Computer Game Graphics and Virtual Reality

MSC IN COMPUTER SCIENCE

ATHENS UNIVERSITY OF ECONOMICS AND BUSINESS

A New Perspective

This advanced image synthesis course aims at introducing the students to the amazing world of image generation and its applications, with an emphasis to interactive graphics for games and virtual reality and photorealistic production rendering.

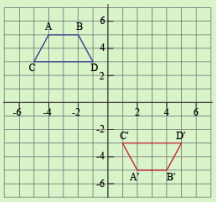
Breadth vs Depth. A wide range of topics are covered, capturing mostly at a high level the basics of real-time image generation algorithms and graphics hardware technology, production-quality pipelines and methods and effects, materials and appearance, as well as colour manipulation. Application topics include virtual and mixed reality and the use of volume rendering to medical imaging. Interested students can delve into more details through focused reading material, personalized projects (see below) and the bibliography.

Personalization. Computer graphics is an inspiring domain and as a course we firmly believe that it should remain so. To deliver this promise, the students are encouraged to select one of many options of engagement and therefore, assessment, be that a written-examination-only system or a combination of paper study and project. For projects, there are many options available, ranging from ray tracing to VR and Unity/Unreal-based game development, either as a personal project or a team assignment.

Background. Although a basic background in computer graphics (undergraduate level) is appreciated, it is not a prerequisite, since the principles of 2D and 3D computer graphics are (briefly) re-introduced in this course. Some elementary mathematics and principles of probability theory are required (as well as some computer programming skills for those who will choose a development project).

Course Details

Computer Graphics Foundations



Introduction to computer graphics
Image representation, basic concepts and pipelines, tools, applications, and production pipelines. Surface representations and data primitives and organization. Coordinate systems, geometric transformations, viewing and projections.

Real-time graphics - part 1: The rasterization pipeline
The rasterization graphics pipeline. Stages, polygon clipping and sampling, the graphics processing unit (GPU) architecture, programmable stages and image composition. Aliasing and antialiasing.

Appearance and shading
Materials and surface properties, local shading models (overview) and their properties, basic radiometric properties and the reflectance equation. Texturing and texture maps.

Production Rendering

Ray tracing
The ray tracing pipeline, applications, pros and cons, ray generation, scene traversal and acceleration structures, specular reflection and transmission. Comparative study vs rasterization.

Light transport theory and stochastic path tracing
The rendering equation formulations, integral approximations, Monte Carlo integration, path sampling. Modelling of arbitrary light sources and global illumination via path tracing. Other path tracing-based methods: bidirectional path tracing, photon mapping, Metropolis light sampling (brief overview or approaches, pros and cons). Distribution effects (depth of field, motion blurring).

Volume Graphics
Principles of light transport in participating media, volume rendering techniques, real-time volumetric visualization, applications to medical imaging and scientific visualization.

Interactive Graphics

Real-time graphics – part 2: computer game graphics
Real-time shading pipelines. Handling transparency via multi-fragment rendering, multi-pass algorithms: shadow generation, illumination caching, environment mapping and introduction to real-time global illumination techniques. Post-processing effects for games (tone-mapping and colour grading, defocus blurring, motion blurring, bloom etc.)

Virtual and Mixed Reality
Introduction to stereo rendering, immersion, technologies and systems for VR interaction. AR: principles and technologies. Interaction metaphors for VR.

Animation and Motion Capture
Principles and theory of basic computer animation, motion capture and tracking techniques and technologies, real-time animation concepts and implementation.

Grading options

Option	Written exam	In-depth survey	Project	Details
Normie	7/10		3/10	Regular project, programming language of choice (C++ preferred)
Code junkie	5/10		5/10	Implementation of a core graphics algorithm in C++. Path tracing or VR options (with Oculus Rift) available.
The Nerd	5/10	5/10		Survey of methods or technology with comparative study, implementation difficulties, performance analysis and extensive references.
The “writer”	10/10			No surveys, no projects, just plain ole exams, for those who are not so comfortable with their programming or research skills.

About the instructor

Georgios Papaioannou is an assistant professor at the Department of Informatics of the Athens University of Economics and Business (AUEB) and head of the AUEB computer graphics group. His research is focused on real-time computer graphics algorithms, photorealistic rendering, shape analysis and geometry processing. He received a 4-year BSc in Computer Science in 1996 and a PhD degree in Computer Graphics and Shape Analysis in 2001, both from the University of Athens, Greece. Since 1997, he has worked as a research fellow and principal investigator in many research and development projects. From 2002 till 2007 he worked as a lead software engineer in virtual reality systems at the Foundation of the Hellenic World. Prof. Papaioannou has been teaching elementary and advanced computer graphics, programming and human-computer interaction courses since 2002 and he is the principal investigator for AUEB for EU-funded and national research projects, with more than 70 publications and technical reports in the computer graphics domain and over 1000 citations to his work.

Course material and suggested reading

The main reading material for the course comes from the book: Graphics and Visualization: Principles & Algorithms, T. Theoharis, G. Papaioannou, N. Platis, N. M. Patrikalakis, AK Peters, USA, 2008, which is also available in Greek (Γραφικά και Οπτικοποίηση: Αρχές & Αλγόριθμοι, εκδόσεις ΣΥΜΜΕΤΡΙΑ). Additional lecture notes and slides on the e-class platform. Additional lecture notes on VR by Steven M. can be found at http://msl.cs.uiuc.edu/vr/ .

Note: Stay calm and breathe normally. For completeness, most of the slides provide a deeper analysis of the topics covered than it is required for the level of the course. Students are not required to study the entirety of the material provided (though they are most welcome to do so).

Suggested Reading:

- Real-Time Rendering, Third Edition, T. Akenine-Möller, E. Haines, N. Hoffman, CRC Press, 2008 (new edition coming Q2 2018).
- Physically Based Rendering: From Theory to Implementation, Matt Pharr, Wenzel Jakob, Greg Humphreys, 3rd Edition, Morgan Kaufmann, 2016.

Additional information

If you want to get involved in computer graphics research, you can find more information on the research of the Computer Graphics Group at: http://graphics.cs.aueb.gr and specific details about lectures and contact information on the e-class pages.