Master of Science
Graphics, Multimedia and Virtual Reality

Courses description

Advanced graphics programming techniques

The course presents methods for complex 3D scenes rendering using GPU advanced programming techniques. Optimization of the rendering pipeline as well as simulation of natural effects are studied during the lectures and laboratory classes. The main current technologies for developing complex and efficient graphical applications are described in the course and used for practical assignments: OpenGL, GLSL/Cg and OpenCL. The course deals with lighting methods, textures mapping methods (including environment mapping and bump mapping), shadow mapping, adding fog, particle systems, tessellation. The algorithms taught within the course are implemented as practical assignments.

Advanced systems for image analysis and processing

After the introductory presentation of the file formats and data structures for image analysis the course discuss a number of topics related to signal sampling and transformations (Fourier, Walsh, Hadamard, cosine, Haar, wavelets, etc.). In the chapter "Image enhancements" are studied statistical values, extending contrast, histogram modification techniques, increasing image clarity. For image filtering are considered methods in frequency domain and space domain. To restore images noise models are discussed and further filtering solutions in the spatial domain and the frequency domain. An important section of the course is represented by operations on images: arithmetic operations, operations based on convolution, derivative-based operations, morphological operations, including basic morphological algorithms (border extraction, region fill, extraction of connected components, convex hull, thinning, thickening, skeletons, pruning) and morphological operations on images with gray levels (dilation, erosion, opening, closing, morphological smoothing, morphological gradient, "top-hat" transformation, textural segmentation, granulometry). The chapter "Segmentation techniques" approaches the threshold techniques, contour detection based on Laplace, Roberts, Prewitt, Sobel, Canny, Hough operators, including region based segmentation.

The last chapter refers to the numerical systems for image processing (massive processors, systolic systems, pipeline systems, MIMD systems with distributed memory and shared memory, imaging systems connected to PC).

3D Modeling Techniques

Most of the models used in 3D applications (meshes, terrains, animations, textures etc.) are hand-created, using specific techniques and dedicated software and even hardware tools. Their understanding and the ability to use them at least at a basic level is important for any 3D applications developer.
This course has a highly practical nature. Its goal is to understand the general concepts and techniques of 3D modeling not only theoretically, but mostly through hands on practice within some of the mostly known software packages currently used for such purposes (Maya).
Special emphasis is placed on developing the students' ability to optimize models, from conception to realization, according to purpose: extremely high quality rendering or real-time rendering.
Also the course pays attention to understanding the connections with the artistic aspects of modeling, such as enhancing the realism of 3D models and scenes.

Introduction to Virtual Reality

Virtual reality can be briefly defined as a set of technologies and concepts that allows the user interaction with a computer-simulated environment, whether or not directly related to reality.
Nowadays, virtual reality is a complex and evolving area, with a very wide range of applications, ranging from games to medicine, military, education, industry and science.
The course aims to present the main concepts and techniques used in virtual reality, the main types of application and to identify trends and perspectives.
A distinctive feature of this course, compared to other courses on virtual reality at the same level, is the emphasis on interdisciplinary related issues (social, psychological, medical, economic, legal, etc.) as well as the understanding of immersion from many perspectives. In this way it aims to create the ability to understand the various aspects to be taken into account when designing a virtual reality system.

Volume Data Visualization and Computer Animation techniques

The first part of the course presents the theory, methods (Marching Cubes, Ray-casting and others) and modern implementation techniques for visualization and reconstruction of volumes from volume data (such as Computer Tomograph datasets), with important applications in medicine, archaeology, geology, biology, cultural heritage, scientific visualization. Methods of real-time visualization and reconstruction using GPU shader programs and GPGPU techniques are presented both in the lecture and in the project hours.
The second part of the course presents the main Computer Animation techniques, applied in a variety of domains, from advertisements and computer games to the film production: image warping, rigid body animation, soft object animation, character animation and others.
As a practical task, students must undertake a research project on one of the topics covered in the course, which has to be concluded with an application.

