MRes in Computer Graphics, Visualization and Virtual Environments

2007/2008

Computer Science
Swansea University

1. Summary of the Programme

1.1 Aim of the Programme

The digital economy is a high growth, hi-tech area which demands skilled employees who can take a lead role in developing the science and application of new technologies. Computer Graphics and its associated areas underlie many of the recent developments, whether it is from visualising a pre-operative scan of a patient, to engaging the public imagination by showing an animation of a new building development. The MRes in Computer Graphics, Visualisation and Virtual Environments provides an education in this highly active and relevant area.

The Department of Computer Science has a strong international reputation in several areas of visual computing, including *Volume Graphics and Visualization*, *Flow Visualization* and *Video Visualization*. In particular the links between the Department and the Digital Technium allows the scheme to expose students to an environment of high growth entrepreneurial businesses, innovation, the latest technology, academic research and industrial and academic partnerships within the digital economy. The overall aim of this programme is to give students the research background within a major area of the digital economy upon which they can build and innovate, and the transferable skills they need to exploit their efforts. Students will be destined for employment opportunities in further research in academia, hi-tech companies, the public sector, or will consider exploiting their research through company creation.

1.2 Length of the Programme

This is a one-year programme at the master level. It differs from the traditional MSc programme in the following respects:

- It has 70 taught credits (instead of 120 in MSc), and 110 credits on an individual project (instead of 60 in MSc).
- It starts the 110-credit project module from the beginning of the programme (in October 2007), and the project continues until the end of the programme (in September 2008). Hence, unlike MSc programmes, the taught credits are running in parallel with the project, and do not serve as the prerequisites for the project module.
- Every student is assigned a project supervisor/tutor from the beginning of the programme. The design of the project is normally formulated between the supervisor and student, taking in to account the research interests of both.

1.3 The Modules in the Programme

Compulsory (170 credits)

- CS_M07 Data Visualization (10 credits)
- CS_M27 Programming and Graphics APIs (20 credits),
- CS_M37 Research Method and Project Specification (10 credits)
- CS_M57 Project (110 credits)
- CS_M79: Interaction Technologies: Hardware and Devices (10 credits)
- CS_M97 State of the Art in Visual Computing (10 credits)

Optional (choose 10 credits out of 30):

- CS_M17 Volume Graphics (10 credits)

- CS_M49 Interaction Technologies: Labs and Field Work (10 credits)
- CS_M69 Interaction Technologies: Information Retrieval (10 credits)

See Section 2 for detailed module descriptions.

1.4 Management of the Programme

Original Programme Design:	Dr. Mark W. Jones, who led the original proposal of the programme
Programme coordinator:	Dr. Benjamin Mora
Programme admissions:	Dr. Benjamin Mora
Programme year head:	Dr. Benjamin Mora
Project coordinator:	Dr. Mark W. Jones
Director of teaching:	Dr. John Sharp (who has the overall responsibility of teaching organization)
Director of teaching quality:	Professor Faron Moller (responsible for teaching quality assurance)
Head of MRes/MPhil/PhD programmes:	Professor Faron Moller

2. Module Descriptions

CS_M07 Data Visualization

Credit Points: 10
Taught in: Semesters 1 and 2
Lecturer: Dr. Laramee
Assessment: 30% coursework, 30% presentation, 40% written examination (in May/June)

Synopsis:

Data Visualization is concerned with the automatic or semi-automatic generation of digital images that depict data in a meaningful way(s). It is a relatively new field of computer science that is rapidly evolving and expanding. It is also very application oriented, i.e., real tools are built in order to help scientists from other disciplines.

Syllabus:

Introductory topics include: purposes and goals of visualization, applications, challenges, the visualization pipeline, sources of data: data dimensionality, data types, and grid types.

Volume visualization topics include: slicing, surface vs. volume rendering, transfer functions, interpolation schemes, direct volume visualization, ray casting, shear-warp factorization, splatting, image order vs. object order algorithms, gradients filtering, interpolation, isosurfacing, marching cubes.

