ECEN 605

LINEAR SYSTEMS

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Course information

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Assignments and Tests

- All homeworks are required.
- There will be three tests.
- Homework grade 60%
- Test grade 40%

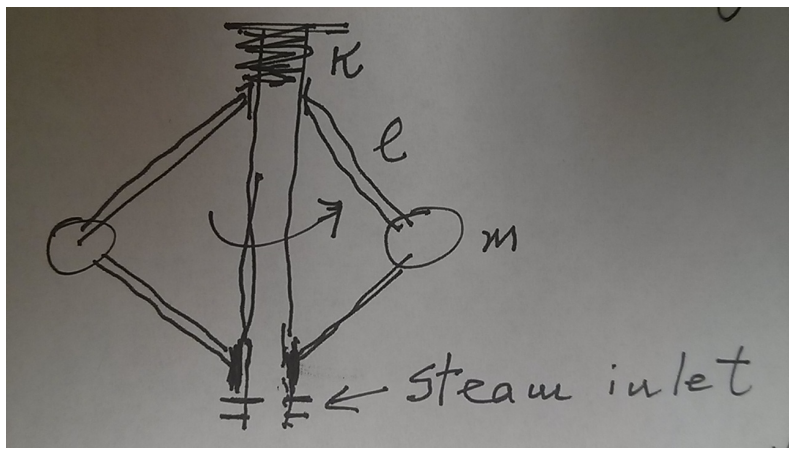
Syllabus

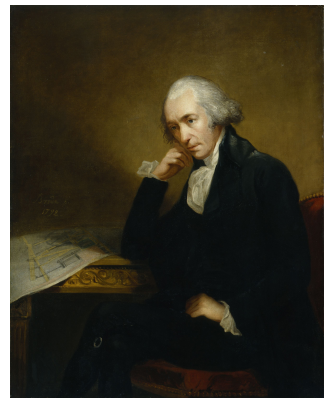
1. Single input Single output systems
   - 1.1 Laplace Transform Review
   - 1.2 Linear Algebra Review
   - 1.3 Static and Dynamic Models
   - 1.4 State Variable and Transfer Function Models
   - 1.5 Stability and Stabilization
   - 1.6 Tracking, disturbance rejection and pole placement
   - 1.7 Classical control, Nyquist criterion and stability margins
2. Multivariable Systems
   - 2.1 Realization Theory
   - 2.2 Stated Feedback
   - 2.3 Observers
3. Linear Quadratic Optimal Control
   - 3.1 H_2 optimal control (LQR)
   - 3.2 H_∞ optimal control

A Short History of Control

1764

Watt's Governor for speed control of steam locomotives by negative feedback





James Watt
(1736 $\sim$ 1819)

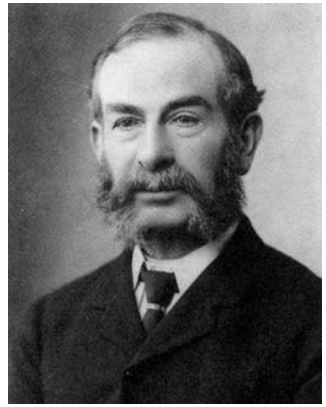
1860

"On Governors" Maxwell developed a third order dynamic model. The characteristic roots were functions of (m, l, k) the design parameters. Oscillations corresponded to the prosimity of the characteristic roots to the $j\omega$ axis, as in "resonant" systems such as oscillators and bridges.

James Clerk Maxwell (1831∼1879)

1877

Routh criterion developed a method of counting root distribution of a polynomial with respect to the left and right half planes, without calculating the roots. Wins Adams Prize.



Edward John Routh
(1831∼1907)

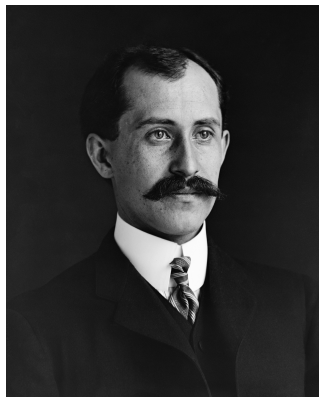
1892

Lyapunov's Ph.D thesis develops criteria for the stability analysis of nonlinear systems.

