HCI Graduate Education at Delft University of Technology

Charles van der Mast
Media & Knowledge Engineering, MMI group
Delft University of Technology
Mekelweg 4, 2628 CD Delft, The Netherlands
c.a.p.g.vandermast@ewi.tudelft.nl

ABSTRACT
In this paper we describe the position of HCI graduate education at Delft University of Technology. Graduate education is not organised independently of the master programmes. The contents and structure of the bachelor and master programmes HCI are described. The position of the graduate programme to the master programme is described. Examples of courses and thesis projects are given. At delft, HCI graduate education is not yet recognised as an independent goal and discipline. At best it is integrated in the programme Media and Knowledge Engineering and the related research groups.

Author Keywords
HCI, academic programmes, educational approach.

ACM Classification Keywords
H5.m. Information interfaces and presentation (e.g., HCI): Miscellaneous.

INTRODUCTION
Delft University of Technology has a long tradition of research and education on HCI and its local predecessors supervisory control and human factors. Since the early seventies research from the discipline of mechanical engineering started concerning operational control aspects of automation in industrial installations, including decision making, alarm management and predictive displays. Later direct control was added (e.g. prosthetics). Finally, at the graduate programs of industrial design engineering and computer science courses were given on human factors, educational software (as a pioneering application for HCI) and designing highly interactive systems. Courses on HCI were given as elective and specialisation courses in the regular master programmes computer science and industrial design engineering. In 2001 the integrated 5-year master programmes (bachelor included in a 5-year master programme) at Delft were broken into a standardized 3-year bachelor and a 2-year master's degree programme. This was happening at all universities in the Netherlands in order to harmonise educational programmes and degrees within Europe. Each year the student has to earn 60 ECTS credit points (European Credit Transfer System). Delft has special arrangements with other European universities within the IDEA league (**I**mperial College of Science and Technology London; **D**elft University of Technology; **E**idgenössische Technische Hochschule, Zürich; Rheinisch-Westfälische Technische Hochschule, **A**achen). Students with degrees from the partners are accepted easily.

In 2000 the director of the computer science program started a market study with about 50 non-university research labs and companies in the Netherlands about the needs for a master degree in an HCI-oriented programme. The results were positive and the advice was given to choose a strong basis in computer science. The name became Media and Knowledge Engineering (MKE).

One year later the master programme Design for Interaction (DfI) was started at Industrial Design Engineering aiming at analysing and conceptualising of human-product interactions in relation to the physical, cultural, technological, and societal contexts in which the product is used. The program builds on the traditional disciplines of ergonomics and aesthetics, and to the emerging area of experience design.

The PhD programs at all departments/disciplines of Delft are less structured. The PhD students are working on externally funded research projects within research groups. The thesis should be finished within a period of four years and the (light) educational program is specified individually in most groups. New students who are missing knowledge and experiences at arrival have to follow a set of basic or elective courses of the master programme MKE. Most PhD students have to participate in teaching courses related to their research topic. We know that teaching it is the best way to learn subject material.

Although research and teaching on HCI is done over decades organisational embedding of HCI as a topic is of recent years. In 2001 the department Mediamatics was founded at the faculty of Electrical Engineering Technical Mathematics and Computer Science. By this department the MKE programme is given. The participating research groups are Information and Communication Theory,

Computer Graphics and Man-Machine Interaction (MMI). MMI is the home of HCI. It is founded in May 2004 focussing on HCI, Artificial Intelligence, Knowledge Engineering and Multi-Modal Interaction.
In the next sections an overview is given of the goals and the educational approach of the bachelor and master programmes in which HCI is an essential component. We will conclude with a discussion of the perspective we see for our programmes including graduate education in HCI.

