

M4 : The Behavioral Approach to Modeling and Control

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The aim of this series of lectures is to provide a comprehensive introduction of the behavioral approach to systems theory. A mathematical model is viewed as a subset. For dynamical systems, this subset consists of the time-trajectories the model allows. This subset is called the behavior of the system. This vantage point respects the nature of first principles models, and allows for maximal flexibility in using various system representations in applications. In this setting, interconnection is viewed as variable sharing, and control is viewed as interconnecting a plant to a controller. By avoiding an a priori partition of the system variables in inputs and outputs, this approach keeps the development much closer to the physics of systems.

The following main topics with some relevant keywords will be covered.

1. Models and Behaviors.

Mathematical models; dynamical systems; latent variables; examples; linear time-invariant differential systems; kernel representations; the elimination theorem; input/output representations.

2. Controllability and Observability.

Controllability as trajectory transfer; test for controllability; image representations; observability; primeness tests; observers.

3. Control in a Behavioral Setting

Control as interconnection; examples; regular and superregular controllers; feedback; the hidden and the uncontrolled behavior; conditions for implementability; stabilization.

4. Rational Symbols

Differential equations defined by rational symbols; subrings of the field of rational functions; parametrization of the set of stabilizing controllers; the gap as a measure of the distance between systems; norm preserving representations; model reduction.

5. The Most Powerful Unfalsified Model

Falsification and more powerful models; existence of the most powerful unfalsified model; the role of the Hankel matrix; recursive computation of a basis of annihilators; comparison with ARMAX modeling.

6. Modeling by Tearing, Zooming, and Linking

Modularity; the interconnection architecture; graphs with leaves; examples from circuits, mechanics, and hydraulics; relations with signal flow graphs and with bond graphs; terminals versus ports.

7. Dissipative Systems

The supply rate and the storage function; available storage and required supply; quadratic differential forms; conditions for positivity of the storage functions; Lyapunov functions for high order differential equations.



Jan C. Willems was born in Bruges in Flanders, Belgium. He studied engineering at the University of Ghent. After his graduation in 1963, he went to the US, and obtained the M.Sc. degree from the University of Rhode Island in 1965, and the Ph.D. degree from the Massachusetts Institute of Technology in 1968, both in electrical engineering.

He was an assistant professor in the Department of electrical engineering at MIT from 1968 to 1973, with a one year leave of absence at Cambridge University. From 1973, he was Professor of Systems and Control in the Mathematics

department of the University of Groningen. In 2003, Professor Willems became emeritus professor from the University of Groningen. Presently he is guest professor at the department of electrical engineering, with the research group on Signals, Identification, System Theory and Automation (SISTA), at the K.U. Leuven, Belgium. Professor Willems is a life fellow of the IEEE. He served terms as chairperson of the European Union Control Association and of the Dutch Mathematical Society (Wiskundig Genootschap). He has been on the editorial board of a number of journals, in particular, as managing editor of the SIAM Journal of Control and Optimization as and founding and managing editor of Systems & Control Letters. In 1998, he received the IEEE Control Systems award.

More details, a list publications and lectures, and a description of his research interest may be found at

<http://homes.esat.kuleuven.be/~jwillems/index.html>