Annexe A: New/Revised Course Content in OBTL+ Format

Course Overview

The sections shown on this interface are based on the templates UG OBTL+ or PG OBTL+
If you are revising/duplicating an existing course and do not see the pre-filled contents you expect in the subsequent sections e.g. Course Aims, Intended Learning Outcomes etc. please refer to Data Transformation Status for more information.

Expected Implementation in Academic Year	AY2024-2025
Semester/Trimester/Others (specify approx. Start/End date)	Semester 2
Course Author * Faculty proposing/revising the course	Keen Mun Kelvin Yong
Course Author Email	kmyong@ntu.edu.sg
Course Title	Optimisation using Artificial Intelligence
Course Code	CB4246
Academic Units	3
Contact Hours	39
Research Experience Components	Not Applicable

Course Requisites (if applicable)

Pre-requisites	
Co-requisites	
Pre-requisite to	
Mutually exclusive to	
Replacement course to	
Remarks (if any)	

Course Aims

Optimisation has always been one of the main considerations in all industries. With the proliferation of data science and hence Artificial Intelligence (AI) in recent years, Optimisation using AI has become more popular and efficient. This course aims to provide you with the capability to perform optimisation using AI in your work/research or in your area of interest. You will first learn about the overview of optimisation using AI. You will then be equipped with the knowledge and skill to deploy machine learning tools for optimisation through hands on lessons via Python language over the Jupyter Notebook platform.

Course's Intended Learning Outcomes (ILOs)

Upon the successful completion of this course, you (student) would be able to:

ILO 1	An Overview of Optimisation using AI: Gain insight and understanding of optimisation through AI. Understand the fundamentals and essence of Data Science, AI, and Optimisation and their relationship with each other.
ILO 2	Python Language, Jupyter Notebook Basics and Exploratory Data Analysis: Perform Python programming through Jupyter Notebook for AI applications on optimisation. Perform data acquisition and analyse the data to identify their main characteristics through visualization tools.
ILO 3	AI Applications for Optimisation: Perform optimisation using supervised, unsupervised, reinforcement learning, AI search algorithms and deep learning tools.
ILO 4	Ethical Awareness and challenges of using AI for Optimisation: Identify the ethical issues of using AI for Optimisation and develop best practices. Explain and determine the key challenges of using AI for Optimisation.
ILO 5	Capstone Project Competency: Design, develop and evaluate optimisation solutions independently and as a team using AI tools taught.

Course Content

1. Introduction to Optimisation, Data Science and AI
2. Machine Learning and Deep Learning in AI
3. Basic Python Programming for AI applications via Jupyter Notebook
4. Exploratory Data Analysis
5. Optimisation using Unsupervised, Supervised and Reinforcement Learning techniques
6. Optimisation using Search Algorithms and Deep Learning techniques
7. Ethical Awareness of using AI for Optimisation
8. Challenges of using AI for Optimisation

Reading and References (if applicable)

1. Charu C. Aggarwal (2020). Linear Algebra and Optimization for Machine Learning: A Textbook. Springer.
2. Anand J. Kulkarni, Suresh Chandra Satapathy (2020). Optimization in Machine Learning and Applications. Springer.
3. Russell, S., & Norvig, P. (2021). Artificial intelligence: A Modern Approach. Global Edition. Pearson.
4. K.R. Chowdhary (2020), Fundamentals of Artificial Intelligence 1st Edition. Springer.
5. Tom Taulli (2019), Artificial Intelligence Basics: A Non-Technical Introduction. Apress.

Planned Schedule

Week or Session	Topics or Themes	ILO	Readings	Delivery Mode	Activities
1	Introduction to Optimisation, Data Science and AI and their relationship	1	Suggested Reading list [1] – [5]	In-person	Lecture, In-class problem-solving and Hands-on sessions
2	Introduction to Python Programming and Jupyter Notebook with AI applications	1,2	Suggested Reading: Any online reference related to python programming and Jupyter Notebook	In-person	Lecture, In-class problem-solving and Hands-on sessions
3	Optimisation using unsupervised, supervised learning techniques Part I	1-4	Suggested Reading list [1] – [5]	In-person	Lecture, In-class problem-solving and Hands-on sessions
4	Optimisation using unsupervised, supervised learning techniques Part II	1-4	Suggested Reading list [1] – [5]	In-person	Lecture, In-class problem-solving and Hands-on sessions
5	Optimisation using reinforcement learning techniques	1-4	Suggested Reading list [1] – [5]	In-person	Lecture, In-class problem-solving and Hands-on sessions