BACHELOR PROGRAMME CS

Since 2001 the bachelor programme computer science is given in an extra MKE variant, providing two team projects per year on a typical HCI-related subject. The goal of this variant and the projects is to teach important HCI topics theoretically and practically during all years besides the fundamental computer science courses. A second goal is to stimulate the students to develop their creative skills in an interdisciplinary way by team work. More than one third of the computer science bachelor students (total number of CS students 200-100 a year; decreasing last years) chose for the MKE variant during last years. The projects are (each 6 ECTS): Introduction tot HCI by developing a multimedia service on a cell phone, Introduction to artificial intelligence by developing a set of intelligent agents for monitoring, filtering and presenting specific information from pages from the internet, Inroduction to image processing by developing a program for recognition of sign language by hands to control a standard application on a PC, Computer graphics by developing a computer game, Introduction multimodal interaction by developing an application that supports a multimodal dialogue (image, keyboard, speech in and out) with a human, and Multimedia by developing a multimedia cd-rom for an external client. All projects are done simultaneously with a more traditional course on the fundamentals related to the topic of the project. At the end of the bachelor programme the student should do a small (5 ECTS, about 10 weeks) bachelor project in a team of 2-3 students for an external client. The goal is to experience the integration of the content of most courses including techniques for project management and software engineering. Emphasis of the project should be on development, not on analysis. Students with the bachelor degree may go to work in companies, but most continue studying for a master degree at the same department or at other universities in the Netherlands or Europe.

MASTER DEGREE PROGRAMME MKE

The goal of the MSc programme in MKE is “to educate students to become professional media and knowledge engineers who have knowledge, capabilities and attitudes needed to take part, alone or in cooperation with other specialists, in solving problems in society, science, or in private or public institutions. The graduated master of Science has the ability to continually update her/his professional knowledge, and to indepently acquire knowledge from related fields within his discipline”, see at http://msc.its.tudelft.nl/mke/. The individual study programme should be made and approved at the end of the first semester after finishing the three core courses (18 ECTS) representing the subject matter of the three research groups Information and Communication Theory, Computer Graphics and Man-Machine Interaction. In the individual study programme Specialisation course have to be specified for 21-27 ECTS. The free electives (not to be chosen from the list of specialisation courses) have to sum up to 15-21 ECTS. The goal is to broaden the knowledge. Some special minors of 21 ECTS are available. Minors are carefully selected sets of courses in other disciplines, e.g. pattern recognition, economics and psychology. The minors are given by other research groups at Delft or other universities. The second year of the programme MKE is composed of a research assignment of 15 ECTS and a thesis project of 45 ECTS. The thesis project should be carried out in a local or external research group. The goal of the master programme is explicitly to prepare the student to participate in state-of-the-art research. Part of the graduates will candidate for a PhD position.

Currently more than 80 % of the students who finish the bachelor project continue with the master programme MKE or the master programme CS. Some are switching internally and have to do some extra courses in the so called pre-master programme. This is a programme for students who are missing an acceptable amount of knowledge before admission to the programme. Students with bachelor degrees from other universities have to do an individual pre-master programme with the same conditions. In this pre-master, also several courses in mathematics are available for external students.

COURSE DESCRIPTIONS MASTER MKE

Core Courses:

IN4151 3D computer graphics and VR (6ECTS)
Introduction 3D computer Graphics. Colour and reflection. Colour models, reflection, BRDF. Ray tracing. Optical effects, intersection algorithms. Monte-Carlo ray tracing. Diffuse inter-reflection, sampling, aliasing, stochastic ray tracing. Radiosity. Energy exchange, global illumination, meshing. Image-based rendering. Light-field rendering, acquisition. Acceleration techniques. Spatial subdivision, parallel rendering, hardware implementations. Virtual reality. Display systems, tracking, interaction. Imposter techniques. Environment mapping, geometric simplification, occlusion culling. Animation. Key frame, model-driven animation. Articulated structure animation, collision detection.

IN4010 AI techniques (6ECTS)
Knowledge representation, search, reasoning, problem solving, heuristics for intelligent behaviour. Course is based on the object-oriented "Actor/Agent Paradigm".

