# 52. IWK

Internationales Wissenschaftliches Kolloquium

International Scientific Colloquium

**PROCCEDINGS** | **10 - 13 September 2007**

## FACULTY OF COMPUTER SCIENCE AND AUTOMATION

## COMPUTER SCIENCE MEETS AUTOMATION

## VOLUME II

Session 6 - Environmental Systems: Management and Optimisation

Session 7 - New Methods and Technologies for Medicine and Biology

Session 8 - Embedded System Design and Application

Session 9 - Image Processing, Image Analysis and Computer Vision

Session 10 - Mobile Communications

Session 11 - Education in Computer Science and Automation

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## Preface

Dear Participants,

Confronted with the ever-increasing complexity of technical processes and the growing demands on their efficiency, security and flexibility, the scientific world needs to establish new methods of engineering design and new methods of systems operation. The factors likely to affect the design of the smart systems of the future will doubtless include the following:

- As computational costs decrease, it will be possible to apply more complex algorithms, even in real time. These algorithms will take into account system nonlinearities or provide online optimisation of the system's performance.
- New fields of application will be addressed. Interest is now being expressed, beyond that in "classical" technical systems and processes, in environmental systems or medical and bioengineering applications.
- The boundaries between software and hardware design are being eroded. New design methods will include co-design of software and hardware and even of sensor and actuator components.
- Automation will not only replace human operators but will assist, support and supervise humans so that their work is safe and even more effective.
- Networked systems or swarms will be crucial, requiring improvement of the communication within them and study of how their behaviour can be made globally consistent.
- The issues of security and safety, not only during the operation of systems but also in the course of their design, will continue to increase in importance.

The title "Computer Science meets Automation", borne by the 52nd International Scientific Colloquium (IWK) at the Technische Universität Ilmenau, Germany, expresses the desire of scientists and engineers to rise to these challenges, cooperating closely on innovative methods in the two disciplines of computer science and automation.

The IWK has a long tradition going back as far as 1953. In the years before 1989, a major function of the colloquium was to bring together scientists from both sides of the Iron Curtain. Naturally, bonds were also deepened between the countries from the East. Today, the objective of the colloquium is still to bring researchers together. They come from the eastern and western member states of the European Union, and, indeed, from all over the world. All who wish to share their ideas on the points where "Computer Science meets Automation" are addressed by this colloquium at the Technische Universität Ilmenau.

All the University's Faculties have joined forces to ensure that nothing is left out. Control engineering, information science, cybernetics, communication technology and systems engineering – for all of these and their applications (ranging from biological systems to heavy engineering), the issues are being covered.

Together with all the organizers I should like to thank you for your contributions to the conference, ensuring, as they do, a most interesting colloquium programme of an interdisciplinary nature.
I am looking forward to an inspiring colloquium. It promises to be a fine platform for you to present your research, to address new concepts and to meet colleagues in Ilmenau.

Professor Peter Scharff
Rector, TU Ilmenau

Professor Christoph Ament
Head of Organisation

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52nd Internationales Wissenschaftliches Kolloquium
Technische Universität Ilmenau
10 – 13 September 2007

C. Noack / S. Schwintek / C. Ament

# Design of a modular mechanical demonstration system for control engineering lectures

## 1.Introduction

In lectures concerning Control Engineering methods for controller design and parameter estimation are only shown by simple theoretical examples at the blackboard or in seminars. For Students it is only possible to make practical experience at labs, separated from the lectures.

Experimental Demonstration direct at the lectures would have the advantage, to make the context of the presented methods easier to understand and better to remember, without substitution of the practical experience gained at labs.

The idea was to design a small and light demonstration system, which can be easily transported and installed at the lecture theatre with the ability of modularity to make several different experimental demonstrations directly at the lecture.

It would be possible for the students to take part in the whole controller design process from modelling over controller design up to optimisation, So the student really can see several different practical effects like nonlinearities and noise which doesn't exist in basic theoretical examples and the consequences they have to the linear controller design.

Using methods of automated Code generation and Hardware in the loop testing, it is possible to generate Controllers easily direct in software and let them operate at a practical experiment.

## 2.Mechanical construction

The Requirements to the mechanical construction were formulated to apply the chosen structure, which can be used for teaching purpose. With change of location special requirements occur. First the structure must be easy to carry and second the sensors must be insensitive to the changing environmental influences. A notebook is used to visualize the measurements of the sensors and control the system. Due to the limited time before lectures the system must be build up fast. In a list of requirements more details concerning function, structure and economic items are formulated. The most important ones are the length of the distance should be about 300mm and a mass of 250g should be moved with a velocity of 0.3m/s. Due to that, requirements for the actuator element were fixed.