Week or Session	Topics or Themes	ILO	Readings	Delivery Mode	Activities
6	Optimisation using unsupervised, supervised, reinforcement learning techniques (Revision) and CA1:Assignment 1	1-4	Suggested Reading list [1] – [5]	In-person	Revision and Hands-on Assignment
7	Optimisation using AI Search Algorithms Part I	1-4	Suggested Reading list [1] – [5]	In-person	Lecture, In-class problem-solving and Hands-on sessions
8	Optimisation using AI Search Algorithms Part II	1-4	Suggested Reading list [1] – [5]	In-person	Lecture, In-class problem-solving and Hands-on sessions
9	Optimisation using AI Search Algorithms (Revision) and CA2: Assignment 2	1-4	Suggested Reading list [1] – [5]	In-person	Revision and Hands-on Assignment
10	Optimisation using Deep Learning	1-4	Suggested Reading list [1] – [5]	In-person	Lecture, In-class problem-solving and Hands-on sessions
11	Overall Revision and CA3: Quiz	1-4	Suggested Reading list [1] – [5]	In-person	Revision and Quiz
12	Capstone Project Discussion	1-5	Suggested Reading list [1] – [5]	In-person	Project discussion

Week or Session	Topics or Themes	ILO	Readings	Delivery Mode	Activities
13	CA4: Capstone Project Presentation	1-5	Suggested Reading list [1] – [5]	In-person	Project presentation and evaluation

Learning and Teaching Approach

Approach	How does this approach support you in achieving the learning outcomes?
Lecture	You will be exposed to the many knowledges and concepts systematically through lectures. You will also have the opportunities to clarify your questions during lectures.
Hands-on Lecture Tutorials	Hands-on Lecture Tutorials will provide you the chance to apply the concepts learnt through discussion and engagement with fellow classmates and instructor. This will also serve as a reference if you have understood each lecture.
Project Work	You will engage in project work with your fellow classmate outside class time to experience the real working environment of working on a task as a team to develop teamwork capabilities. You will also have a chance to discuss the project work with the instructor during class time to gather important and insightful feedback on the work for better learning experience.
Student Presentation	You will present your finalized project work to the class with Q&A from fellow classmates and instructor for holistic development and better understanding of the concepts used via feedback by instructor at end of the presentation assessment.

Assessment Structure

Assessment Components (includes both continuous and summative assessment)

No.	Component	ILO	Related PLO or Accreditation	Weightage	Team/Individual	Rubrics	Level of Understanding
1	Continuous Assessment (CA): Assignment(CA1: In-class Assignments 1)	1-4	a,b,c,d,e,g	5	Individual	Holistic	Relational
2	Continuous Assessment (CA): Assignment(CA2: In-class Assignments 2)	1-4	a,b,c,d,e,g	5	Individual	Holistic	Relational
3	Continuous Assessment (CA): Test/Quiz(CA3: In-class Online Quiz)	1-4	a,b,c,d,e,g	30	Individual	Analytic	Relational
4	Continuous Assessment (CA): Project(CA4: Capstone Project with In-class presentation)	1-5	a,b,c,d,e,g,h,i,k	60	Team	Analytic	Extended Abstract

Description of Assessment Components (if applicable)

CA1 and CA2: Challenging Assignment questions will be given during 2 separate lecture sessions (of equal weightage). You are required to finish each of them within 1 hour and submit in class using your own laptop.

CA3: You are required to finish and submit Online Quiz via NTULearn within 1 hour in class using your own laptop.

CA4: You are required to work in a 2 person team to design, develop, evaluate optimisation solutions using AI via project work. You are also required to submit a report and present your work as a team in class.

Formative Feedback

In-Class Assignments: Feedback will be provided to you as a class after proper evaluation of your submissions. The model answers will be discussed in the class, and you will also get to know the basic score statistics of the cohort taking the course.

Online Quiz: Feedback will be provided to you as a class after proper evaluation of your submissions. The answer of some questions (usually those where many students got it wrong) will be discussed in the class, and you will also get to know the basic score statistics of the cohort taking the course.

