assist noted author and professor Richard Dorf in offering complete coverage of this rapidly expanding field No other single volume available today offers this combination of broad coverage and depth of exploration of the topics The Electrical Engineering Handbook will be an invaluable resource for electrical engineers for years to come

Nonlinear-system Analysis and Synthesis Ming-Lei Liou,1963 *Analysis and Control of Nonlinear Systems* Jean Levine,2009-05-28 This book examines control of nonlinear systems Coverage ranges from mathematical system theory to practical industrial control applications The author offers web based videos illustrating some dynamical aspects and case studies in simulation **Nonlinear Control Systems** Zoran Vukic,2003-02-04 This text emphasizes classical methods and presents essential analytical tools and strategies for the construction and development of improved design methods in nonlinear control It offers engineering procedures for the frequency domain as well as solved examples for clear understanding of control applications in the industrial electrical process manufacturing and automotive industries The authors discuss Properties of nonlinear systems stability linearization methods operating modes and dynamic analysis methods phase trajectories in dynamic analysis of nonlinear systems and harmonic linearization in dynamic analysis of nonlinear control systems operating in stabilization mode **Nonlinear System Analysis and Synthesis: Fundamental principles** J. Karl Hedrick,Henry Martyn Paynter,1978 Nonlinear-system Analysis and Synthesis Stanford University. Stanford Electronics Laboratories,Ming-Lei Liou,1963 **Nonlinear System Identification** Stephen A. Billings,2013-09-23 Nonlinear System Identification NARMAX Methods in the Time Frequency and Spatio Temporal Domains describes a comprehensive framework for the identification and analysis of nonlinear dynamic systems in the time frequency and spatio temporal domains This book is written with an emphasis on making the algorithms accessible so that they can be applied and used in practice Includes coverage of The NARMAX nonlinear autoregressive moving average with exogenous inputs model

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