Program: ECE **Faculty/College**: TGGS
Degree Level: Master

Course 090245342

Algorithmic Differentiation

King Mongkut's University of Technology North Bangkok
The Sirindhorn International Thai-German Graduate School of Engineering
Electrical and Computer Engineering Program

Section 1: General Information

1. **Course code and course title**

   090245342 Algorithmic Differentiation

2. **Total credits**

   3 credits ☐ (2-2-5) ☑ (3-0-6) ☐ (3-0-9) ☐ (2-3-7)

3. **Curriculum and course category**:

   Curriculum: *Master of Engineering in Electrical and Computer Engineering*

   Course category: Required Courses

   ☐ Core Course ☐ Specific Core Course
   ☐ Industrial Internship ☐ Master Thesis

   Elective Courses

   ☑ General Elective ☐ Specific Elective ☐ Other Elective

4. **Course coordinator/ Instructors**

   Course Coordinator: _____

   Instructor(s): Dr.rer.nat. Ekkapot Charoenwanit

5. **Semester/ year of study**

   ☐ Semester 1 (Aug. to Dec.) ☑ Semester 2 (Jan. to May) Academic Year: 2021

6. **Pre-requisite (if any)**

   ☑ No ☐ Yes, please provide: .....

7. **Co-requisites (if any)**

   ☑ No ☐ Yes, please provide: .....

8. **Venue of study**

   Lecture Day/Time: Thursdays at 09.00-12.00

   ☑ On-site: Lecture Room No.:… TBA…… Floor:……TBA…….
   ☑ TGGS, KMUTNB ☐ Faculty of Engineering, CU ☐ RWTH

   ☑ On-line*: Teaching Media: ☑ Microsoft Teams ☐ Google Meet
   ☐ Zoom ☐ Webex
   ☐ Other (specify) ……..….

9. Information for quality assurance in education

This course shows evidence of:

- ☐ Development of implementation from previous practices, e.g. the improvement of class teaching, course content, content classification and methods used for learning assessment
- ☐ Involvement from professional bodies/ external agencies in instruction; thus Enhancing student academic and professional experiences
- ☑ Integration of research or creative activities with instruction; use of research-based learning management; knowledge management practices for learning improvement
- ☐ Integration of academic services and course implementation
- ☐ Combination of cultural heritage preservation efforts into instruction or student activities

10. Date of latest revision:

28th July 2021

Section 2: Course Description and Implementation

1. Course Description

Finite difference method. Steepest descent algorithm. Newton's algorithm. Derivative code. Tangent and Adjoint modes of AD. High-order derivatives. Checkpointing strategies for adjoint mode of AD. Vertex elimination. Edge elimination. Face elimination. Parallelization strategies.

Number of hours per semester

Lecture	Practice	Self-study
45 hours/ semester (*3 hours/week**)	*30 hours* (*2 hours/week**)	*75 hours/ semester* (*5 hours/week**)

Remark: * *Based on 15 weeks of lecture*

Course Category: ☑ Lecture ☑ Practice ☑ Laboratory

Course Evaluation: ☑ A-F ☐ S/U ☐ P

3. Number of hours per week for academic guidance to individual students

☑ 1. Giving academic advice (minimum number of hours per week) during the office hours

☐ 1 ☐ 2 ☑ 3 ☐ 4 ☐ 5 ☐ .....

Wednesdays at 13.00-16.00

The students can arrange to have office hours at times other than the specified office hours by telephone or email.

☑ 2. Adopting information technology-based academic advising

☑ Email: ekkapot.c@tggs.kmutnb.ac.th

☑ Phone : 0971179626
(Do not distribute this mobile number without permission.)

☐ Communication Apps: Line ID:
(Please notify the lecturer before adding him/her.)

☐ Meeting Online: The platform will be informed to students upon request.

☐ Other (specify) ……...……

☐ 3. ……

4. Course Learning Outcomes (CLOs): Students should be able to:

CLO 1. To understand key mathematical concepts, namely, partial derivatives of multivariable functions and derivative-based numerical methods, etc.

CLO 2. To understand the forward mode and the reverse mode of algorithmic differentiation

CLO 3. To apply the knowledge of the forward mode and the reverse mode to generate computer programs that compute derivatives

CLO 4. To apply various software techniques that can enhance the performance of algorithmic differentiation

Remark: 1. Guidelines according to Bloom's Taxonomy is available at https://courses.dcs.wisc.edu/design-teaching/PlanDesign_Fall2016/2-Online-Course-Design/2_Learning-Objectives-Alignment/6_objectives_blooms-taxonomy.html

2. For the master level course, CLOs should be "apply" and "analyze" or possibly consider the doctoral CLOs "evaluate" and "create". "Remember" and "Understand" are for the undergraduate level courses, however, they can be implemented only at the beginning of the course.