Capstone Project: You will be guided, and the instructor will also help you during the course of the project, as and when required. There will be many regular interactions with the instructor during class to provide you with constructive criticism and feedback.

NTU Graduate Attributes/Competency Mapping

This course intends to develop the following graduate attributes and competencies (maximum 5 most relevant)

Attributes/Competency	Level
Collaboration	Intermediate
Communication	Intermediate
Information Literacy	Basic
Critical Thinking	Intermediate
Design Thinking	Basic

Course Policy

Policy (Academic Integrity)

Good academic work depends on honesty and ethical behaviour. The quality of your work as a student relies on adhering to the principles of academic integrity and to the NTU Honour Code, a set of values shared by the whole university community. Truth, Trust and Justice are at the core of NTU's shared values. As a student, it is important that you recognize your responsibilities in understanding and applying the principles of academic integrity in all the work you do at NTU. Not knowing what is involved in maintaining academic integrity does not excuse academic dishonesty. You need to actively equip yourself with strategies to avoid all forms of academic dishonesty, including plagiarism, academic fraud, collusion and cheating. If you are uncertain of the definitions of any of these terms, you should go to the academic integrity website for more information. On the use of technological tools (such as Generative AI tools), different courses / assignments have different intended learning outcomes. Students should refer to the specific assignment instructions on their use and requirements and/or consult your instructors on how you can use these tools to help your learning. Consult your instructor(s) if you need any clarification about the requirements of academic integrity in the course.

Policy (General)

You are expected to complete all assessments, assigned readings, activities, assignments, attend all classes punctually and complete all scheduled assignments by due dates. You are expected to take responsibility to follow up with assignments and course related announcements. You are expected to participate in all project critiques, class discussions and activities.

Policy (Absenteeism)

Assessment activities will determine your course grade. Absence from any assessment without a valid Leave Of Absence (LOA) and without informing the instructor prior the assessment activity will be marked as "ABSENT" (0 marks) and will affect your final course grade significantly. There will be no make-up opportunities for missing the assessment activities.

Policy (Others, if applicable)

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Last Updated By: Yong Keen Mun Kelvin (Dr)

Appendix : Rubric/Assessment Criteria for Components listed in Assessment Table

Appendix 1: Assessment Criteria for In-Class Assignments (10%)

You will take 2 in-class assignments during the semester, based on the material covered during the lectures. Each assignment involves formulating and executing an AI solution for optimisation. It is graded out of 20 marks and contributes 5% to your total course score.

Appendix 2: Assessment Criteria for In-Class Quiz (30%)

You will take 1 online in-class quiz during the semester, based on the material covered during the lectures. This quiz is graded out of 60 marks and contributes 30% to your total course score.

Appendix 3: Assessment Criteria for Capstone Project (60%)

You will submit the program code(s) and a final report for the capstone project which illustrate your competency in the applications of AI for optimisation. You will need to do a presentation also for the capstone project. This capstone project will be graded out of 100 points and contributes to 60% of your total marks. Evaluation is as per the following rubrics.

(a) Team assessment (70%)

Criteria	Standards		
	Fail standard (0-40 %)	Pass standard (41-74 %)	High standard (75-100 %)
Identify the core definition of the problem, and plan the AI-driven solution.	Identifying completely wrong definitions of the problems, and planning solutions that are somewhat related but are not the actual solutions expected for the problems.	Identifying the correct and relevant definitions of the problems in line with the course materials, planning solutions reasonably in line with solutions expected for the problems, and trying to relate the course materials to the planned solutions. Accuracy and clarity can be further improved.	Identifying the correct and relevant definitions of the problems in line with the course materials, planning technically accurate steps for the solutions that are expected for the problems, and clearly connecting the course materials to the planned solutions.
Explore the data effectively and devise required AI-models to solve the problems.	Ad hoc analysis of the data and arbitrary steps in building the AI-model without properly connecting the concepts with	Logical exploration of the data that demonstrates a good understanding of the concepts from the course, and building AI-models with reasonable accuracy	Clear logical flow of data exploration of that demonstrates a good understanding of the concepts from the course (and beyond), and

