Control System Dynamics

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Abstract

Automatic control systems have become essential features in virtually every area of technology, from machine tools to aerospace vehicles.

This book is a through, easy-to-read introduction to automatic control engineering, emphasizing the way physical properties of individual interconnected devices in a system influence the dynamics performance of the entire control system.

The author begins with the fundamentals of modeling mechanical, electrical, and electromechanical systems in the state-variable format. The emphasis is on classical feedback control theory and design, and their application to practical electromechanical and aerospace problems. Following a careful grounding in classical control theory, the author provides an introduction to modern control theory, including digital control and nonlinear system analysis. Problems at the end of each chapter(more than 230 altogether) help the reader apply principles discussed in the text to practical engineering situations.

Engineering students and practicing engineers will find what they need to know about control system analysis and design in this clear and comprehensive text.

1. Introduction to Control System Engineering

1.1. Backgournd

Dynamcis (動力学) ... the central role in automatic control engineering(自動制御工学の中心的役割)

Analytical techniques (解析手法)
Design priciples (制御原理)
... Methods of dealing with dynamics problems (動力学問題を取り扱う (単なる) 方法)
(From specialized point of view of the automatic feedback control system) (自動制御工学系という特別な見地からの)

⇓ This collection of methods and procedure[**?**]
⇓ (手法，手続きの体系化)

Servomechanism theory (サーボ機構[0] 理論)
Basic control theory (基礎制御理論)
... Basic subject to be mastered by a beginning control system engineer (制御工学系エンジニアがマスターすべき基礎的な課題)

Constitution of a typical automatic control system (典型的な自動制御系の構成) ... Several interconnected devices designed to perform a prescribed task. (目的の作業をするために有機的に統合されたいくつかの装置)

Controlling the table of a machine tool corresponding to a command

Simultaneous workby interconnected devices (内部装置の同時作業)
||
A feedback connection (フィードバック連結)
⟹
- Electromechanical actuators (電気機械アクチュエータ)
- Sensors[0] (センサ)
- A control conputer (制御コンピュータ)etc.

[0]サーボ機構:機械の動く変位や速度といった出力変数に忠実に自動的に動かそうとする制御系

[0]Sensor: Measurement of the position and velocity of the controlled object, the corrents or voltages at the actuator(センサ：制御対象の位置，速度，アクチュエータの電流あるいは電圧の測定)

One of the jobs for the engineer (エンジニアの仕事として)

Only the information about the physical properties of the indivisual component elements (個別の構成要素の物理特性のみ既知) $\Longrightarrow$ Determination of the dynamic response of the entire system to a given command (与えられた命令に対するシステム全体の応答を決定)

$\longrightarrow$ Even in relative simple systems for a formidable task

$\Downarrow$

Requirement of quantitative dynamic analysis(定量的な動力学解析の必要性)

1.2. Modern Control Theory and the Digital Computer

Classical control theory (古典制御理論) . . . *single-input-single-output*(SISO) systems (一入力一出力系)

A complex automatic control system(複雑な自動制御系)[1]

$\longrightarrow$ Driven by several input commands(いくつかの入力命令により稼働)

$\Downarrow$

Multiple-input-multiple-output(MIMO) system (多入力多出力系)$\Longrightarrow$ *Modern control theory*(現代制御理論)

Modern control theory $\supset$ Classical theory . . . A deeper understanding

(現代制御理論は，古典制御理論を含み，その理解を助ける)

Concurrent development of the digital computer (同時的なデジタルコンピュータの発達)

Possibility of the practical application of modern control theory for the engineer

(現代制御理論の実問題への応用の可能性)

Modern control theory . . . the differential equations for the dynamics of a system

(現代制御理論では，系の動力学を微分方程式群で表現)

Convenient expression for multiple inputs and multiple outputs

(多入力多出力系に対して都合の良い表現方法)

$\Rightarrow$ the *vector matrix differential equation* or the *state-variable* form of the equations

(ベクトル行列微分方程式，方程式の状態変数表示)

Computer-aided calculation (コンピュータ援用計算)

Digital computer

- Powerful computing capacity (強力な計算能力)
- High speed of operetion of the digital signal processing (デジタル信号処理の高速演算)
- Escape from approximation method[1] (近似計算からの脱出)
- An integral operating element in the control system (制御系に必ず必要な要素)

$\Longrightarrow$ Not only the functions of electronic controllers but also data storage and logical operations (コントローラーだけでなく，データの蓄積，論理演算にも利用可能)

1.3. Organization of the book

To concentrate our attention on classical control theory(古典制御理論に注意を集中)

1. Classical control theory provides a convenient way to understand stability, which is the most important problem in feedback control systems.
2. Classical control theory can be used successfully to design some multi-output feedback control systems.
3. Classical control theory, as a subset of modern control theory, is universally regarded as a prerequisite to modern control theory. Examples from classical control theory are frequently used to explain the advanced techniques of modern control theory.
4. The inclusion of a reasonably comprehensive treatment of modern control theory here would have doubled the size of this book.

[1] For example, an airplane, a chemical process plant(例えば，飛行機，化学行程プラント)

[1] Approximation methods still remain important in the initial stages of a design and to verify the results of compter-based analysis.