Politechnika Krakowska
im. Tadeusza Kościuszki

Karta przedmiotu

obowiązuje studentów rozpoczynających studia w roku akademickim 2020/2021

Wydział Inżynierii Materiałowej i Fizyki

Kierunek studiów: Fizyka Techniczna w Języku Angielskim — Profil: Ogólnoakademicki

Forma sudiów: stacjonarne — Kod kierunku: FTja

Stopień studiów: II

Specjalności: Computer modelling (modelowanie komputerowe w języku angielskim)

1 Informacje o przedmiocie

Nazwa przedmiotu	Adaptive numerical methods
Nazwa przedmiotu w języku angielskim	Adaptive numerical methods
Kod przedmiotu	WIMiF FTJA oIIS C8 20/21
Kategoria przedmiotu	Przedmioty kierunkowe
Liczba punktów ECTS	3.00
Semestry	2

2 Rodzaj zajęć, liczba godzin w planie studiów

Semestr	Wykład	Ćwiczenia	Laboratorium	Laboratorium komputerowe	Seminarium	Projekt
2	15	0	0	15	0	0

3 Cele przedmiotu

Cel 1 Presentation of the theoretical background behind the finite elements method for solving differential equations of physics. Presentation of methods for increasing the accuracy of numerical simulations conforming to technical requirements.

Cel 2 The student learns to understand and design adaptive numerical routines (in one-dimension), mainly in a programming language (preferably C or Fortran) and with the help of a symbolic computation language (Mathematica).

Cel 3 The student applies adaptive numerical routines to solving various kinds of elliptic problems a physicist may encounter.

4 Wymagania wstępne w zakresie wiedzy, umiejętności i innych kompetencji

1 The student is expected to know the fundamentals of linear algebra (linear spaces, matrix algebra) and mathematical analysis, as well as to be acquainted with the fundamentals of differential equations and variational calculus.

2 The student is expected to have some background in programming, to know basic numerical algorithms (including standard routines for quadratures and for ordinary and partial differential equations).

5 Efekty kształcenia

EK1 Wiedza The student understands the presented adaptive algorithms and the numerical routines they use. The student knows the finite element method and the related mathematical theory.

EK2 Umiejętności The student is able to design and program the presented adaptive 1D algorithms and apply them in solving problems described by ordinary differential equations. The student uses adaptive algorithms for solving 2D problems described by partial differential equations.

EK3 Umiejętności The student is able to write a (LaTeX) report discussing the solution of home-work tasks or group projects, and to prepare and give an oral presentation of the obtained results.

EK4 Kompetencje społeczne The student develops his or her teamwork skills to achieve a shared goal in problem solving.

6 Treści programowe

Wykład		
Lp	Tematyka zajęć Opis szczegółowy bloków tematycznych	Liczba godzin
W1	The concept of finite elements method. A general one-dimensional second order elliptic problem. Various kinds of boundary conditions. Problems reducible to the one-dimensional case and problems defined on curved lines in space.	1
W2	The variational (weak) formulation of elliptic problems (remarks on variational calculus for systems with a single degree of freedom). Equivalence of the weak and strong formulations of the general problem in one-dimension. Approximate analytical solutions from the least squares principle. The Galerkin type variational principle in the finite elements method. The idea of the finite elements method illustrated with the classical linear approximation example (p=1).	2

