AGH UNIVERSITY OF SCIENCE AND TECHNOLOGY

Code:	UBPJO-116	Module name:	CAD/CAE Systems		
Academic year:	2013/2014	Semester:	Fall	ECTS credits:	4
Programme:	University Base of Courses in English				
Course homepage:	https://intcourses.agh.edu.pl	Lecture language:	English		
Responsible teacher:	Paszyński Maciej (paszynsk@agh.edu.pl)				
Academic teachers:	Paszyński Maciej (paszynsk@agh.edu.pl)				

Description of learning outcomes for module

MLO code	Student after module completion has the knowledge/ knows how to/is able to	Method of learning outcomes verification (form of completion)
Social competence		
M_K001	Knows basic principles of modeling geometries with B-splines within CAD systems	Completion of laboratory classes
Skills		
M_U001	Is able to solve model engineering problem using finite difference method and CAE system	Completion of laboratory classes
M_U002	Is able to solve model engineering problem using finite element method and CAE system	
Knowledge		
M_W001	Knows the principles of the finite difference method	Completion of laboratory classes
M_W002	Knows the principles of the finite element method	Completion of laboratory classes
M_W003	Knows basic design principles of Computer Aided Design systems	Completion of laboratory classes
M_W004	Knows basic principles of Computer Aided Engineering systems	Completion of laboratory classes
M_W005	Knows how to model geometry using B-splines within CAD systems	Completion of laboratory classes

FLO matrix in relation to forms of classes

MLO code	Student after module completion has the knowledge/ knows how to/is able to	Form of classes										
		Lectures	Auditorium classes	Laboratory classes	Project classes	Conversation seminar	Seminar classes	Practical classes	Others	Fieldwork classes	Workshops	E-learning
Social competence												
M_K001	Knows basic principles of modeling geometries with B-splines within CAD systems	-	-	-	-	-	-	-	-	-	-	-
Skills												
M_U001	Is able to solve model engineering problem using finite difference method and CAE system	+	-	+	-	-	-	-	-	-	-	-
M_U002	Is able to solve model engineering problem using finite element method and CAE system	+	-	+	-	-	-	-	-	-	-	-
Knowledge												
M_W001	Knows the principles of the finite difference method	+	-	+	-	-	-	-	-	-	-	-
M_W002	Knows the principles of the finite element method	+	-	+	-	-	-	-	-	-	-	-
M_W003	Knows basic design principles of Computer Aided Design systems	+	-	+	-	-	-	-	-	-	-	-
M_W004	Knows basic principles of Computer Aided Engineering systems	+	-	+	-	-	-	-	-	-	-	-
M_W005	Knows how to model geometry using B-splines within CAD systems	+	-	+	-	-	-	-	-	-	-	-

Module content

Lectures

Introduction to Computer Aided Design and Computer Aided Engineering (2 hours)

CAD/CAE market. Basic steps of the engineering process: Modeling of geometry in CAD system, modeling of objects by B-splines and NURBS, generation of material data for particular objects, meshing for CAE computations, discretization by using finite difference or finite element method, solution of the system of linear equations by direct or iterative solver algorithm, analysis of the accuracy of the simulation, mesh adaptation, postprocessing

Basic methods of Computer Aided Engineering: Finite element method (2 hours)

Introduction to finite element method. Exemplary finite element method for heat transfer problem. Derivation of the formulation in 2D. Discretization methods. Interfacing with the solver algorithm.

Mesh adaptation algorithms (2 hours)
Introduction to the mesh adaptation algorithm. Automatic algorithm for hp adaptation. Design principles for object-oriented adaptive CAD/CAE systems. Exponential convergence of the numerical error with respect to the mesh size for the hp adaptive algorithm.

Direct solvers utilized in CAD/CAE systems (2 hours)
Mesh based solvers utilized in CAD/CAE systems. Multi-frontal solver algorithm and its applications. Parallel version of the multi-frontal solver algorithm for shared-memory and distributed memory architectures. Computational costs of the multi-frontal solvers.

Summary of the lecture (2 hours)
Comparison of computational costs of adaptive finite element method and isogeomtric finite element method, for sequential and parallel, distributed and shared memory simulations.

Introduction to Computer Aided Design: modeling of geometry with B-splines and NURBS (2 hours)
Basic principles of modeling of geometry with B-splines and NURBS. Know vectors, B-splines basis functions. Idea of Non-Uniform Rational B-splines (NURBS). Examples of modeling two and three dimensional objects.