The procedure of construction corresponded to the procedure of Krause [4]. After commitment of requirements in a sketch and list of requirements a sketch of function was developed by dividing the whole systems function in part functions. Next a combination table was made out of technical principles which fulfil the part functions. Combining the part function principles, different solutions for the whole system will be applied. For example the actuator can be an electric, pneumatic, hydraulic or mechanic drive. Every principle has its advantages and disadvantages. The solutions are compared under consideration of the requirements. After this you will have the best solution for your special task. Now the parts can be constructed or chosen.

The actuator is a DC-motor which fits most to the requirements. The linear characteristic curve makes the control simple. The motor needs only an H-bridge to generate turns in both directions. More advantages are the low costs, the electrical connection and the low weight. With the calculated force needed to move the sledge the moment can be calculated. The moment and the revolution allow choosing a fitting motor by searching in datasheets.

To change a rotation in translation a suitable gearing is needed. The best solution of this task is a synchronous belt. A synchronous belt drive provides a linear transmission function, need less space than other gearings and is very quiet. The disadvantage of a synchronous belt drive is the preload force which increases the loadings of the convolution and other elements like the bearings.

The guidance of the sledge is realized by a slide linear guiding. These types of linear guides allow high loadings, are very quiet, cheap and smaller than comparable roller linear guides. With the given mass and velocity of the sledge the slide linear guiding was chosen in a diagram. Slide bearing were also chosen to support the convolutions because of the same advantages that the linear guidance has.

The set up of the sledge serves following tasks. It builds up the connection with the synchronous belt by clamping. Further elements that serve the experimental set up are fixed on the sledge. To change the experimental set up fast it is necessary to construct

a modular platform. The set up for the experiments position control and inverse pendulum consists of two slide bearings that support the convolution. On this convolution the pendulum and the angle sensors are attached.
The position of the sledge is measured by a potentiometer with 10 revolutions. This potentiometer is attached on the driving convolution by a compensating coupling. Potentiometers provide an analogue signal which is useful because the binary inputs of the PC-card are limited. Using an incremental sensor for this task will lead to a complex interpretation circuit which will increase the costs. Other linear measurement systems are often more expensive and need more space. To measure the angles routing plastic potentiometers are used. These potentiometers have besides the general advantages of a potentiometer a smaller work moment, which means that the influence of friction is reduced.
The construction provides a good attempt. The dimensions of the bridge crane fits with the requirement of 500x300x300 $mm^3$. The abidance of the dimensions also requested a large amount of parts to be produced because for the bought parts not many components were found. The motor provides the needed power and has reserves for different experimental set ups. Because of the use of slide bearings the system runs quiet but the higher friction can cause higher control complexity. The synchronous belt is the optimal solution for this linear drive and the used preload apparatus is very simple, but not the best solution. The chosen sensors fulfil the requirements on the resolution and they are also cheap. The requirement of low weight isn't really fulfilled. To achieve that the frame elements must be thinner and should be connected by brackets

## 3.Electrical construction and data aquisition

In order to control the built system a data acquisition device and a current amplifier were necessary. For data acquisition a 6024-E DAQ card from national Instruments was chosen, because it meets the demands of usability at an notebook with an PCMCIA Interface, high resolution with 16 Bit analog input resolution and 12 Bit analog output resolution and also an fast sample time and also the operatebility with Matlab/Simulink, where the software design was done. The analog output signal was simply amplified by a current amplifier designed and constructed by the electronical workshop of the Institute for Control Engineering at Technische Universität Ilmenau.

## 4.Linear drive theoretical modelling

For lecture purposes a simple demonstration example was chosen to show the basic principles of controller design on real systems. In order to implement a controller a theoretical modelling was required. A state space design method was used in this case to get a proportional state space controller. In the beginning a theoretical analysis of the DC motor and the Linear Drives after [1] and [2] was made to get models for these Systems. After that these Models were combined to get a model of a DC motor driven linear drive. The resulting model is:

$$\begin{bmatrix} \dot{s} \\ \ddot{s} \\ \dot{i} \end{bmatrix} = \begin{bmatrix} 0 & 1 & 0 \\ 0 & -\frac{K_R}{J_{Ges}} & \frac{K_T r}{J_{Ges} n} \\ 0 & -\frac{K_M n}{Lr} & -\frac{R}{L} \end{bmatrix} \begin{bmatrix} s \\ \dot{s} \\ i \end{bmatrix} + \begin{bmatrix} 0 \\ 0 \\ \frac{1}{L} \end{bmatrix} u$$

With $s$-position, $\dot{s}$-velocity, $\ddot{s}$-acceleration, $i$-current, $R$-Resistance, $L$-inductance, $K_R$-friction factor, $K_M$-revolution constant, $K_T$-torque constant, $n$-transmission factor, $r$-radii, $J_{Ges}$-moment of inertia. For this state space model a state controller by pole placement after [3] was designed. The Model with controller was implemented and simulations, presented at Figure 1, were performed.