Flow visualization topics include: simulation, measured, and analytical data, steady and time-dependent (unsteady) flow, direct and indirect flow visualization, applications, hedge hog plots, vector glyphs, numerical integration schemes, streamlines, streamline

placement, geometric flow visualization techniques, line integral convolution (LIC), texture-based techniques, flow topology, critical points/singularities.

Information visualization topics include: abstract data, hierarchical data, tree maps, cone trees, focus and context techniques, hyperbolic trees graphs and graph layouts, multi-dimensional data, scatter plots, scatter plot matrices, icons, parallel coordinates, interaction techniques, linking and brushing.

Learning Outcomes:
Students will gain competence in the field of data visualization. They will understand the basic methods available for the computer-aided depiction of data from several inter-disciplinary and application oriented sources. They will also gain and understanding of the problems that have been solved as well as the challenges that remain.

Transferable Skills:
Comparative analysis, the ability to identify sources of data and the challenges when visualizing data as well as the challenges that scientists and practitioners from other disciplines face.

Reading:
W. Schroeder, K. Martin and B. Lorensen, *The Visualization Toolkit*, 3rd Ed, Kitware Inc, 2004.
C. D. Hansen and C. R. Johnson, *The Visualization Handbook*, Academic Press, 2004.
C. Ware, *Information Visualization: Perception for Design*, 2nd Ed, Morgan Kaufmann Publishers Inc, 2004.

CS_M17 Volume Graphics

Credit Points: 10
Taught in: Semesters 1 and 2
Lecturer: Professor Chen
Assessment: 40% coursework (extended abstract 20%, presentation 20%), 60% open-book written examination (in May/June)

Synopsis:

Volume Graphics is a newly-emerging sub-field of computer graphics. The aim of the module is to study a range of techniques for modelling, rendering and manipulating volumetric data types.

Syllabus:

Volumetric Data Types: Scalar fields, regular and irregular data types. Objects in volumetric data. Typical applications of volume graphics (including medical imaging and scientific visualisation).

Volume and Surface: Concepts of iso-surfaces. Surface extraction. Ambiguity problems and solutions, and acceleration techniques. Voxelisation and distance fields.

Direct Volume Rendering: Ray-casting algorithms. Forward projection algorithms. Acceleration techniques. Discrete ray tracing.

Constructive Volume Geometry: Concepts and models. Relationships with constructive solid geometry and implicit surfaces.

Advanced modelling and rendering: Frequency domain representations. High dimensional volumetric data. Image based rendering.

Volume Deformation: Distortion and morphing. Applications in forensic science.

Other Techniques: Volume graphics hardware. Volume-based animation.

Learning Outcomes:
Students will be aware of the theoretical foundations and applications of volume graphics, and gain an understanding of the main techniques for modelling, manipulating and rendering true 3D spatial representations. They will acquire skills in designing computer graphics algorithms.

Transferable Skills:
Problem solving. Information retrieval, ability to read critically, to précis and judge information, and ability to manage learning processes. Ability to evaluate and deploy new technologies. Oral presentation, and interactive discussions.

Course Texts:
M. Chen, "Volume Graphics", in A. Kent and J. G. Williams (eds), *Encyclopedia of Mocrocomputers*, Vol 26, 2000.
M. Chen, A. E. Kaufman and R Yagel (eds), *Volume Graphics*, Springer, 2000.

Reading:
ACM SIGGRAPH, *Course notes on Volume Visualisation: Principles and Practice*, 1996.
A collection of research papers (compiled by lecturers).

CS_M27 Programming and Graphics APIs

Credit Points: 20
Taught in: Semesters 1 and 2
Lecturer: Dr. Mora
Assessment: 100% coursework: primary study (12.5%), advanced study (12.5%), investigative study (25%), project proposal (10%), and project (40%).