ET4269 Multimedia compression (6 ECTS)
In today's communication, storage and DSP technology, signals of various kinds (speech, audio, image, video,

graphics) are usually represented in digital format. Besides the many advantages that digital representation formats bring the most significant drawback is the huge transmission or storage capacity required for digitized analog signals. For that reason, it is important to find digital representation formats that are more efficient, either via data compression or data reduction techniques. This course concentrates on the efficient and compact representation of audio-visual information in a digital format. To this end a number of relevant compression and reduction techniques are described. Applications are found in telecommunications, multimedia, digital TV, HDTV, as well as in signal and image processing. The course covers the following subjects: Characteristic properties of audio-visual signals. Data compression and reduction. Information theoretic limitations. Scalar quantization. (Differential) Pulse Code Modulation. Vector quantization. Subband coding and filter bank design. Transfoom Coding: KLT, DWHT, DFT, DCT. JPEG-DCT still picture coding standard. Motion estimation. Motion-compensated DPCM/DCT based codec.

Specialisation courses (4-6 ECTS):

IN4003 Geometric modelling

Summary Methods and techniques from solid modelling, surface modelling and feature modelling. The main topics are: spatial data structures, constructive solid geometry, boundary representations, model specification, model conversions, parametric curves and surfaces (Bézier, B-spline, NURBS), polygon and polyhedron meshes, parametric modelling, constraint-based modelling, design with features, feature recognition, feature conversion and collaborative modelling.

IN4008 Data visualisation

Theory and general principles of data visualization are discussed, and illustrated by practical examples from many application areas. Topics covered: models of the visualization process; basic 3D computer graphics; 2D graphs and charts; generation, representation and processing of data; colour and the use of colour; volume visualization and medical applications; visualization of vector fields and flows; feature extraction, and virtual reality. Guest lectures will be given on various topics.

IN4010TU Real time AI and automated speech recognition

Knowledge representation, search, reasoning, problem solving, heuristics for intelligent behaviour. Course is based on the object-oriented "Actor/Agent Paradigm".
Expert systems in technical environments

IN4015TU Neural networks

Data fitting with linear adaptive systems, pattern recognition, introduction to Artificial Neural Networks (ANNs), multilayer perceptions (MLPs), MLPs as classifiers, designing and training MLPs, function approximation with MLPs, competitive networks, recurrent networks, technical applications of ANNs.

IN4034 Design of highly interactive systems

This is an advanced course on theories, principles and guidelines, managing the design process, software tools, examples of highly interactive systems, e.g. virtual worlds, multimodal interfaces, mobile phones, video conferencing systems, knowledge management systems, websites, computer-based training, multimedia CD-ROMs, etc. In the lab a small highly interactive system should be designed and implemented for a specific user group, e.g. children, the elderly, handicapped people, second language speakers/immigrants.

IN4083 Usability engineering

There is not one unified theory of HCI. The HCI research field is rather broad and fragmentary. In an introductory HCI course, the (Bachelor) students learned some basic approaches and an introduction on the foundations with respect to human (in particular cognition), computer (components) and interaction (user interface, dialogue styles). For the Usability Engineering (UE) course, we choose to provide a coherent engineering approach to human-computer interaction, based on the book of Rosson & Carroll (2001). This way, the UE course will provide a general framework to extend and apply usability knowledge. Based on this framework, we will elaborate on current theories, methods and technologies for establishing advanced (intelligent) user interfaces and for interactions with complex information and communication systems. The selected journal papers focus on these theories, methods and technologies.