	relevant concepts from the course. No or little evidence of critical evaluation of the proposed solution.	to solve the problems. Reasonable evidence of critical thinking related to the proposed solution, and producing solutions with some degree of intuition and justification (rigorous steps for AI-model building or validation of models and results may be missing).	building AI-models with high accuracy to solve the problems. Extensive evidence of critical thinking related to the proposed solution, and producing solutions with clear intuition and proper justification, including rigorous steps for AI-model building and validation of the models and results.
Overall Editorial Standard of the Solution and the Final Report.	Disorganised format and arrangement of the code and report, without any comment or little/no mention of references/resources.	Clear logical flow and well-formatted arrangement of the code and report, with all essential components. Reasonable comments and reasonable documentation of references /resources.	Clear logical flow and well-formatted arrangement of the code and report, with all essential components. Detailed set of technical comments to illustrate the choices made towards the solution, and to highlight the inferences. Proper documentation of references /resources.

(b) Individual assessment (10%)

Criteria	Standards		
	Fail standard (0-40 %)	**Pass standard (41-74 %)**	**High standard (75-100 %)**
Understanding of the Project	Little understanding of problem definition, solution techniques, data exploration and AI tools used in the project. Individual contribution is too low compared to the team-mates.	Decent understanding of problem definition, solution techniques, data exploration and AI tools used in the project. Individual contribution to the project is proportional to the team size and project difficulty.	Clear understanding of problem definition, solution techniques, data exploration and AI tools used in the project. Individual contribution to the project is significantly high compared to team-mates.

(c) Self and Peer assessment (20%)

Criteria (Weighs)	**Score from 1 to 9*** (**1**: Never; **3**: Rarely; **5**: Occasionally; **7**: Frequently; **9**: Always)	
(For 2-members team)	*Member A (Ownself)*	*Member B (Team Partner)*
Member name		
a. Fulfilling one's responsibilities duly (15%)		
Behaved responsibly--such as attend meetings punctually and regularly; participate in discussion; complete assigned tasks/roles punctually.	*Score from 1 to 9*	
	Qualitative comments/reasons	
b. Fulfilling one's responsibilities effectively (25%)		
Behaved and contributed effectively--such as quality of work produced; creativity of ideas; extensiveness of research and thinking.	*Score from 1 to 9*	
	Qualitative comments/reasons	
c. Managing interpersonal relationships (30%)		
Listened attentively to and sought inputs from others; helped team resolve conflicts and achieved common understanding to function effectively; promoted respect for others and differences; fostered camaraderie.	*Score from 1 to 9*	
	Qualitative comments/reasons	
d. Providing support to others to achieve goals (30%)		
Behaved fairly and ethically—such as sharing responsibilities and giving credits. Exhibited group citizenship behavior--such as helping others to learn and complete their work through guidance and	*Score from 1 to 9*	
	Qualitative comments/reasons	

encouragement; standing up for others when needed.		

* Score of 1 should be given only when a team member does not really deserve to be awarded any mark for the team assignment (i.e., zero mark) because the member either has not or has barely participated and/or contributed to the team assignment in any meaningful manner.

Mapping of Course ILOs to EAB Graduate Attributes

Course Code & Title	(CB4246) Optimisation using Artificial Intelligence
Course Type	Elective Module

Overview											
(a)	●	(b)	●	(c)	◐	(d)	◐	(e)	●	(f)	
(g)	◐	(h)	○	(i)	○	(j)		(k)	●		

Legend:

●	Fully consistent (contributes to more than 75% of Student Learning Outcome)
◐	Partially consistent (contributes to about 50% of Student Learning Outcome)
○	Weakly consistent (contributes to about 25% of Student Learning Outcome)
Blank	Not related to Student Learning Outcome

Course ILOs		**EAB Graduate Attributes**
1	An Overview of Optimisation using AI: Gain insight and understanding of optimisation through AI. Understand the fundamentals and essence of Data Science, AI, and Optimisation and their relationship with each other.	a,b,e,g,k
2	Python Language, Jupyter Notebook Basics and Exploratory Data Analysis: Perform Python programming through Jupyter Notebook for AI applications on optimisation. Perform data acquisition and analyse the data to identify their main characteristics through visualization tools.	a,b,c,d,e