Synopsis:

This module builds upon the materials presented in modules CS_217 and CS_307, and provides students with an opportunity to further their knowledge of computer graphics, and develop their hand-on skills in graphics programming. Whilst the module focuses on the OpenGL API as the main platform for the study, it also provides scope for students to explore other graphics environments. The assessment includes two small pieces of programming-based coursework, an investigative report, an oral presentation, and a small programming-based project in visual computing. The report and presentation are to be completed in a simulated research conference setting.

Syllabus:

Graphics Programming (Primary Study): 3D object modeling; geometrical transformation; simple texture mapping; 3D viewing and projection; illumination and shading; atmospheric effects; anti-aliasing.

Graphics Programming (Advance Study): display list; texture coordinates, multi-texturing; tessellators, quadrics, evaluators and NURBS; shadows.

Graphics Programming (Investigative Study): ray tracing (e.g., Pov-Ray); web-graphics (e.g., X3D and VRML); game engines and environments (e.g., Horde3D, Ogre3D, Irrlicht, Blender); similar API (e.g., Direct3D), major OpenGL extensions (e.g. OpenSceneGraph), GPU programming (e.g., Vertex Shader).

Investigative Study: Each student will undertake an independent investigation, involving problem specification, self-learning, solution identification, and result analysis. In particular, the student will compare the two approaches taken in the two programming-based assignments, write an investigative report in the form of a conference paper, and present the paper in a 25 minute oral presentation to an audience.

Graphics Programming (Small Project): Each student will make a proposal for the project, including objectives and marking scheme. Once this is agreed by the examiners of the module, and the student is required to complete the project, which will be assessed based on the agreed marking scheme. **Note:** This programming project can be related to the MRes thesis of the student concerned, and is usually designed to complement the MRes thesis (such as an implementation of a related algorithm in the literature). However, the project should not be part of the main objectives of the MRes thesis.

Learning Outcomes:
Students will acquire an understanding of computer graphics systems and development methodologies and hand-on experience of computer graphics programming. Their confidence and competence in system analysis and design, and fluency in using programming languages and tools will be improved. In addition, students will experience the software engineering process of a small visual computing project.

Transferable Skills:
Written communication and documentation, oral presentation and interactive discussions. Small project management and time management. Problem solving, and comparative analysis. Ability to manage learning processes.

Course Texts:
D. Hearn and M. P. Baker, *Computer Grapics with OpenGL*, 3rd Ed, Prentice Hall, 2003.
D. Shreiner, M. Woo, J. Meider and T. Davies. *OpenGL Programming Guide: The Official Guide to Learning OpenGL*, Version 2.1, 6th Ed, Addision Wesley, 2007.
D. Shreiner, *OpenGL Reference Manual: The Official Reference Document to OpenGL*, Version 2, 5th Ed, Addision Wesley, 2006.

CS_M37 Research Methodology and Project Specification

Credit Points: 10
Taught in: Semesters 1 and 2
Lecturer: Dr. Jones
Assessment: 100% coursework: report on literature review, project design and specification (40%); presenting a research paper (20 minutes) selected from the review (20%); write an extended abstract (2 pages) for a research paper (8 pages minimal) selected from the review (20%); small team work (20%).
Note: *Only available to those students studying for the MRes in Computer Graphics, Visualisation and Virtual Environments*

Synopsis:

This module will allow students to explore a particular topic in Computer Graphics to a great depth. Students will practise using various methods to acquire knowledge, will undertake the writing of a scientific survey paper, and will present their work to an audience of knowledgeable academics within the chosen area. Students will also receive advice on starting their own businesses, patents, IPR and innovation.

Syllabus:
Verbal communication, presentation skills, literature searches on a specific topic or set of topics in Computer Graphics, scientific writing, project development, managing research, innovation, patents and IPR, motivation.

Learning Outcomes:
Students will have:

- demonstrated detailed understanding of a topic or set of topics in Computer Graphics;
- the ability to review and critically assess the literature on a specific topic or set of topics in Computer Graphics that are at the current limits of theoretical or research understanding;
- the ability to analyse and present the results of a literature review both as a scientific report and as an oral presentation;
- a working knowledge of patents, IPR and innovation, and their usefulness for start-up businesses.