in4145 Educational software

The learning objectives of this course are for students to be able to understand and implement different types of educational software, to understand learning theories and how they apply to educational technology, and to understand the process of developing, installing and using educational technology in a variety of educational and training domains. Topic outline: Definition of educational software and its life cycle. Types of educational software. Ways of thinking about and modeling educational software development; including the levels why, what, how. Theories of learning. Developing and implementing Web Lectures (including a lab to develop a web lecture of 15 minutes). Educational software at Open Universities in UK and the Netherlands. Computer-based training in the military context. Computer-supported collaborative learning – theories and tools (using papers by Mark Guzdial, Georgia Institute of Technology). Cognitive Tutors (using papers by Anderson et al at Carnegie Mellon University). Educational software used by a commercial tele-education institute for the general public. Processes and structures of corporate e-learning. The Classroom 2000 Research Project – computers for capture and replay of

annotated live lectures. e-Learning for training in the business context.
Students have to study and summarize articles, videos and chapters on educational software. They have to give an in-class presentation on one subject and they have to do subject matter research and then create and publish a video web lecture.

ET4085 Advanced image processing
Image restoration (inverse filtering, Wiener filtering, geometric transformation), advanced morphological image processing and extension to grey-scale images, image segmentation (boundary detection, region-based segmentation, watersheds), representation and description of image objects, image features (structure tensor, local shape, Hough transform), camera calibration (intrinsic and extrinsic parameters, projection matrix), stereopsis (correspondence, epipolar geometry, essential and fundamental matrix), motion estimation (optical flow, feature-based techniques).

ET4157 Wavelets and filter banks
Multirate digital signal processing techniques have been practiced by engineers for more than two decades. This discipline finds applications in speech/audio and image compression, the digital audio industry, statistical and adaptive signal processing, digital communications, and in many other fields. It also fits naturally with certain classes of time-frequency representations such as the Gabor transform and the wavelet transform, which are useful in analysing the time-varying nature of signal spectra. During the course we discuss the fundamentals of multirate signal processing (decimation, interpolation, polyphase representations) and study multirate filter banks (alias cancelation, perfect reconstruction). Moreover, we will discuss the concept of time-frequency transforms and focus on Gabor and wavelet transforms.

ET4161 Information theory
This couse explains the basic ideas of information theory and the correspondances between the elements of this theory and certain natural concepts of importance in a wide number of fields, such as transmission, storage, authoring and protection of data. On the basis of simple concepts from probabiliby calculus, models are developed for a discrete information source and a discrete communication channel. Further, the theoretical basics for developing source coding algorithms is provided, as well as the basics of ptimal data transmission through a discrete communication channel.

ET4270 Statistical signal processing
Role of random signals, correlation and power spectral density in statistical signal processing; modeling, detection and estimation of parameters and signals in the presence of noise; linear filtering theory: Wiener and Kalman filters; adaptive noise cancelling; estimation of autocorrelation and power spectral density; applications in the area of signal processing and telecommunications.

ET4271 Cryptography
In the course attention will be paid to cryptographic Algorithms and mechanisms for security and privacy protection in information services and products. In the course the following issues will be considered: Confidentially, Data integrity, Authenticity, Digital signatures, Non-repudiation and Privacy.

IN4085 Pattern recognition
Recapitulation of Multi-dimensional statistics, data visualisation, density esimation, cluster analysis. Representation of real world objects by features, prototypes and dissimilarities. Training pattern classifiers by examples. Feature extraction. Bayes' rule. Classification by statistical discriminants, neural networks, decision trees or support vector machines. Statistical learning theory. One-class classifiers. Combined appraoches. EM algorithm. Partially supervised leaming. Evaluation procedures, cross validation. Overtraining, regularisation.

IN4144 Multimedia data management
Database technology is omnipresent in administrative applications, offering a balance between flexibility and efficiency. Flexibility is obtained by enforcing data independence, a strict separation between requests expressed in a declarative query language and the actual approach to computing the answer to the request. Changing the physical properties of the data, such as the storage scheme or its access structures, does not affect client programs. Efficiency is obtained through query optimization, in the translation from the original declarative query into the query plan expressed in terms of physical operators. The course starts with the basic ideas underlying relational database technology: data abstraction and data independence, query processing, query optimization. We study query processing strategies in more detail, with an emphasis on the role of access structures at the physical layer of the database management system (DBMS). The second part of the course explains the differences between data retrieval and information retrieval, giving a crash course into IR and multimedia search by content. Limitations of search by similarity are discussed, especially in high dimensionality. The final part of the course presents different design alternatives for integrated systems for data and information retrieval. Implications on DBMS architecture are the central focus.

