## Section 1.2: Computer Technology

The using and development of digital computers have had significant impact on computer control. With ideas of using digital computers in control systems emerging from the 1950s, development in computer control had achieved significant process by the end of the 20th century. The prosperous fifty years of development in computer control can be mainly split into six periods, with the pioneering period starting at about 1955, the direct-digital-control period and minicomputer period in the 1960s, and the development in the microcomputer period, the general use of digital control, and distributed control taking the lead in the following decades respectively.

The pioneering period started when the industry saw digital computers as a potential tool for automation and the universities regarding it as a new research field. But the slow, expensive, and unreliable computer systems were very discouraging to users. To overcome the unreliability, set-point control was mainly used, with interrupt features added to execute urgent tasks. Lower computer costs, less processing time, and the flexibility in computer-controlled systems characterized the direct-digital-control period. Knowledge on process control and the number of computer control applications skyrocketed. However, the difficulty in performing unconventional control strategies was the main drawback. In the minicomputer period, progress in integrated-circuit technology gave life to the term minicomputers, a term used for computers that were smaller, faster, more reliable and cheaper. During this period, digital computer control was sized into smaller units to be more available for smaller projects.

Throughout the last three decades of the 20th century, prices for microprocessors dropped significantly. This led to the fact that practically all controllers are now computer based and the possibility of building a system containing several microcomputers to perform parallel multitasking. As in general use of digital control, performance on controllers and relay logic in industrial automation systems also received large improvements from the uprising of microcomputers. Nowadays, monitoring and controlling processes as well as achieving real-time exchange of data has become the ultimate use of computer control systems. In the future, development in computer process control will be based on process knowledge, measurement technology, computer technology, and control theories.

## Section 1.4: Inherently Sampled Systems

Periodic systems can be simplified by using sampled-data models, which gives them the other name, sampled-data systems. Sampled-data systems can be categorized by defining how sampling is done, namely sampling due to the measurement system and sampling due to pulsed operation. The former covers topics such as radar, analytical instruments, economic systems, and magnetic flow meters, while the latter includes thyristor control, biological systems, internal combustion machines, and particle accelerators.

## Section 1.5: How Theory Developed

Theories for sampled systems are mainly extensions of ideas for continuous-time systems. Since computer-controlled systems process discrete time variables, Nyquist pioneered a way to recover a signal from discrete values only. The importance of the sampling theorem comes when understanding the phenomena occurring in discrete-time systems. With the development of difference equations, which appears as a version of differential equations for discrete time systems, many properties could be understood by analyzing the difference equations. Closely related to sampled data analysis, numerical analysis is based on optimizing several terms of difference equations.

To describe new systems such as radar systems, research on transform theories for discrete-time systems progressed. First came the z-transform, followed by discrete Laplace transform for pulse-controlled systems. A major drawback of z transform is that it only tells what happened to the system at the sampling instant, neglecting the hidden oscillations in between. Linvill, in 1951, proposed another approach that viewed sampling as an amplitude modulation which effectively described intersample behavior. Delayed z-transform, also known as modified z-transform, was another approach that could describe intersample behavior. By the end of the 1950s, z-transform had matured and provided as good tools for analysis on sampled systems.

In the following decade, the notions of reachability and observability on systems arose. The development of the state-space approach to control theory solved this problem. By assuming the disturbances were random processes, optimal control problem for linear systems could be solved and led to the development of stochastic control theory. This work is known as the Linear Quadratic Gaussian theory. In the beginning of the 1970s, the algebraic character of the problems established the algebraic system theory, resulting in better understanding of the linear system theory.

The dropping price on microprocessors made algorithms cost-effective, providing the possibility of obtaining adaptive control algorithms in controllers. The appearance of commercial adaptive regulators also made it possible to achieve automatic tuning. Based on the above and aid from system identification, the development of digital control gradually formed.

## Section 1.6: Notes and References

By reading original papers, one gets to understand more about the knowledge in a specific field. As in the case of computer control, several research topics that distributed across the second half of the 20th century structured the basis that formed computer control. Some of the research topics were based on sampling, such as sampled-data theories, sampling theorem, and sampled-data systems. These research topics were mostly contributed by researchers in England, the United States, and the Soviet Union. Other topics included formulating control problems, system identification, and distributed computer systems. Control theories such as optimal and stochastic control and adaptive control are also a main contribution to the field of computer control.

References

[1: Åström & Wittenmark 2011]

Karl Johan Åström and Björn Wittenmark, “Computer-Controlled Systems: Theory and Design,” 3rd ed., Massachusetts, Courier Corporation, 2011, pp. 2-29