Transferable Skills:
Students will demonstrate an ability to:

- engage and present their own academic work to other professionals in their own field;
- study autonomously, and become fully aware of resources to aid the study, of research topics in Computer Graphics;
- manage their own research effectively (in terms of time, direction of study, sources of information and relevance to the topic).

Course Texts:
ACM Transaction on Graphics
ACM Transactions on Graphical Tools
Computer Graphics Forum
IEEE Computer Graphics and Applications
Computer Vision and Image Understanding
Other journals and conference proceedings (including SIGGRAPH, IEEE Visualisation, and Eurographics).

CS_M49 Interaction Technologies: Labs and Field Work

Credit Points: 10
Taught in: Semester 1
Lecturer: Professor Thimbleby
Assessment: 100% coursework

Synopsis:

This is a compulsory module for the Computer Science FIT Masters programmes, and provides laboratory skills and experience.

Syllabus:
Practical and laboratory skills; evaluation methods; managing experiments with users, including ethical considerations.

Learning Outcomes:
The ability to demonstrate thorough practical understanding of laboratory methods. The ability to build and evaluate interactive systems. The ability to write up and document experimental work.

Transferable Skills:
Practical skills in organising laboratory work, including planning and recording experiments, building and evaluating interactive systems.

Course Texts:
There are no adequate texts for this module at level M. Students will be directed to internet resources and research literature.

CS_M57 Computer Graphics, Visualisation and Virtual Environments: Project

Credit Points: 110
Taught in: Whole session
Coordinator: Dr. Jones
Assessment: 100% dissertation and viva
Note: *Only available to those students studying for the MRes in Computer Graphics, Visualisation and Virtual Environments*

Synopsis:

Within one month of the commencement of the course, the student will decide upon a topic of research in discussion with their supervisor. The student will evaluate current research and propose their own work programme based on the contribution they will make. Students will attend regular progress meetings with their supervisor, submit all deliverables, and submit their thesis in accordance with the University Regulations no later than **September 30th**.

Syllabus:
This module will give students experience of working independently and in depth on a Graphics related project. Following approval of a project plan, the student will carry out the research programme including the following: attendance at progress meetings with supervisor(s), submission of interim research progress report(s), preparation of a journal style paper or poster, presentation of their research at a departmental conference and submission of their thesis in accordance to University regulations.

Learning Outcomes:
Students will:

- have a great depth of knowledge in a complex and specialised area;
- be working at the current limits of theoretical or research understanding;
- be able to make confident decisions about research direction and the tools to use for the job;

- be able to synthesise ideas and create responses to problems that expand existing knowledge and is able to develop new approaches in new situations;
- be able to independently evaluate and accurately report on their own or others work.

Transferable Skills:
Autonomous use of resources; self-directed learning; can isolate, assess and resolve problems of all degrees of predictability, can engage in a full and professional manner with other researchers in the area.

Reading:
ACM Transaction on Graphics
ACM Transactions on Graphical Tools
Computer Graphics Forum
IEEE Computer Graphics and Applications
Computer Vision and Image Understanding
and other journals and conference proceedings (including SIGGRAPH and IEEE Visualisation).

CS_M69 Interaction Technologies: Information Retrieval

Credit Points: 10
Taught in: Semester 1
Lecturer: Dr. Buchanan
Assessment: 30% coursework, 70% written examination (January)

Synopsis:
This module provides a thorough understanding of how search engines work and how users interact with them. The course covers the retrieval of documents from the web and from text databases, and also searching for images and audio recordings.

Syllabus:
Fundamentals of information seeking and information retrieval: log rule and text indexation; compression of text indexes; indexation of images and audio materials; user factors in information retrieval

Learning Outcomes:
Thorough comprehension of multimedia retrieval systems and the mathematical basis of modern information retrieval algorithms. Deep understanding of and ability analyse the human-centred aspects of these systems. Ability to specify, design, build implement and test such a system.