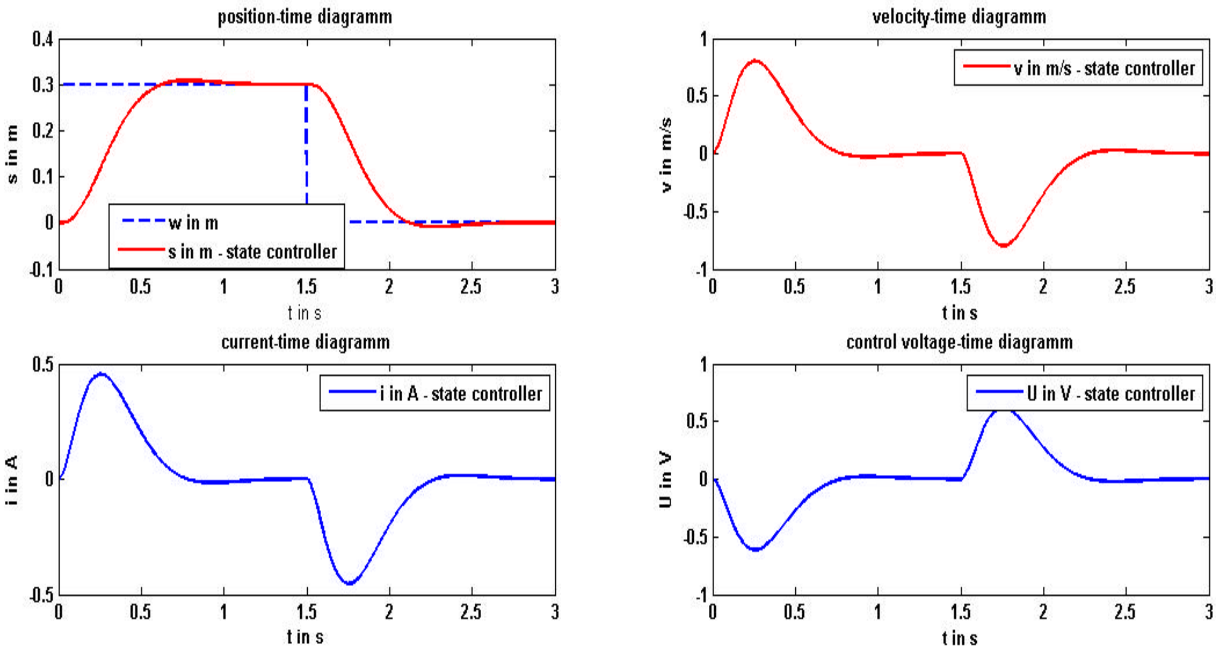


**Figure 1:States and controlling voltage over time**

## 4.Practical implementation

The Practical implementation was done on another bigger system, because the modular demonstration system was currently at construction. The parameters of this system were measured and estimated by heuristical methods. The system was implemented with these parameters, a controller was designed, implemented and tested.

## 5. Practical implementation of the linear drive

The model for the linear drive was implemented and simulated. The results of the Simulation and the measured values for estimation are shown at Figure 2.

