화학공학의 역사
(로켓과 공정제어)

충남대 화공과
김 인호

Modern control theory by two approaches

- First, a short history of automatic control theory is provided.
- Then, we describe the philosophies of classical and modern control theory.
- Feedback control is the basic mechanism by which systems, whether mechanical, electrical, or biological, maintain their equilibrium or homeostasis.

Feedback control

- Feedback control may be defined as the use of difference signals, determined by comparing the actual values of system variables to their desired values, as a means of controlling a system.
- An everyday example of a feedback control system is an automobile speed control, which uses the difference between the actual and the desired speed to vary the fuel flow rate.
- Since the system output is used to regulate its input, such a device is said to be a closed-loop control system.

Feedback control history

- Feedback control progress is closely tied to the practical problems to be solved during any phase of human history.

1. The preoccupation of the Greeks and Arabs with keeping accurate track of time. This represents a period from about 300 BC to about 1200 AD.
2. The Industrial Revolution in Europe. The Industrial Revolution is generally agreed to have started in the third quarter of the eighteenth century's.
3. The beginning of mass communication and the First and Second World Wars. This represents a period from about 1910 to 1945.
4. The beginning of the space/computer age in 1957.

Flyball governor

- In 1788 Watt completed the design of the centrifugal flyball governor for regulating the speed of the rotary steam engine.
- This device employed two pivoted rotating flyballs which were flung outward by centrifugal force.
- As the speed of rotation increased, the flyweights swung further out and up, operating a steam flow throttling valve which slowed the engine down. Thus, a constant speed was achieved automatically.

Mathematical control theory

- In the mid 1800's mathematics was first used to analyze the stability of feedback control systems. Since mathematics is the formal language of automatic control theory
- In 1840, the British Astronomer, G.B. Airy, developed a feedback device for pointing a telescope.
- Airy discovered that by improper design of the feedback control loop, wild oscillations were introduced into the system.
- He was the first to discuss the instability of closed-loop systems, and the first to use differential equations in their analysis [Airy 1840].

Stability theory

- J.C. Maxwell analyzed the stability of Watt's flyball governor [Maxwell 1868]. His technique was to linearize the differential equations of motion to find the characteristic equation of the system.
- The work of A.M. Lyapunov was seminal in control theory. He studied the stability of nonlinear differential equations using a generalized notion of energy in 1892 [Lyapunov 1893].

The Bell Telephone System

- The mathematical analysis of control systems had been carried out using differential equations in the time domain.
- At Bell Telephone Laboratories during the 1920's and 1930's, the frequency domain approaches developed by P.-S. de Laplace (1749-1827), J. Fourier (1768-1830), A.L. Cauchy (1789-1857), and others were explored and used in communication systems.

The Bell Telephone System

- Regeneration Theory for the design of stable amplifiers was developed by H. Nyquist [1932]. He derived his Nyquist stability criterion based on the polar plot of a complex function.
- H.W. Bode in 1938 used the magnitude and phase frequency response plots of a complex function [Bode 1940]. He investigated closed-loop stability using the notions of gain and phase margin.

Ship and gun control

- N. Minorsky [1922] introduced his three-term controller for the steering of ships, thereby becoming the first to use the proportional-integral-derivative (PID) controller.
- "Theory of Servomechanisms" by H.L. Hazen [1934]
- The use of mathematical control theory in such problems was initiated. Hazen coined the word servomechanisms, which implies a master/slave relationship in systems.

Classical theory of control

- Using design approaches based on the transfer function, the block diagram, and frequency-domain methods, there was great success in controls design.
- In 1947, N.B. Nichols developed his Nichols Chart for the design of feedback systems.
- With the M.I.T. work, the theory of linear servomechanisms was firmly established.

The Space/Computer Age and Modern Control

- With the advent of the space age, controls design in the United States turned away from the frequency-domain techniques of classical control theory and back to the differential equation techniques of the late 1800's in the time domain.
- It is not possible to design control systems for advanced nonlinear multivariable systems, such as those arising in aerospace applications, using the assumption of linearity and treating the single-input/single-output transmission pairs one at a time.

Sputnik shock

- The launch of Sputnik engendered tremendous activity in the United States in automatic controls design.
- A return was needed to the time-domain techniques of the "primitive" period of control theory, which were based on differential equations.
- The work of Lagrange and Hamilton makes it straightforward to write nonlinear equations of motion for many dynamical systems. Thus, a control theory was needed that could deal with such nonlinear differential equations.
- It is quite remarkable that in almost exactly 1960, major developments occurred independently on several fronts in the theory of communication and control.

The development of digital computers

- In about 1830 C. Babbage introduced modern computer principles, including memory, program control, and branching capabilities.
- In 1948, J. von Neumann directed the construction of the IAS stored-program computer at Princeton.
- In 1950, Sperry Rand built the first commercial data processing machine, the UNIVAC I. Soon after, IBM marketed the 701 computer.
- In 1960 a major advance occurred- the second generation of computers was introduced which used solid-state technology.
- By 1965, Digital Equipment Corporation was building the PDP-8, and the minicomputer industry began.
- In 1969 W. Hoff invented the microprocessor.

Digital control

- Digital computers are needed for two purposes in modern controls.
- First, they are required to solve the matrix design equations that yield the control law. This is accomplished off-line during the design process.
- Second, since the optimal control laws and filters are generally time-varying, they are needed to implement modern control and filtering schemes on actual systems.
- With the advent of the microprocessor in 1969 a new area developed. Control systems that are implemented on digital computers must be formulated in discrete time. Therefore, the growth of digital control theory was natural at this time.
- By 1970, with the work of K. Astrom [1970] and others, the importance of digital controls in process applications was firmly established.