Transferable Skills:
Ability to model complex human artifacts using mathematical formulae; ability to perform empirical tests of computer systems; ethnographic data-gathering.

Course texts:
R. Baeza-Yates and B. Ribeiro-Neto, *Modern Information Retrieval*, Addison-Wesley, 1999.
G. Marchionini, *Information Seeking in Electronic Environments*, Cambridge University Press, 1995.

I. Witten, A. Moffat and T. Bell, *Managing Gigabytes*, 2nd Ed, Morgan Kaufmann, 1999.

CS_M79: Interaction Technologies: Hardware and Devices

Credit Points: 10
Taught in: Semester 1
Lecturer: Dr. Eslambolchilar
Assessment: 30% coursework, 70% written examination (January)

Synopsis:

Future interaction technologies rely on developments in hardware, and being able to interface the hardware and software. Students are expected to achieve substantial hands-on practical experience of the 'cutting edge' and issues in the field.

Syllabus:

Input devices, output devices. Drivers. Hardware protocols, eg, USB, phidgets etc. Software protocols, eg, MVC.

Non-standard devices, such as haptic, multiple mice, 3D displays, special purpose sensors.

Learning Outcomes:

Thorough knowledge of hardware and i/o devices. Ability to build interactive devices and program drivers. Knowledge of non-standard devices, such as haptic devices and phidgets etc.

Transferable Skills:

Practical skills in building complex systems, both hardware and software, and debugging hardware/software interfaces.

Reading:

Mobile HCI and CHI conferences papers relevant to handheld devices, ubiquitous computing and mobile computing.

D. Kodicek, *Mathematics and Physics for programmers*, Charles River Media, 2005.

Python, Online materials to learn Python for programming on handheld devices, http://docs.python.org/tut/.

CS_M97 State of the Art in Visual Computing

Credit Points: 10
Taught in: Semester 1
Lecturer: Professor Chen
Assessment: 50% coursework (small survey 30% and presentation 20%), 50% open-book written examination (January)

Synopsis:

This module is based on seminars, self-studies, and group discussions. The aim of the module is to develop a broad understanding and appreciation of the development of technologies in visual computing. Students will have the opportunities to engage visual computing professionals, and discuss their research. They will follow their own study plan within an

advanced topic area, and present their own précis of the topic. At the same time, they will acquire new knowledge from group discussions and other students' presentations.

Syllabus:

Each student is required to choose two topic areas, and will lead the literature collection and discussions on these two topics. The topics are typically chosen from the latest research in computer graphics, visualisation, virtual environments, geometric processing, multimedia, image and video processing, computer vision, and major applications of visual computing.

For the short survey and presentation, each student will normally focus on one topic area. The presentation is typically scheduled in December, and the deadline for the survey will be in January (prior to the examination).

Students are required to attend all relevant seminars including departmental seminars, purposely scheduled seminars and other students' presentations. In addition, all students are required to take part in scheduled group discussions, and lead the discussions on their chosen topics.

The collection of all these topics will form the broad scope of the studies of the particular class concerned, and on which the open-book examination will be set.

Learning Outcomes:

The students will:

- be conversant in many of the most recent graphical techniques;
- acquire broad knowledge of various areas of visual computing, and a good understanding of the technical developments in one particular topic area;
- develop confidence in appraising and comparing research in different aspects of the subject.

Transferable Skills:

Information retrieval, ability to read critically, to précis and judge information, and ability to manage learning processes. Ability to evaluate and deploy new technologies. Oral presentation, and interactive discussions.

Course Texts:

ACM SIGGRAPH Course Notes and Presentation Slides
Eurographics State-of-the Art Reports
Eurographics Tutorial Notes and Presentation Slides
IEEE Visualization Tutorial Notes and Presentation Slides
Relevant papers in journals and conferences, such as ACM Transaction on Graphics, IEEE Transactions on Visualization and Computer Graphics, Computer Graphics Forum, IEEE Computer Graphics and Applications.