Elective courses:
A list of tens of specific advanced courses on mathematics, computer engineering, computer science, business, and more is available. All are given by other research groups. During the master programme there are

also many possibilities to go abroad for foreign exchange, both for courses and fro the thesis project. One special exchange programme can be mentioned with College of Computing of Georgia Tech. Last years about 20 students from Delft did their thesis project on an HCI-related subject in Atlanta.

Examples of master thesis projects:

- Abstract Specification Techniques for User Interfaces.
- Knowledge Management for educational software development teams.
- The development of a graphical user interface for SNIPER_Lesions.
- Design and implementation of a website supporting the recruitment process.
- Design and evaluation of a website for TU Delft on mobile phones.
- Human-robot interaction.
- Fear of Flight Phobia Treatment with VR.
- Dynamic traffic routing using Ant-Based Control
- Human-AIBO interaction
- Virtual Observer, A tool for conducting behavioral observation in virtual environments.
- Enhancing classroom learning with web lectures.
- Interactive visualisation on the VR response workbench
- Visualisation for virtual colonoscopy
- User interface design for the virtual lighting console

WEB LECTURES

Since the fall semester 2004 we developed in collabortation with College of Computing at Georgia Tech an MMI Education Digital Library at http://yukon.twi.tudelft.nl. This collaboration will be continued in then future. In Spring 2005 we developed a series of web lectures for the course usability engineering given by guest lecturers from research projects on concrete topics including small assignments on the subject matter. As part of the course educational software students produced interesting web lectures on a tpoic of their choice. Currently students are producing web lectures on skills in using tools as Maya, Photoshop, Premiere, 3D Studio, Director, Flash.

PHD PROGRAMME

As discussed earlier the PhD programme in the HCI research groups is not structured with specific courses. For each student a specific program is made to follow some courses. Also workshops and special courses (1-2 times a year, one week) are arranged for all PhD students in HCI, mostly in collaboration with other universies in the Netherlands.

Examples of some recent PhD thesis projects

- Agent-based supervision of complex task environments in tele-care
- Adaptive interface support in process control
- Intelligent cockpit environment
- Groups of collaborating users and agents
- Facial action unit recognition from face video
- HCI and presence in virtual reality exposure therapy
- Virtual colonoscopy
- Visualisation of shoulder joint replacement surgery

CONCLUSION

In this overview of HCI education at Delft University of Technology we can conclude that graduate education in HCI is not yet well structured at this university.
The long tradition in the old engineering sciences at Delft introduces some conservatism to consider HCI as a “soft science” that is not yet fully accepted as an important component to deploy real interdisciplinary research. This means that graduate education in HCI has to develop next years into a stronger position. The board of the university decided that HCI should be stimulated, but implementation of new chairs, labs and programmes takes time. But HCI and HCI graduate education is becoming stronger at many departments but mostly around the Media and Knowledge Engineering programme. This is a slow development process, but probably a good one.

FIVE QUESTIONS

Here are my five questions that I would like to discuss.
1. How to design a balanced graduate programme with all hard and soft components needed to work on HCI.

2. How important is it to have more disciplines represented in the research teams of the school and hence in the teaching team.

3. How to remediate applicants with minor deficiencies in knowledge and skills.

4. How to accept smart applicants from very different cultural backgrounds who maybe cannot communicate very well on the complete domain of HCI (as being practised at your university; e.g. Chinese HCI students at Dutch university); how to cope cultural differences for the student himself. And, how important is it to train students to collaborate in multicultural teams.

5. Can web lectures be used to disseminate subject matter and skills in a cross-discipline direction.