Multimedia Systems and Techniques

The course contains four important parts: audio processing, images, video and multimedia authoring. For the first domain digital audio data representation is discussed, audio waves, PCM, sampling rate and aliasing, quantization and quantization error, audio dithering, noise formation, nonlinear quantization, frequency analysis, statistical analysis. Digital audio processing chapter presents MIDI specification, dynamic processing, audio restoration, audio processing software, digital audio filters, audio filters design, digital audio compression. The chapter "Digital processing of speech" introduces aspects of phonetic representation of speech, production models for speech, short time speech analysis, speech spectrogram, homomorphic speech analysis. Part two dedicated to images deals with image representation and description (boundary descriptors, regional descriptors, relational descriptors). In object recognition are discussed decision-theoretic methods (matching, optimum statistical classifiers, neural networks) and structural methods (matching shape numbers, string matching, syntactic recognition of strings, syntactic recognition of trees). The course makes a brief overview of steganography. The chapter "Digital video" discusses digital video data representation, video standards, digital video resolution and bandwidth, digital video processing and motion estimation. The last part refers to the multimedia authoring, making a brief presentation of Adobe Director and Lingo syntax elements.

Multimedia communications

This course introduces students to three main domains: information theory, multimedia standards and multimedia communication.
The first parts refers to statistical (Shannon-Fano, Huffman, Arithmetical), dictionary (LZ77, LZ78, LZW, Deflate) and context compression (PPM, MTF, Burrows-Wheeler) used for lossless data compression; JPEG-Lossless, JBIG, JBIG2, Fax-Group, MRC for lossless image compression; FLAC, Apple Lossless, MPEG-4 ALS, Monkey's Audio, TTA for audio lossless compression; compression in DCT domain (JPEG, MPEG), wavelet domain (JPEG-2000) and fractal compression for images and video lossy compression and MDCT (MP3, WMA) for lossy audio compression.
The last part refers to post-processing for removing compression artifacts (denoising, deringing, deblocking), analyzing media for recovering representative characteristics, and storing on distributed systems, indexing, searching and transmission.
The course has three main teaching methods: presentation of the theory, held by the teacher; presentations based on cutting-edge research articles sustained by the students; and a project developed by the students, starting from proposed ideas, in-progress projects, or a new idea which students can propose.

Information Tools for Entrepreneurship and Technological Management

The course “Information Tools for Entrepreneurship and Technological Management” develops students’ knowledge and skills required to design and implement a technical project in an entrepreneurial spirit, be it as a start-up or in other organizational forms. The first part of the course clarifies the diversity of present-day entrepreneurial practices, familiarizes students with product vision, with assessing current developments in technology – including limitations, trends, and associated opportunities to position a novel solution for an old or new customer need. In the second part of the course, students develop competencies in understanding and managing emotions for themselves and well as in relation to their team collaborators, in time management, in introductory elements of financial planning, and in computer supported collaborative work – including the study of dedicated information solutions. In the third part of the course students are trained in delivering public presentations for a product, in conceptual, ethical and legal issues concerning intellectual property, in branding approaches and techniques, and in market research and marketing.

The course has an important practical dimension, involving students in laboratory activities for all topics under discussion. Students therefore follow the development of a product from design to public presentation of its various stages, exploring multiple facets of such a project through group and interactive activities, through familiarization with multiple information solutions for communication, design and teamwork, and through public presentations of ideas or projects. Students develop their technical skills in working with current, dedicated information tools, as well as their abilities to communicate directly and in front of an audience, and to work in a team.

After finalizing the course, students will be able to assess the opportunity of developing a specific project in its technological context, they will be able to formulate initial estimates for the requirements of starting an entrepreneurial project, and will master the main concepts and information tools needed to carry through such a project.

Developing Virtual Reality Applications

Nowadays, virtual reality is a complex and evolving area, including many technologies and concepts, and with a wide range of applications, ranging from games to medicine, military, education, industry and science.
This course builds on the foundation provided by the course "Introduction to Virtual Reality" and has a very practical nature. Its aims are: to familiarize the students with a wide range of technologies currently used in virtual reality, from software architectures to dedicated hardware; to create the abilities to design virtual reality applications, taking into account interdisciplinary perspectives and analyzing the immersion from many angles; to develop the capacity to implement a virtual reality system.
Within the laboratory classes, students will work in teams to design and implement medium sized virtual reality applications, putting into practice the concepts learned in this course and in the previous introductory course and using the available laboratory equipment and programs (HMD, tracking, haptic, photogrammetry, modeling, etc.).