Wykład		
Lp	Tematyka zajęć Opis szczegółowy bloków tematycznych	Liczba godzin
W3	Definition of a generic and standard finite element. Shape functions over the standard finite element. Higher degree approximations (p>1) for the finite elements method, Lagrange polynomials as basis shape functions, hierarchical shape functions. Mappings to generic elements. Element quantities and data structure in one-dimension (global and local quantities, numbering conventions, localization issues). Global functions. Construction of general nonuniform one-dimensional meshes (grids).	2
W4	Reduction of the exact continuous problem to a discrete approximating sparse linear problem. The general stiffness matrix and the source vector. Application of numerical quadratures to computing bilinear forms and source-terms. An algorithm for obtaining the global stiffness matrix from element matrices. A numerical procedure for solving linear problems with sparse matrices.	1
W5	Basic information on error estimates and convergence issues in the finite elements method. Goal oriented strategies, types of control errors and their estimates. Examples. Methods for increasing the accuracy of numerical solvers of ordinary differential equations. Automatic adaptive mesh refinements: reducing the control errors by means of h-type, p-type and mixed hp-type techniques.	2
W6	Remarks on partial differential equations of physics and engineering, characteristic boundary problems or initial problems. The basic idea of finite elements method for higher-dimensional tasks.	1
W7	A general second order elliptic boundary problem in the two-dimensional case and its variational formulation (remarks on variational calculus for systems with several degrees of freedom, supplementary constraints and intrinsic coordinates). Equivalence of strong and weak formulations. Examples - the stationary heat transfer equation.	1
W8	The finite element method for general two-dimensional elliptic problems. Standard elements in two-dimensions: linear triangular elements (p=1), higher degree triangular elements (p>1), bilinear (p=1) and higher degree (p>1) quadrilateral elements. Ways of dealing with various kinds of boundary conditions.	2
W9	An algorithm for obtaining the global stiffness matrix from element matrices. Application of the finite elements method to finding numerical solutions of elliptic problems in the two-dimensional case.	1.5
W10	Remarks on estimating the solution errors (residuals, smoothing, extrapolations). Methods and criteria of mesh refinements. Reducing the control errors by means of h-type, p-type and hp-type techniques. Effectiveness of the techniques. Mesh optimization in increasing the accuracy of numerical solutions of partial differential equations.	1.5

Laboratorium komputerowe		
Lp	Tematyka zajęć Opis szczegółowy bloków tematycznych	Liczba godzin

Laboratorium komputerowe		
Lp	Tematyka zajęć Opis szczegółowy bloków tematycznych	Liczba godzin
K1	Numerical subroutines for the one-dimensional adaptive finite elements method. Construction of general nonuniform one-dimensional meshes. Discretization of elliptic problems in the finite elements method (obtaining the stiffness matrix and the source vector). Implementation of adaptive strategies.	6
K2	Application of the finite elements method to finding numerical solutions of elliptic problems in the one-dimensional case. One-dimensional stationary heat transfer equation and one-dimensional beam equation.	1
K3	Convergence of finite elements method in the one-dimensional case for uniform meshes and for h-type adaptive meshes. Example problems with smooth and singular solutions.	1
K4	Convergence of the finite elements method in the one-dimensional case for p-type and hp-type adaptive meshes. Robustness of adaptation algorithms in accelerating the error reduction process. A LaTeX-beamer project report.	2
K5	Two-dimensional problems for static electromagnetic fields defined on open and closed domains. Stationary problems and waveguides. The compactification issue, mapping to rectangular grids. Convergence of the two-dimensional finite elements method on equidistant rectangular grids. Observation of the influence of the grid constant onto the accuracy of obtained solutions.	2
K6	The finite element method with an h-type adaptive algorithm in two-dimensions. Application to electromagnetic problems and to hydrodynamical problems for compressible and incompressible flows. A LaTeX-beamer project report.	3

7 Narzędzia dydaktyczne

N1 Lectures

N2 Exercises in Computer Laboratories

N3 Individual or teamwork projects and reports

N4 Discussions, individual consultations

N5 Multimedia presentations

N6 A computer algebra system; an environment for compiling, linking and running computer programs