Introduction to Isogeometric analysis (2 hours)
Utilization of the same basis functions for modeling of geometry and for engineering simulations. Integration of the engineering simulations in CAE systems. Computational costs of isogeometric analysis.

Basic methods of Computer Aided Engineering: Finite difference method (1 hour)
Introduction to finite difference method. Exemplary finite difference method for heat transfer problem. Derivation of the formulation in 1D, 2D and 3D. Discretization methods.
Interfacing with the solver algorithm.

Laboratory classes

Installation of the virtual machine with MUMPS solver, compilations and linking of libraries (2 hours)
Students download, compile and link the CAE environment in virtual linux machine.

Implementation and execution of one dimensional finite difference method (2 hours)
Student write a simple C code in virtual machine with one dimensional finite element method. They compile and link to MUMPS solver.

Implementation and execution of two dimensional finite difference method (2 hours)
Student write a simple C code in virtual machine with two dimensional finite element method. They compile and link to MUMPS solver. This is an extension of the previous lab for more complicated case.

One dimensional hp adaptive finite element method (2 hours)
Students install and compile one dimensional hp adaptive finite element method code and learn how to solve a prescribed engineering problem using the 1D code.

Modeling geometries for two dimensional finite element method (2 hours)
Students learn how to prepare an input file with geometry description for two dimensional hp adaptive finite element method.

<u>Comparison of convergence of h adaptive and p adaptive method in 2D hp-FEM (2 hours)</u>
Students play with two dimensional hp adaptive system and compares convergence methods for simple engineering problems.

<u>Solving challenging problems with CAD/CAE systems (2 hours)</u>
Students will implement some aspects of the model and execute the hp adaptive finite element method code for solution of the Stokes flow problem.

<u>Computational costs and memory usage of the solvers (1 hour)</u>
Students will experiment with limitations of the method by increasing the problem size and measuring execution times and memory usage of the solver (1 hours)

Method of calculating the final grade

1. It is necessary to obtain positive average grade from the labs
2. Final grade depends on the average grade obtained from the labs:

if sr>4.75 then OK:=5.0 else
if sr>4.25 then OK:=4.5 else
if sr>3.75 then OK:=4.0 else
if sr>3.25 then OK:=3.5 else OK:=3

Prerequisites and additional requirements

Basics of C/C++ programming
Basics of linear algebra
Basics of PDE

Recommended literature and teaching resources

Cottrell, J. Austin; Thomas J.R. Hughes, Yuri Bazilevs (October 2009). Isogeometric Analysis: Toward Integration of CAD and FEA. John Wiley & Sons. ISBN 978-0-470-74873-2
Demkowicz L. Computing with hp-Adaptive Finite Elements. Vol. 1Chapmann & Hall / CRC Press 2007

Scientific publications of module course instructors related to the topic of the module

[1] Maciej Paszynski, Jason Kurtz, Leszek Demkowicz, Parallel Fully Automatic hp-
Adaptive 2D Finite Element Package. Computer Methods in Applied Mechanics and Engineering, 195 (2006) 711-741.
[2] Maciej Paszynski, Leszek Demkowicz, Parallel Fully Automatic hp-Adaptive 3D Finite Element Package. Engineering with Computers, 22 (2006) 255-276.
[3] Pawel Matuszyk, Maciej Paszynski, Fully automatic hp adaptive finite element method for the Stokes problem in two dimensions. Computer Methods in Applied Mechanics and Engineering, 197 (2008) 4549-4558.
[4] Nathan Collier, David Pardo, Lisandro Dalcin, Maciej Paszynski, Victor Calo, The cost of continuity: A study of the performance of isogeometric finite elements using direct solvers. Computer Methods in Applied Mechanics and Engineering, 213-216 (2012) 353-361.
[5] Maciej Paszynski, Victor Calo, David Pardo, A direct solver with reutilization of previously-computed LU factorizations for h-adaptive finite element grids with point singularities. Computers and Mathematics with
Applications, 65, 8 (2013) 1140-1151.

Additional information

Demkowicz L. Kurtz J., Pardo D., Paszyński M., Rachowicz W., Zdunek A., Computing with hp-Adaptive Finite Elements. Vol. 2: Frontiers: Three Dimensional Elliptic and Maxwell Problems with Applications, Chapmann & Hall / CRC Press 2007

Student workload (ECTS credits balance)

Student activity form	Student workload
Participation in lectures	30 h
Participation in lectures	30 h
Preparation for classes	30 h
Realization of independently performed tasks	10 h
Summary student workload	100 h
Module ECTS credits	4 ECTS