Control Systems MSc projects: 2004-05 with George Weiss

**Stability of linear periodic control systems**
**Project #: GW1**

The aim of this project is to investigate Nyquist-type stability criteria for feedback systems where the open loop system is linear, SISO and periodic. We employ a recently derived Fourier-series type decomposition of the open loop system in terms of an infinite sequence of stable transfer functions and modulator blocks. Assuming that only a small number of terms in the infinite series are significant (ie, assuming that the Fourier type series is in fact a finite sum) we try to derive stability criteria in terms of these finitely many transfer functions. Simulation experiments will be used to verify the validity of theoretical results or of guesses.

**Control of an inverted pendulum-like mechanical system**
**Project #: GW2**

The mechanical system under consideration consists of an arm rotating around a vertical axis to which a rod is attached.
A second rod is attached at the other end of the first rod.
The first (longer) rod can rotate in a vertical plane around the joint which links it to the arm. The smaller rod is attached to it, and it can also rotate around a joint. Thus, the system has three degrees of freedom. The arm can be rotated by a small DC motor (acting through a gear). The angle of the arm and the angle of the long rod are measured by encoders which transmit optically pulses to an interface which counts these pulses. The angles are then available as digital signals. All this setup is available in the control and signal processing lab on level 3. The aim of the project is to improve and explain the algorithm to stabilise the long rod in a "standing" position (like an inverted pendulum). The small rod acts as a disturbance on this pendulum, since its position cannot be measured.
The system is connected to a data aquisition system (from National Instruments), so that it can be controlled via SIMULINK (i.e., the controller is built in SIMULINK and the block diagram with all the signals can be monitored on a PC). This project will be useful to provide students in future years with an interesting control experiment. The whole set-up is currently working, and the task is to eliminate some problems, improve the algorithms and write a nice lab book for future students.
The work will be in cooperation with a fourth year student doing his final project.

**Passive systems and their control using the internal model principle**
**Project #: GW3**

This project is for a mathematically minded student who wants to get aquainted with a new and active area of systems modeling and control theory.

Passive systems are dynamical systems in which the energy has been defined as a function of the state and an energy balance equation holds, saying that the rate of change of the energy equals the (inner) product of the input signal and the output signal. If, in the energy balance equation, we replace the inequality by equality (ie, no energy is lost) then the system is called impedance conservative. For example, any electric circuit built of passive elements, without sources, is a passive system (the power is the product of the voltages and currents at the ports of the circuit). If there are no resistors, then the circuit is a conservative system.

If the equations of a system are obtained from modeling or identification, it is not easy to establish if the system is passive (in particular, conservative) with respect to some suitable defined energy function (this must not be the energy known from physics, as in the case of the electric circuit).
It is an interesting problem to establish the existence of such an energy function. It is also interesting to explore the structure of passive (in particular, conservative) systems.
If a big systems is composed of components which are passive (conservative), then (under certain conditions) the interconnected system inherits this property. In particular, if one system is a plant and the

other is an internal model, both passive, then we get a robust controller that rejects certain disturbances (such as sinusoidal signals).

Such systems are interesting from the control point of view, and this is exploited in "passivity based control". The student taking this project would have to read relevant publications (mostly recent) in this area, try to summarize them in a creative way and try out various ideas in simulations and numerical computations.

**Numerical implementation of a control algorithm for power converters and induction generators**
**Project #: GW4**

With an ambitious program for developing wind powered generators, and other environmentally friendly energy sources, there is an increasing interest in DC to AC converters. The control of such a converter is a serious control theoretic challenge. Various control algorithms have been developed, including in this department. This project would examine implementation issues of the control algorithms using a high quality digital signal processor. The student undertaking this would work in a team together with Research Assistants and Associates who are building such converters in the department. The student could concentrate on one of the following, depending on his/her interests:

* Control theoretic aspects (understanding and comparing variouscontrol algorithms),
* Numerical implementation issues (such as the effects of time discretization and the sampling rate),
* Programming the DSP, striving for its optimal usage (given the limited time available between two sampling moments).
* The use of DC/AC converters to control induction generators (as done in wind-driven power generators).

**Connecting a wind-driven power generator to the utility grid**
**Project #: GW5**

In the near future, the proportion of UK power generated from wind should increase dramatically to about 10%. Huge wind farms are being planned/constructed. Companies such as Vestas and GE are examining various architectures for such wind-farms. For
example: should the generator be synchronous or induction, if the latter then should it be single or doubly fed? Should the generator be connected directly to the utility grid, or should it happen through a DC link? There is a large literature on various options. We also have contacts with GE who want to get us involved in their investigations. An important aspect is the behaviour of the different architectures under fault conditions. This project involves modeling the various options, to understand their advantages and shortcomings. (A presentation on the state of the art in this field will be given in February by a researcher from GE.)