POZNAN UNIVERSITY OF TECHNOLOGY

EUROPEAN CREDIT TRANSFER AND ACCUMULATION SYSTEM (ECTS)

COURSE DESCRIPTION CARD - SYLLABUS

Course name
Visualization of Multidimensional Data [S1Bioinf1>WDW]

Course

Field of study
Bioinformatics

Year/Semester
3/6

Area of study (specialization)
–

Profile of study
general academic

Level of study
first-cycle

Course offered in
Polish

Form of study
full-time

Requirements
elective

Number of hours

Lecture
30

Laboratory classes
30

Other
0

Tutorials
0

Projects/seminars
0

Number of credit points

4,00

Coordinators

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Lecturers

Prerequisites

Knowledge: Student starting this module should have basic knowledge regarding programming languages, geometry and computer system architectures. Skills The student should have the skills to solve simple algorithmic problems, program in C/C++ and to acquire knowledge from the designated sources of information. Social competences: The student should also understand the need to extend his/her competences and be ready to work in a team. Moreover, the student should show such attitudes as honesty, responsibility, perseverance, curiosity, creativity, manners, and respect for other people.

Course objective

1. Teach students the basics in the field of data visualization methods. 2. Teach students the methods of pre-processing of visualized data. 3. Teach students the methods of converting symbolic data to graphical representation. 4. Teach students the basic concepts in the field of computer graphics. 5. Teach students the mathematical foundations of multidimensional data visualization. 6. Teach students the methods for visualization of data that changes over time 7. Teach students the basics of modelling light. 8. Teach students various methods of representing 3D models 9. Teach students the basics of raster algorithms and halftone approximation algorithms. 10. Teach students the basics of polygon clipping algorithms. 11. Develop students" skills of programming simple visualization applications.

Course-related learning outcomes

Knowledge:
1. Knows the mathematical and physical foundations of data visualization [K_W02, K_W03]
2. Knows the basic concepts and issues related to computer graphics and visualization of 3D models. [K_W09]
3. Knows the visualization algorithms of 3D models and data structures used in them [K_W08]]

Skills:
1. Can make a complex data analysis based on visualization techniques [K_U03]
2. Can design and implement a simple program that visualizes and animates a set of three-dimensional models [K_U07]
3. Can choose an algorithm for the visualization of three-dimensional objects and corresponding data structures appropriate to a given problem [K_U06]
4. Can independently acquire knowledge and raise qualifications [K_U14]

Social competences:
1. Understands the need to learn throughout whole life and to broaden his competences. - [K_K01]
2. Is able to collaborate and cooperate in a team fulfilling different roles. - [K_K02]

Methods for verifying learning outcomes and assessment criteria

Learning outcomes presented above are verified as follows:

Learning outcomes presented above are verified as follows:
Formative assessment:
a) lectures:
- based on answers to questions related to subjects covered during previous lectures,
b) laboratory classes:
- evaluation of correctness of implementation of assigned tasks (following provided lab. instructions),
Total assessment:
a) verification of assumed learning objectives related to lectures:
- evaluation of acquired knowledge on the basis of the written exam (a test, 50 questions, total points achievable 50, 25 points needed to pass).
b) verification of assumed learning objectives related to laboratory classes:
- based on the project implemented by a team of students, each students" grade is evaluated based on the quality of his/hers part as well as answering to several project related questions.

Programme content

The lecture program covers the following topics:

- Fundamentals of data visualization.
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- Processing visualized data.
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- Data visualization methods.
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- Basic concepts in computer graphics.
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- Fundamentals of 3D mathematics.
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- Techniques for animating 3D models.
-
- Scene lighting modeling.
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- Fundamentals of ray tracing algorithms.
-
- Algorithms for clipping 2D and 3D figures to a specified window.
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- Methods for describing 3D models.
-

- Basic raster algorithms.

Laboratory Exercise Topics

- Fundamentals of the Direct3D API.
- Calculating geometric transformation matrices.
- Drawing 3D models.
- Texturing objects.
- Implementing lighting models.
- Advanced graphic effects.