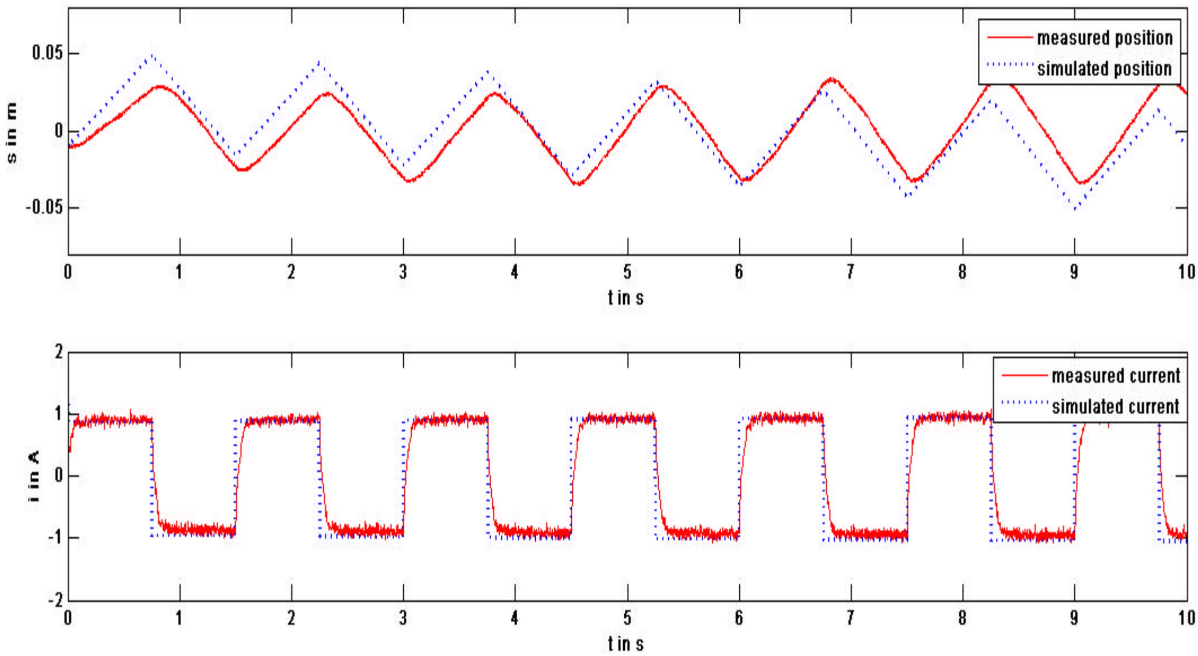


**Figure 2: Measured and simulated position and current over time**

The simulated position shown at Figure 2 is slightly different from the measured that can be a reason of nonlinearities in the real system. You can also see a small drift of the measured position, which is a result of different parameters for the different directions of the linear drive. After this simulation a linear state controller was designed, the system was implemented into a Simulink model working with the Real Time Workshop to control the real system via the 6024-E DAQ card and was tested, which is shown at Figure 4.

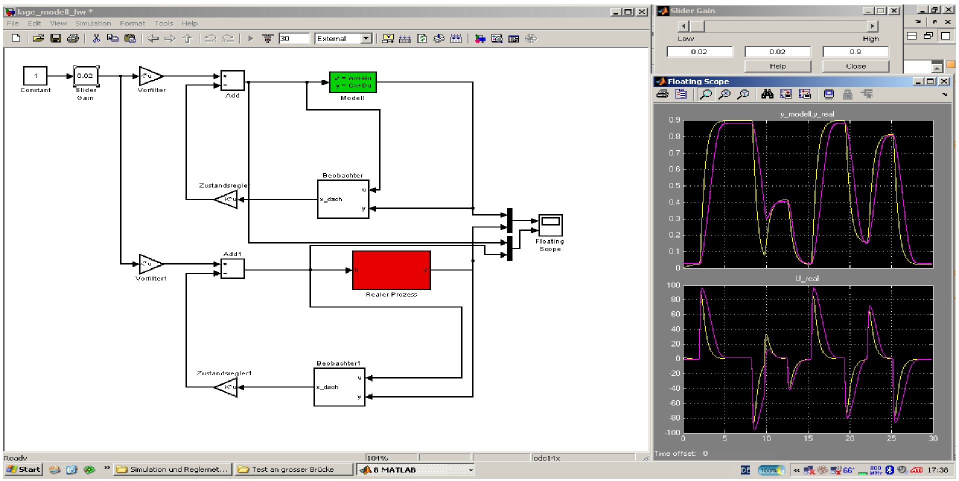

**Figure 4: graphical user interface to control the demonstration system**

Here you can see the developed graphical user interface to control the demonstration system. In the scope on the right hand side you can see the measured values and the simulated ones there also is a sliding controller to drive the linear drive to a specific position. On the left hand side the simulation model (top) and the interface to the DAQ card (bottom) is shown.

## 6. Future prospects

After all it was shown how to construct and control a small frame modular system for lectures with capabilities of easy useability and installability for the teaching lecturer. It is also possible to create more difficult demonstrations by adding other mechanical components like springs or dampers and also to control them in advanced lectures. In [1] also 3 other demonstrations (loading bridge, inverted pendulum and parameter estimation at the linear drive) are shown.


**References:**

[1]Noack, Christoph: Konzeption und Aufbau eines modularen Didaktik Systems zur Regelung mechatronischer Systeme, Studienarbeit, 2007 TU-Ilmenau, Fachgebiet Systemanalyse

[2]Luntze, Jan: Vorlesungsunterlagen Rechnergestützte Systemanalyse, 2006, Ruhr Universität Bochum

[3]Föllinger, Otto: Regelungstechnik, 1994 Hüthig Verlag Heidelberg

[4]Krause, Werner: Konstruktionselemente der Feinmechanik, 1993 ,Hanser Fachbuchverlag München



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