IUTAM working party WP2 – Dynamical Systems and Mechatronics

MEMBERS: Professors Felix Chernousko, Moscow,
Friedrich Pfeiffer, Munich (Chair),
Robin Sharp,London,
Masayoshi Tomizuka, Berkeley

Definition

The synergetic integration of physical (mechanical) systems, decision making and information technologies in design, manufacture and operation of plants, structures, machines or processes with respect to system dynamics and control and with the goal of better system performance.

Characterisation

Physical (mechanical) systems of concern are mainly assemblies of subsystems with measurable and sometimes predictable behavioural properties, the latter through models and their correct mathematical representation. The process of modelling physical, or more specifically mechanical systems definitely is more an art than a science and follows aspects like engineering experience and intuition. This process is the main key for a success in a sense, that the model should represent reality as good as possible.

Mechanical and mathematical models for components and subsystems are hugely developed, but experimental verification is often very poor or non-existent. This is already true for components, it is the more true for large systems. Therefore we obviously still have a need for new requirements. Multibody system analysis software has made many analyses of large systems relatively straightforward but distributed flexibility, variable boundaries and time-varying features continue to pose problems. Analytical solutions, even in an approximate sense, are only possible for smaller or for linear systems giving some insight in parameter dependencies, but, in general, they do not extend to systems of both high order and of difficult and generally nonlinear forms. Modelling becomes worse for continuum systems governed by partial differential equations, and in spite of many nice mathematical concepts their combination with control and information technologies is still extremely difficult, both, theoretically and practically. The problems with respect to parameter dependencies, to sensitivities concerning initial conditions and to steady state numeric include many open questions.

On the other hand, numerical solutions are generally achievable and, as computers become more powerful, they become less costly to obtain. Modelling and simulation are at the core of contemporary studies for systems analysis. Capability in analysis naturally leads to (virtual systems) optimisation and later to optimal system synthesis. Evaluating large systems including a physical (mechanical) subsystem of large order and including further on large control and decision making subsystems usually requires today co-simulations of very large computer codes with all the problems of numerical stability and integration algorithms. First order models of even complex systems may be quite easily obtained and solved but they may not be useful practically. At least from an engineering point of view a strict correspondence of theory and practice is mandatory. Very detailed and accurate models are likely to be needed for practical purposes, which require a deep physical understanding of the system under consideration.

The most relevant information technology is from control theory, which is very highly developed. Much contemporary work involves the application of advanced topics in control, optimal control, nonlinear control with constraints, robust control, predictive control and the like to systems of ever increasing complexity. A recurring theme is "how should one deal with such increasing levels of complexity?". The control theory itself does not answer to this question. Mechatronics addresses issues important in implementing control laws provided by the theory on actual systems by utilizing digital signal processors, sensors and actuation devices. In trying to optimise systems, studies must address not only control issues but also issues of reliability, fault tolerance and failure modes. This indicates an aspect of system design, which will be with us for ever. In this sense, mechatronics is nothing but the best practice for designing systems.

Mixed hardware and software systems are of interest, for example in the case of “hardware-in-the-loop” tests. In such cases, devices with more complex and uncertain behaviour are included in system studies as they are, with interfacing to the remaining “virtual” system. An important sub-class of uncertain systems concerns the human operator. Man-machine interaction problems demand special treatments of the human component.

Research areas with a good future

Dynamics and control of multibody systems including distributed flexibilities, additional bilateral and unilateral constraints of non-smooth character.

Non-linear vibration advances and applications.

Mathematical advances with application to high order nonlinear systems, including also systems of practical significance.

Advancement of techniques for modelling difficult system features like impacts, energy dissipation in structures and assemblies through friction and hysteresis, hydraulic flows, high frequency effects (waves, rate dependent material properties) etc.

New methods for control of mechanical and mechatronic systems

Simultaneous optimisation of system design and control.

Advancements in parameter identification and state estimation.

Methods for dealing with ever increasing system complexity of integrated mechatronical systems including physics (mechanics), control and information technologies.

Methods for faster, more accurate, more reliable numerical solution of describing equations, parameter optimisation, large system synthesis etc. This includes also methods for capitalising on problem features like multi-time-scale dynamics.

Man-machine interaction problems – car driving, bike riding, aircraft piloting, pilot induced oscillations, pilot – helicopter interaction failures.

Application studies in robotics, space exploration, transportation, micro-systems especially medical and computational, mechatronic “smart” structures, power transmission, machine optimisation and synthesis.

Garching, April 6, 2005
Friedrich Pfeiffer (collecting the contributions of all members)