Course topics

Lectures cover the following topics
Subject 1: Basics of Data Visualization. Defining the problem of visualization and its goals. Visualization process. Data sources and structures for visualization.
Subject 2: Preprocessing of data. Classification of visualized data (quantitative and qualitative, dimensionality). Simensionality reduction. Data smoothing (noise removal).
Subject 3: Visualization methods. Classification of visualization methods. The issue of the effectiveness of data visualization methods. Various methods of mapping data to graphical primitives and various types of charts ore discussed.
Subject 4: Basic issues in the field of computer graphics. Similarities and differences between computer graphics and visualization. Limitations and consequences of different ways of presenting visualized data (e.g. monitor / printout, etc.). Basic algorithms for solving the problem of invisible surfaces, basic texturing and anti-aliasing methods.
Subject 5: Basic mathematical definitions related to the visualization of multidimensional data: homogeneous coordinates, matrix representation of geometric transformations, quaternions. Conversion between coordinate systems. Perspective and orthogonal projection.
Subject 6: 3D model animation techniques, including: per-vertex animation, skeletal animation and inverse kinematics. The student learns about the advantages and disadvantages of each of these techniques, as well as the potential application areas.
Subject 7: Physical basics of modeling light transport and visualization, including: basic radiometric quantities, bidirectional reflectance distribution function (BRDF function) and its properties, light transport equation, mathematical models of light sources, BSF Schlick function as a simplification of the BRDF function. Popular lighting models used in the visualization of three-dimensional models, including: scattered light models (Lambert"s model), reflected light (Phong, Phong Blinn model), and physics-based lighting modeling (Cook-Torrance model).
Subject 8: Algorithms for visualization of three-dimensional scenes based on the ray tracing technique. Theoretical basics are discussed: generation of rays (main, shadow, reflected and refracted). testing the intersection of a radius with various objects (plane, sphere, AABB (axis aligned bounding box) and a triangle). The Whitted algorithm is discussed with extensions improving the quality of the generated image. Finally, methods of optimizing ray tracing algorithms are discussed.
Subject 9: Monte Carlo Rendering. Mathematical foundations and algorithms.
Subject 10: Clipping of two- and three dimensional objects (Cohen-Sutherland, Cyrus-Beck, Sutherland-Hodgman and Greiner Hodgeman algorithms).
Subject 11: Various forms of spatial models and methods of their visualization (polygon meshes, voxels, mathematical surfaces and particle systems). Methods of converting voxel and mathematical representations to polygon meshes are also discussed.
During laboratories the students learn basic of computer graphics and implement simple exercises:
Laboratory 1: Introduction to Direct3D API. Discussion about the basic program structure. Introduction to several basic topics related to drawing and animating of 3D models.
Laboratory 2-4: Direct3D exercises related to moving, rotating and animation of 3D objects on a scene. Students gain the skills to correctly construct geometrical transformation matrices.
Laboratory 5: Methods allowing to draw arbitrary trimeshes.
Laboratory 6: Texturing and shading of objects in Direct3D via ready made shader programs. Introduction of several texturing algorithms including bi- and trilinear filtering as well as mip mapping.
Laboratory 7: Introduction to HLSL language. Simple exercises based on implementation of simple geometry transforming shaders and simple lighting models.
Laboratory 8: Per-vertex and per-fragment implementations of lighting models in HLSL, including

Lambert and Phong models.
Laboratory 9: Texturing in HLSL. Multitexturing.
Laboratory 10-12: Exercises in data visualization.
Laboratory 13-15. Preparation of final project

Teaching methods

1. Lectures: multimedia presentation, presentation illustrated with examples presented on black board, solving tasks, multimedia showcase.
2. Labs: solving tasks, practical exercises, discussion, teamwork, multimedia showcase.

Bibliography

Basic
1. G. Banaszak, W. Gajda: „Elementy algebry liniowej” część I i II, WNT, Warszawa, 2002
2. B. Kaczmarek: „Elementy algebry i analizy macierzy”, Wydawnictwo PP, 1689, Poznań, 1992
3. P. Walsh: „Advances 3D Game Programming with DirectX 10.0”, Wordware publishing, 2008
4. F. D. Luna: „Introduction to 3D Game Programming with DirectX 10”, Jones & Bartlett Publishers, 2008
5. C.D. Hansen, C.R. Johnson (eds.): The Visualization Handbook, Elsevier, 2005
Additional
1. A.N. DcGorban, , B. Kégl, D.C. Wunsch, A. Zinovyev, (Eds.) Principal Manifolds for Data Visualization and Dimension Reduction
2. F.H. Post, G.M. Nielson, G.-P. Bonneau, Data Visualization: The State of the Art, Proceedings of the 4th Dagstuhl Seminar on Scientific Visualization

Breakdown of average student's workload

	Hours	ECTS
Total workload	100	4,00
Classes requiring direct contact with the teacher	60	2,50
Student's own work (literature studies, preparation for laboratory classes/ tutorials, preparation for tests/exam, project preparation)	40	1,50