3. CLOs can be defined as many as appropriate for the course.

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5. **The mapping between Expected Learning Outcomes (ELOs) from the curriculum and Course Learning Outcomes (CLOs)**

Table 5.1 ELOs-CLOs Consistency *(for a subject-specific course/ a specific curriculum)*

Remark: All ELOs and ELOs for the course (highlighted row) are as written in the Official Approved Curriculum.

ELOs/CLOs consistency	CLO 1	CLO 2	CLO 3	CLO 4
ELO1	✓	✓	✓	✓
ELO2	✓	✓	✓	✓
ELO3	✓	✓		
ELO4	✓	✓		
ELO5				
ELO6				
ELO7				
ELO8	✓	✓		
ELO9				
ELO10				

Table 5.2 Mapping desirable characteristics of KMUTNB graduates and CLOs *(for non-specific courses designed for various curriculums)*

Consistency between desirable characteristics of KMUTNB Graduates- CLOs	CLO 1	CLO 2	CLO 3	CLO 4
1. **Professional credentials with critical thinking skills**	✓	✓	✓	✓
2. **Integrity and social responsibility**				
3. **Innovative and technopreneur mindset**	✓	✓		
4. **Global Competence**	✓	✓		

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Section 3: Student Improvement in relation to Course Learning Outcomes (CLOs)

Organizing learning to develop skills/ knowledge; evaluation of CLOs in accordance with the ones identified in Section 2.4

Course Learning Outcomes (CLOs)	Teaching Methods compliant with CLOs	Evaluation Methods compliant with CLOs
CLO 1	• Lectures • Examples • In-class exercises • Individual assignments	• Assignment evaluation • Assessment of assigned exercises • Exams****
CLO 2	• Lectures • Examples • In-class exercises • Individual assignments	• Assignment evaluation • Assessment of assigned exercises • Exams****
CLO 3	• Lectures • Examples • In-class exercises • Individual assignments • Supervision session	• Assignment evaluation • Assessment of assigned exercises • Exams ****
CLO 4	• Lectures • Examples • In-class exercises • Individual assignments • Supervision sessions	• Assignment evaluation • Assessment of assigned exercises • Exams****

*Remark: * Lecture on the concept of the topic is introduced with basic or fundamental definitions, visualization, and correlations. For the complicated equation, the derivation from the basic laws can be shown to students. So, the students do not memorize the equations but understand the basic concept and basic equation. The lecturer will introduce the advanced and new concepts, technologies, and findings to students from publications such as journals and websites and from the research and industrial experiences.*

*** Active learning by asking questions related to the topic in the lecture and encouraging the students to respond to the questions. If the students cannot respond with answers, then the lecturer will give some guidance until the students can respond.*

**** Quiz in the closed-book format on the basic concepts and equations with simple problem solving to evaluate their learning. The solution will be given to students after grading, so they can identify their mistakes and weakness.*

***** Exam on the basic concepts and equations with simple problem-solving in the closed-book format as a review, whereas the complicated/integrated problem solving will be worked in the open-book format.*

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Section 4: Lesson Plan and Evaluation

1. **Lesson Plan**

Week	Topics/Details	CLOs	Hours	Learning and teaching activities; teaching media (if any)	Lecturer
1	Chapter 1: Motivation, Essential Calculus and Finite Differences	CLO 1	3.0	• Lecture presentation slides • Q&A • Examples • Assignment • Reading assignment	Ekkapot
2	Chapter 2: Derivative-Based Numerical Algorithms	CLO 1	3.0	• Lecture presentation slides • Q&A • Examples • Assignment • Reading assignment	Ekkapot
3	Chapter 3: First-Order Tangent Code by Hand	CLO 1 CLO 2 CLO 3	3.0	• Lecture presentation slides • Q&A • Examples • Assignment • Reading assignment	Ekkapot
4	Chapter 4: First-Order Tangent Code by Operator Overloading	CLO 1 CLO 2 CLO 3	3.0	• Lecture presentation slides • Q&A • Examples • Assignment • Reading assignment	Ekkapot
5	Chapter 5: First-Order Adjoint Code by Hand	CLO 1 CLO 2 CLO 3 CLO 4	3.0	• Lecture presentation slides • Q&A • Examples • Assignment	Ekkapot