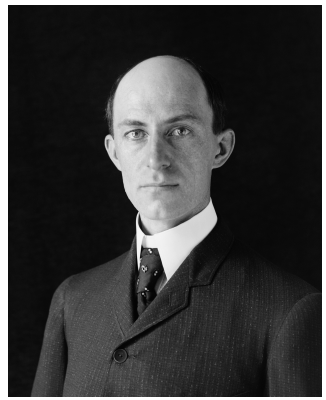
Aleksandr Mikhailovich Lyapunov (1857∼1918)

1900∼1910

Wright Brother's flight research



Orville Wright (1871∼1948)



Wilbur Wright (1867∼1912)

1926

H. S. Black invents the feedback amplifier to provide accurate gains using unreliable components. These forms the basis of operational amplifiers and integrated circuits, fundamental to modern control, communication and signal (audio and video) processing systems. Black's Amplifier.

Harold Stephen Black (April 14, 1898 $\sim$ December 11, 1983)

1932

H. Nyquist develops a criterion to predict closed loop system stability based on measurements of the open loop frequency response of the system. Nyquist Criterion.

Harry Nyquist (February 7, 1889 $\sim$ April 4, 1976)

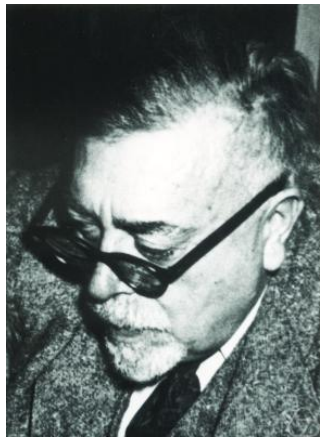
1942 $\sim$ 45

H. W. Bode, building on the work of Nyquist, develops frequency response methods for designing control and feedback systems using logarithmic plots.

Hendrik Wade Bode (December 24, 1905 $\sim$ June 21, 1982)

$1940 \sim 50$

Servomechanism theory is researched and developed to a high level to meed the demands of World War II. MIT Radiation Labs, Norbert Wiener, H.W. Bode, W.R. Evans N. Nichols and others drive the effort.



Norbert Wiener (November 26, 1894 $\sim$ March 18, 1964)

1950 $\sim$ 60

Richard Bellman invents dynamic programming. L.S. Pontryagin develops the Maximum Principle.

Richard E. Bellman (August 26, 1920 $\sim$ March 19, 1984)

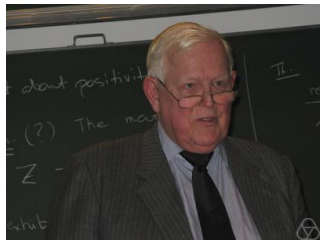
Lev Pontryagin (September 3, 1908 $\sim$ May 3, 1988)

1957 $\sim$

Soviet Union launches the Sputnik.

1960 $\sim$

Kalman introduces quadratic optimization and state space methods. Space race is on. U.S. decides to send a man to the moon. Design of automatic pilots (autopilots.) Man lands on Moon July 24th 1969.



Rudolf Emil Kalman (May 19, 1930 $\sim$)

1960's

Tremendous progress in computer technology drives control and communication.

1970's

Researchers find that the Linear Quadratic Optimal Systems can have very small stability margins.

1980's

Research on Robust Control intensifies. H_∞ optimal control is introduced. Proofs of the stability of Adaptive Control Systems are presented. Kharitonov's Theorem and its extensions are developed.

1990's

UAV's, disk drives, GPS, Machine Learning Control, Robotics. Fragility of Optimal, High Order Systems.

2000's

Genomic Signal Processing, Cancer treatment as a Control Problem, Gene manipulation and control, Nano systems and control, Atomic Force Microscopy. Developments in PID Control.

2010's

Control of UAV's, drones and driverless cars. Control of Smart Grids. Robotic surgery. Systems Biology. Flocking, Formation, Consensus Control of Multi Agent Systems.