Real-time 3D graphics engines

3D engines appeared and evolved due to the growth of the gaming industry and are usually often called "game engines". The development of a 3D engine or usage of an existing one is based on knowledge from many branches of computer science: creation of real-time realistic graphics of great complexity, methods of character animation, simulation of physical effects (collision detection, friction, gravity, etc.), artificial

intelligence (game theory, neural networks, etc.), communication in computer networks and, last but not least, good knowledge of programming and software engineering.
The main objective of the course is to introduce the theoretical and practical notions needed to develop real-time 3D engines and how to use them to create various applications that use interactive 3D virtual spaces. The focus is on 3D engines architectures, the functionality of the various components, aspects of implementation using the Graphics Processing Unit, network communication in "multiplayer" and "Massive Multiplayer Online Games".

Development of graphics applications for mobile devices

In recent years, mobile devices have become more powerful as the various hardware manufacturers are engaged in a continuous competition for market supremacy. Also the Android operating system is currently in a spectacular expansion and every day millions of new devices that use Android are activated. Thus, the market of applications for mobile devices is progressively growing and an important part of it begins to be represented by applications and games that require realistic graphics of great complexity. OpenGL ES (Embedded Systems) is a subset of the OpenGL 3D graphics API that targets mobile devices such as smartphones and tablets.
The main objective of the course is to introduce the theoretical and practical notions needed to develop graphics applications for mobile devices that use Android and OpenGL ES. The focus is on the architecture and how applications are built for the Android operating system and also on how to use the OpenGL ES API for 3D graphics application development.

Documents analysis and automatic content extraction

Document Image Analysis Systems transform “on-paper” legacy documents into digital ones in order to store, multiply, make them more accessible, and to make the content available to applications like text mining and text to speech.
Students will learn about the algorithms used in processing the document: *importing and preprocessing* the imported image (by noise removal, contrast enhancement, skew removal, binarization), *Layout analyzing* for doing block classification (letter, word, paragraph, title, subtitle, image, white space, page number, …), *Hierarchy analyzing* for arranging the objects in a logical order (book title, author, preface, chapter, table of contents, ...), *OCR* for actually transforming from raster image to digital text along with

post-processing for correcting word and grammar mistakes, *Exporting* to a layered format like PDF or MRC.
The course has three main teaching methods: presentation of the theory, held by the teacher; presentations based on cutting-edge research articles sustained by the students; and a project developed by the students, starting from proposed ideas, in-progress projects, or a new idea which students can propose.

Research activities

The research activities are focused on opening a horizon of scientific research and on training skills for practical use of theoretical knowledge.
As a result of research activities, students will acquire a range of specific skills so as to be able:

- To choose and define the functionality of an application taking into account the possibilities of computer graphics, multimedia and virtual reality.
- Use different standards, technologies and domain-specific libraries.
- To identify, select and apply the right approach to solving a certain type of problem.
- To evaluate the advantages and disadvantages of the choice made.
- To learn methods of scientific research, correctly applying the rules of ethics in scientific research.
- To create a research report.
- To carry out effective specific experiments and prototypes.
- To use techniques for testing applications in the field.

Each student will receive a research topic to work during the 4 semesters, work which will be finalized with the dissertation project.
Examples of research topics:

- 3D UPB virtual campus. Implementation of functionalities for presentation, guidance, search, simulation in the virtual space of the real space events, etc.
- Extensible Multiplayer 3D virtual space.
- Software application of guidance in the UPB campus with elements of augmented reality for mobile devices.
- Virtual reality system for treatment by controlled immersion for various phobias
- Real time 3D graphics engine using GPGPU.
- Photorealistic 3D simulations using GPGPU.
- Modeling and rendering realistic characters: movements, facial expressions, clothing and hair.

- Rendering an avatar's emotions by simulating the user's emotions.
- Define models of interaction between virtual characters and environment in the context of rendering real scenes with a big number of people.
- Advanced techniques of visualization, processing and analysis in medical imaging: visualization and modeling of three-dimensional objects extracted from CT or MRI data volumes; shapes extraction from images, for diagnostic or assistance in the medical decision making; semantic annotation of images by physicians, with visual information and patient information; image retrieval by data mining techniques, and others.
- Structural analysis of document image for content extraction.
- Wavelet-based image processing for document conversion.