				• Reading assignment	
6	Chapter 6: Intra- and Inter-procedural Adjoint Code	CLO 1 CLO 2 CLO 3 CLO 4	3.0	• Lecture presentation slides • Q&A • Examples • Assignment • Reading assignment	Ekkapot
7	Chapter 7: First-Order Adjoint Code by Operator Overloading	CLO 1 CLO 2 CLO 3 CLO 4	3.0	• Lecture presentation slides • Q&A • Examples • Assignment • Reading assignment •	Ekkapot
8	Chapter 8: Memory Issues with Adjoint Code, Checkpointing Techniques	CLO 1 CLO 2 CLO 3 CLO 4	3.0	• Lecture presentation slides • Q&A • Examples • Assignment • Reading assignment	Ekkapot
9	Midterm Exam	CLO 1 CLO 2 CLO 3 CLO 4	3.0	• Written Exam	Ekkapot
10	Chapter 9: Second- and Higher-order Derivative Code	CLO 1 CLO 2 CLO 3 CLO 4		• Lecture presentation slides • Q&A • Examples • Assignment • Reading assignment	
11	Chapter 10: Introduction to Elimination Techniques:	CLO 1 CLO 2 CLO 3	3.0	• Lecture presentation slides • Q&A • Examples	Ekkapot

	Vertex Elimination and Edge Elimination on Computational Graphs:	CLO 4		• Assignment • Reading assignment	
12	Chapter 11: Implementation of Elimination Techniques by Operator Overloading	CLO 1 CLO 2 CLO 3 CLO 4	3.0	• Lecture presentation slides • Q&A • Examples • Assignment • Reading assignment	Ekkapot
13	Chapter 12: Combinatorial Problems associated with AD	CLO 1 CLO 2 CLO 3 CLO 4	3.0	• Lecture presentation slides • Q&A • Examples • Assignment • Reading assignment	Ekkapot
14	Chapter 13: Applications of Parallel Computing to AD	CLO 1 CLO 2 CLO 3 CLO 4	3.0	• Lecture presentation slides • Q&A • Examples • Assignment • Reading assignment	Ekkapot
15	Final Exam	CLO 1 CLO 2 CLO 3 CLO 4	3.0	Written Exam	Ekkapot
		Total	45.0		

2. **Evaluation Plan** (**in accordance with OBE** 2 **mapping framework**)

Course Learning Outcomes (CLOs)	Evaluation Methods	Week of Evaluation	Percentage of Evaluation
CLO 1, 2, 3, 4	13 Assignments	1-8,10-14	70%
CLO 1, 2, 3, 4	2 Written Exams : Midterm 15% and Final 15%	9,15	30%

Section 5 Teaching/Learning Resources

Textbooks and materials

1. E. Charoenwanit Algorithmic Differentiation (Presentation Slides)

2. Uwe Naumann. 2012. The Art of Differentiating Computer Programs: An Introduction to Algorithmic Differentiation. Society for Industrial and Applied Mathematics, USA.

3. Andreas Griewank and Andrea Walther. 2008. Evaluating Derivatives: Principles and Techniques of Algorithmic Differentiation (Second. ed.). Society for Industrial and Applied Mathematics, USA.

Section 6 Course Evaluation and Improvement

1. **Course evaluation by students**

The students will have an opportunity to evaluate the effectiveness of the course in the form of paper-based surveys and group interviews at the end of each semester. The results of the survey and the interview including the grading will be reviewed by the curriculum committee to evaluate the course's effectiveness.

2. **Strategies for assessing learning management**

The students will have an opportunity to evaluate the teaching in the form of paper-based surveys and group interviews at the end of each semester. The results of the survey and the interview including the grading will be reviewed by the curriculum committee to evaluate the teaching. The lecturer will be informed of the evaluation for future improvements.

3. **Improvement schemes of course implementation**

The evaluation from the students including the grading will be submitted to the curriculum committee for reviewing and brainstorming to improve the teaching of each course. Comments and

suggestions given by the curriculum committee will be informed to the responsible lecturer of each course.

4. **Verification of students' learning outcomes, referred to OBE 2 and 3**

The grading of this course will be evaluated and reviewed by the Department meeting and the TGGS executive board meeting in order to verify its appropriateness before the final approval.

5. **Course review and improvement plans**

The results of the grading evaluation and student evaluation will be submitted to the curriculum committee for reviewing and brainstorming to improve the effectiveness of the offered courses. Comments and suggestions will be informed to the responsible lecturer of each course.