GENERAL MODELS OF DYNAMICAL SYSTEMS

Ganti Prasada Rao
International Centre for Water and Energy Systems, Abu Dhabi, UAE

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Summary

This article outlines certain important properties of dynamic systems, which happen to be the basis of their classification and characterization. The distinction between dynamic and static or steady-state behavior is explained. Properties such as time variance and time invariance, linearity and non-linearity, lumped and distributed parameters, continuous and discrete-time action, stability and instability etc. are discussed.

1. Mathematical Models

The mathematical equations used to describe the behavior of a system, based either on physical considerations or on measured phenomena, represent the mathematical model of the system. Mathematical models of dynamical systems are usually in the form of differential or difference equations together with algebraic or logical equations. Differential equations describe the system behavior in continuous time, whereas difference equations model dynamical systems in discrete time. The particular form depends on the actual nature of the system. Some important kinds of systems are schematically shown in Figure 1. There exist general approaches to modeling dynamical systems (see Elements of Control Systems)
Usually, mathematical models describe the input-output relations, which are useful in
the analysis or synthesis of a control system as well as in the simulation studies. The
simulation of a system may be made in analog, digital or hybrid computers to enable us
to understand the performance of the system under different situations, while runs on
actual systems may either be not feasible or may happen to be very expensive or risky to
perform. System modeling, simulation and identification methods are useful in
developing the knowledge that is prerequisite to control (see Mathematical Models).

Figure 1. Several aspects of description of the properties of control systems

2. Dynamic and Static Behavior of Systems

The dynamic behavior or the time behavior of a system is exhibited by the system
output $x_o(t)$ for a specified input function $x_i(t)$. This relationship between the input and
output variables is generally expressed in terms of an operator $T$, i.e., for every real $x_i(t)$,
there exists a real $x_o(t)$ such that

$$x_o(t) = T[x_i(t)].$$ (1)

Consider the response $x_o(t)$ of a system for a ‘step input’, an input that is switched from
zero to a unit value at $t=0$, as shown in Figure 2. Here $x_o(t)$ describes the time variation
from the initial state at $t \leq 0$ to a steady final state $x_o(\infty)$. Varying the input step height
\[ x_{i,s} = \text{constant}, \text{and noting the corresponding } x_{0,s} = x_0(\infty), \text{the static characteristic } x_{0,s} = f(x_{i,s}) \text{ that describes the steady state behavior of the system in a given region of operation, is obtained as shown in Figure 3.} \]

![Figure 2. Dynamic behavior of a system](image)

![Figure 3. System behavior: (a) dynamic (b) static or steady-state](image)

**Bibliography**


**Biographical Sketch**

Ganti Prasada Rao was born in Seethanagaram, Andhra Pradesh, India, on August 25, 1942. He studied at the College of Engineering, Kakinada and received the B.E. degree in Electrical Engineering from Andhra University, Waltair, India in 1963, with first class and high honours. He received the M.Tech. (Control Systems Engineering) and Ph.D. degrees in Electrical Engineering in 1965 and 1970 respectively, both from the Indian Institute of Technology (IIT), Kharagpur, India. From July 1969 to October 1971, he was with the Department of Electrical Engineering, PSG College of Technology, Coimbatore, India as an Assistant Professor. In October 1971, he joined the Department of Electrical Engineering, IIT Kharagpur as an Assistant Professor and was a Professor there from May 1978 to June 1997. From May 1978 to August 1980, he was the Chairman of the Curriculum Development Cell.
(Electrical Engineering) established by the Government of India at IIT Kharagpur. From October 1975 to July 1976, he was with the Control Systems Centre, University of Manchester Institute of Science and Technology (UMIST), Manchester, England, as a Commonwealth Postdoctoral Research Fellow. During October 1981- November 1983, May-June 1985 and May-June 1991, he visited the Lehrstuhl fuer Elektrische Steuerung und Regelung, Ruhr-Universitaet Bochum, Germany as a Research Fellow of the Alexander von Humboldt Foundation. Since June 1992 he is on a visit to Abu Dhabi as Scientific Advisor to the Directorate of Power and Desalination Plants, Water and Electricity Department, Government of Abu Dhabi and the International Foundation for Water Science and Technology where he worked in the field of desalination plant control. He is presently a member of the UNESCO-EOLSS Joint Committee.


He has received several academic awards including the IIT Kharagpur Silver Jubilee Research Award 1985, The Systems Society of India Award 1989, International Desalination Association Best Paper Award 1995 and Honorary Professorship of the East China University of Science and Technology, Shanghai. The International Foundation for Water Science and Technology has established the ‘Systems and Information Laboratory’ in the Electrical Engineering Department at the Indian Institute of Technology, Kharagpur, in his honor. He is listed in several biographic publications. Professor Rao is a Life Fellow of The Institution of Engineers (India), Fellow of The Institution of Electronics and Telecommunication Engineers (India), Fellow of IEEE (USA) and a Fellow of the Indian National Academy of Engineering.