The Union of Modern and Classical Control

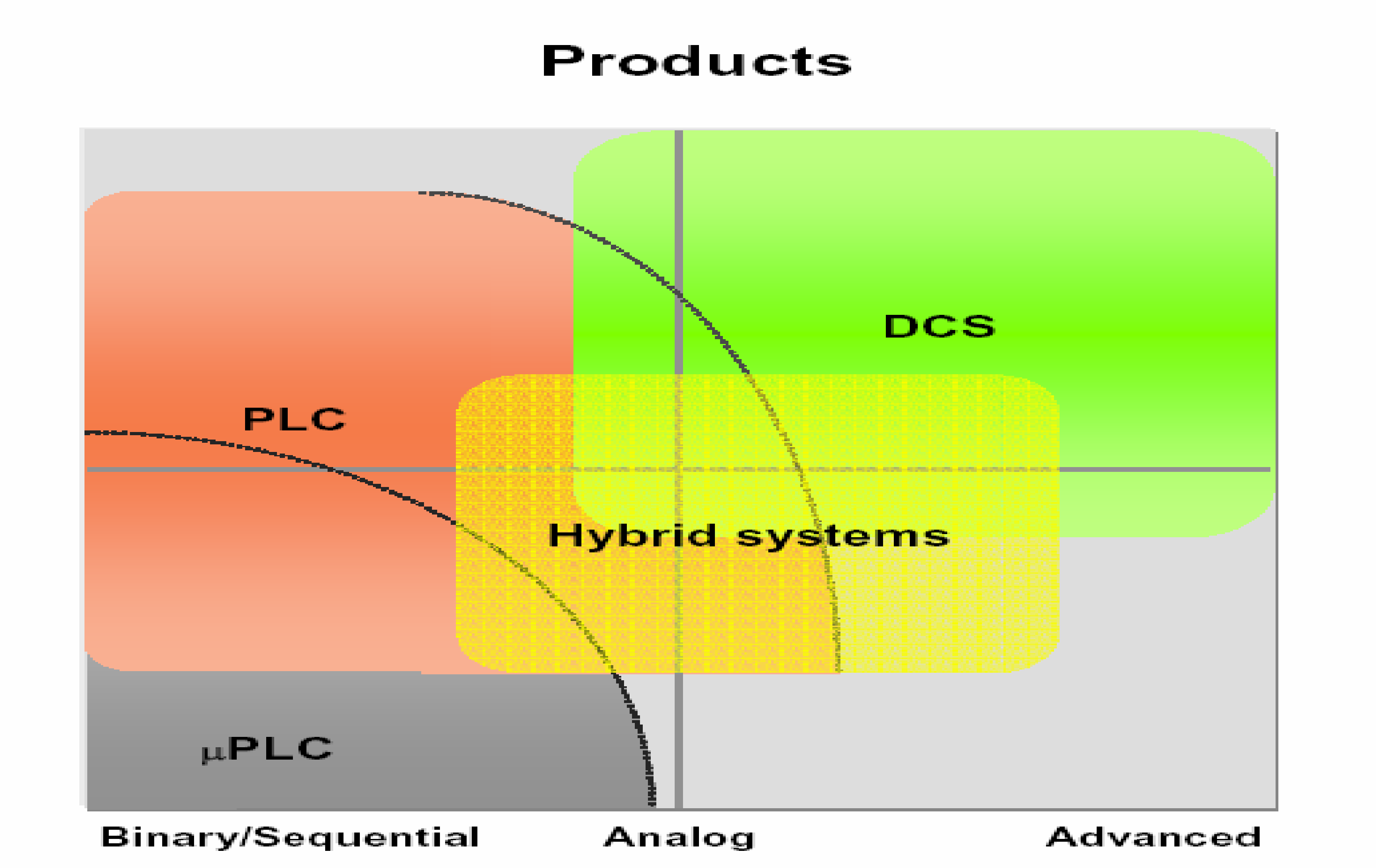
- With the publication of the first textbooks in the 1960's, modern control theory established itself as a paradigm for automatic controls design in the U.S.
- In the 1970's, especially in Great Britain, there was a great deal of activity by H.H. Rosenbrock [1974], and others to extend classical frequency-domain techniques and the root locus to multivariable systems.

Process control

- The development of nuclear reactors during the 1950's was a major motivation for exploring industrial process control and instrumentation. This work has its roots in the control of chemical plants during the 1940's.

- Process Control is the study of automatic control principles applied to chemical processes. It applies principles of mathematics and engineering science to the regulation of the dynamic operation of process systems.

Control systems



Programmable logic controller

- PLC History
  - Early 1900 – electrification!
  - Rolling mills, paper mills, car manufacturing
  - Contactors - Relays – Electronic relays with sequences etc – Programmable devices – PLC´s
  - Early 1970´s - Microprocessor based PLC´s
  - Simple MMC´s (Man Machine Communications)
  - Limited Information Management Capabilities

Distributed control system

- DCS History
  - Early 1900 – oil flow, temperatures etc
  - Oil industry, pulp mills, (power plants)
  - Manual loops - Mechanical controllers - Pneumatic controls - Electronic controllers – Single Loop Controllers - DCS´s
  - Early 1970´s - Microprocessor based DCS´s
  - More advanced MMC´s
  - Somewhat more advanced Information Management Capabilities