3	AI Applications for Optimisation: Perform optimisation using supervised, unsupervised, reinforcement learning, AI search algorithms and deep learning tools.	a,b,c,d,e,g.k
4	Ethical Awareness and challenges of using AI for Optimisation: Identify the ethical issues of using AI for Optimisation and develop best practices. Explain and determine the key challenges of using AI for Optimisation.	b,g,k
5	Capstone Project Competency: Design, develop and evaluate optimisation solutions independently and as a team using AI tools taught.	a,b,c,d,e,g,h,i,k

EAB Graduate Attributes

a) **Engineering Knowledge**: Apply the knowledge of mathematics, natural science, computing and engineering fundamentals, and an engineering specialisation as specified in WK1 to WK4 respectively to the solution of complex engineering problems.

b) **Problem Analysis**: Identify, formulate, research literature, and analyse complex engineering problems reaching substantiated conclusions using first principles of mathematics, natural sciences, and engineering sciences with holistic considerations for sustainable development. (WK1 to WK4)

c) **Design / Development of Solutions**: Design creative solutions for complex engineering problems and design systems, components or processes that meet identified needs with appropriate consideration for public health and safety, whole-life cost, net zero carbon as well as resource, cultural, societal, and environmental considerations as required. (WK5)

d) **Investigation**: Conduct investigations of complex problems using research-based knowledge (WK8) and research methods including design of experiments, analysis and interpretation of data, and synthesis of the information to provide valid conclusions.

e) **Modern Tool Usage**: Create, select and apply appropriate techniques, resources, and modern engineering and IT tools including prediction and modelling to complex engineering problems, with an understanding of the limitations. (WK2 and WK6)

f) **The Engineer and the World**: When solving complex engineering problems, analyse and evaluate sustainable development impacts to: society, the economy, sustainability, health and safety, legal frameworks and the environment (WK1, WK5, and WK7).

g) **Ethics**: Apply ethical principles and commit to professional ethics and responsibilities and norms of engineering practice and adhere to relevant national and international laws. Demonstrate an understanding of the need for diversity and inclusion (WK9).

h) **Individual and Collaborative Team Work**: Function effectively as an individual, and as a member or leader in diverse and inclusive teams and in multidisciplinary, face-to-face, remote and distributed settings (WK9).

i) **Communication**: Communicate effectively and inclusively on complex engineering activities with the engineering community and with society at large, such as being able to comprehend and write effective reports and design documentation, make effective presentations, and give and receive clear instructions, taking into account cultural, language, and learning differences.

j) **Project Management and Finance**: Demonstrate knowledge and understanding of engineering management principles and economic decision-making, and apply these to one's own work, as a member and leader in a team, to manage projects and in multidisciplinary environments.

k) **Life-long Learning**: Recognise the need for, and have the preparation and ability to (i) engage in independent and life-long learning, and (ii) adapt to new and emerging technologies, and (iii) think critically, in the broadest context of technological change (WK8).

No	Knowledge Profile
WK1	A systematic, theory-based understanding of the natural sciences applicable to the discipline and awareness of relevant social sciences
WK2	Conceptually-based mathematics, numerical analysis, data analysis, statistics and formal aspects of computer and information science to support detailed analysis and modelling applicable to the discipline
WK3	A systematic, theory-based formulation of engineering fundamentals required in the engineering discipline
WK4	Engineering specialist knowledge that provides theoretical frameworks and bodies of knowledge for the accepted practice areas in the engineering discipline; much is at the forefront of the discipline
WK5	Knowledge including efficient resource use, environmental impacts, whole-life cost, re-use of resources, net zero carbon, and similar concepts that supports engineering design and operations in a practice area
WK6	Knowledge of engineering practice (technology) in the practice areas in the engineering discipline
WK7	Knowledge of the role of engineering in society and identified issues in engineering practice in the discipline such as the professional responsibility of an engineer to public safety and sustainable development.
WK8	Engagement with selected knowledge in the current research literature of the discipline, awareness of the power of critical thinking and creative approaches to evaluate emerging issues
WK9	Knowledge of professional ethics, responsibilities, and norms of engineering practice. Awareness of the need for diversity by reason of ethnicity, gender, age, physical ability etc with mutual understanding and respect, and of inclusive attitudes

Reference: EAB Accreditation Manual