8 Obciążenie pracą studenta

Forma aktywności	Średnia liczba godzin na zrealizowanie aktywności
Godziny kontaktowe z nauczycielem akademickim, w tym:	
Godziny wynikające z planu studiów	30
Konsultacje przedmiotowe	2
Egzaminy i zaliczenia w sesji	5
Godziny bez udziału nauczyciela akademickiego wynikające z nakładu pracy studenta, w tym:	
Przygotowanie się do zajęć, w tym studiowanie zalecanej literatury	14
Opracowanie wyników	12
Przygotowanie raportu, projektu, prezentacji, dyskusji	12
Sumaryczna liczba godzin dla przedmiotu wynikająca z całego nakładu pracy studenta	**75**
Sumaryczna liczba punktów ECTS dla przedmiotu	3.00

9 Sposoby oceny

Ocena formująca

F1 Student is required to actively take part in the computer laboratory course and attend the lectures

F2 Student is required to prepare complete reports presenting and discussing the results concerning given computational tasks

Ocena podsumowująca

P1 Weighted average of forming grades: (reports/2 + activity/2)

Warunki zaliczenia przedmiotu

W1 All computational tasks must be accomplished

W2 The weighted average of forming grades - at least 3.0

Kryteria oceny

Efekt kształcenia 1	
Na ocenę 3.0	The student has a basic knowledge of presented computational methods
Efekt kształcenia 2	

Na ocenę 3.0	The student has limited skills in designing and programming the presented adaptive 1D algorithms and in applying them to solving problems described by ordinary differential equations. The student presents limited skills in using adaptive algorithms for solving 2D problems described by partial differential equations.
Efekt kształcenia 3	
Na ocenę 3.0	The student has limited skills in writing a report and presenting the results.
Efekt kształcenia 4	
Na ocenę 3.0	The student at least tries to develop his or her teamwork skills.

10 Macierz realizacji przedmiotu

Efekt kształcenia	Odniesienie danego efektu do szczegółowych efektów zdefiniowanych dla programu	Cele przedmiotu	Treści programowe	Narzędzia dydaktyczne	Sposoby oceny
EK1	K_W02b K_W03 K_W05 K_W09b K_U01b K_U03b	Cel 1	W1 W2 W3 W4 W5 W6 W7 W8 W9 W10 K1 K2 K3 K4 K5 K6	N1 N2 N3 N4 N5	F1 F2 P1
EK2	K_U01b K_U03b K_U04b K_U07b K_U08b K_U14 K_U16 b	Cel 2 Cel 3	K1 K2 K3 K4 K5 K6	N2 N4 N5 N6	F1 F2 P1
EK3	K_U03b K_U04b K_U16 b	Cel 1 Cel 2 Cel 3	W1 W2 W3 W4 W5 W6 W7 W8 W9 W10 K1 K2 K3 K4 K5 K6	N2 N3 N4 N5	F1 F2 P1
EK4	K_K03	Cel 3	K1 K2 K3 K4 K5 K6	N2 N3	F1 F2 P1

11 Wykaz literatury

Literatura podstawowa

[1] B. Szabo, I. Babuska — *Finite Element Analysis*, New York, 1991, John Wiley and Sons

Literatura uzupełniająca

[1] J.T. Oden, E.B. Becker — *Finite Elements: An Introduction*, New York, 1996, Prentice Hall

Literatura dodatkowa

[1] W.H. Press, S.A Teukolsky, W.T. Vetterling, B.P. Flannery — *Numerical Recipes 3rd Edition. The Art of Scientific Computing.*, New York, 2007, Cambridge University Press

12 Informacje o nauczycielach akademickich

Osoba odpowiedzialna za kartę

dr hab. Łukasz Bratek (kontakt: lukasz.bratek@pk.edu.pl)

Osoby prowadzące przedmiot

1 dr hab. Łukasz Bratek (kontakt: lukasz.bratek@pk.edu.pl)

13 Zatwierdzenie karty przedmiotu do realizacji

(miejscowość, data) (odpowiedzialny za przedmiot) (dziekan)

Przyjmuję do realizacji (data i podpisy osób prowadzących przedmiot)

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