國立中正大學 資訊工程學系 課程大綱
Undergraduate School Course - EMI Course Syllabus
National Chung Cheng University

<table>
<tr><td>中文課程名稱
(Chinese Course Name)</td><td>機器學習數學分析概論</td><td>開課單位
(Department)</td><td>資訊工程學系暨研究所
(Department of Computer Science and Information Engineering)</td></tr>
<tr><td rowspan="3">英文課程名稱
(English Course Name)</td><td rowspan="3">Introduction to the Mathematical Analysis of Machine Learning</td><td>課程代碼
(Course code)</td><td>114_2_4104073_01</td></tr>
<tr><td>上課時間
(Time)</td><td>週四 E節、F節 13:15－16:00
(Thursday 13:15－16:00)</td></tr>
<tr><td>上課地點
(Location)</td><td>EA205
(Room 205 at College of Engineering I)

校園地圖(Campus Map):
https://ccu-navigation.ccu.edu.tw/app/index.php</td></tr>
<tr><td rowspan="2">授課教師
(Instructor)</td><td rowspan="2">江宗韋
(Tsung-Wei Chiang)</td><td>學分數
(Credits)</td><td>3</td></tr>
<tr><td>授課語言
(Language)</td><td>全英文授課/無限修人數

(EMI Course /
Taught in English /
No Enrollment Limit)</td></tr>
<tr><td>必/選修
(Required/Selected)</td><td>□必修(Required)
☑選修(Selected)</td><td>開課年級
(Level)</td><td>大三大四選修
(Elective for junior and senior undergraduate students)</td></tr>
<tr><td>課程屬性/類別
(Course type)</td><td colspan="3">□人文關懷課程 (Humanistic Care Courses)
□競賽專題課程 (Competition-Based Project Courses)
□問題導向課程 (Problem-Based Learning Courses / PBL)
□專題導向課程 (Project-Based Learning Courses / PjBL)
□總整課程 (Capstone Courses)
□實作課程 (Hands-on Courses / Practical Courses)
□實習 (Internship / Practicum)
☑其他</td></tr>
<tr><td>先修科目或先備能力
(Prerequisites)</td><td colspan="3">修習過基礎機率論及線性代數等相關課程
(Basics of probability theory and linear algebra)</td></tr>
</table>

課程概述 (Course Descriptions)	本課程旨在引領學生初步探索機器學習的核心理論及其數學分析方法。本課程內容將會介紹機器學習中重要理論工具與基礎數學原理，包含：機器學習的可學習性、模型複雜度、泛化界、穩定性、一致性及收斂率等重要理論概念與分析。課程應用線性代數、微積分、機率統計與最佳化理論知識，著重培養學生嚴謹的理論思維，並介紹如何運用精確的數學技巧來分析機器學習問題。該課程特別適合希望藉由數學工具深入解析機器學習數學原理的學生修習。由於本課程聚焦於機器學習理論及其數學原理，不涵蓋各種機器學習演算法或模型的具體介紹，因此學生可另外搭配相關機器學習演算法或AI實務課程一同修讀，以獲得該領域全面的知識學習體驗。 (This course is designed to guide students in initially exploring the core theories and mathematical analysis methods underlying machine learning. The curriculum introduces essential theoretical tools and mathematical principles in machine learning, including learnability, model complexity, generalization bounds, stability, consistency, and convergence rates, among other key concepts and analyses. Drawing upon knowledge from linear algebra, calculus, probability and statistics, and optimization theory, the course emphasizes the development of rigorous theoretical thinking and demonstrates how to apply precise mathematical techniques to analyze machine learning problems. This course is particularly suited for students who wish to delve rigorously into the mathematical foundations of machine learning using robust mathematical tools. As the focus is on theoretical principles and mathematical foundations rather than on introducing various machine learning algorithms or models, students are encouraged to complement their studies with related courses on machine learning algorithms or practical AI applications for a more complete learning experience.)
學習目標 (Learning Objectives)	1. 了解機器學習的入門核心理論與重要理論基礎概念。(Understand the introductory core theories and essential foundational machine learning concepts.) 2. 具備透過數學分析思維來思考機器學習問題、具備初步閱讀相關理論研究文獻之能力。(Develop the ability to approach machine learning problems through mathematical analytical thinking and acquire the preliminary skills to read related theoretical research literature.) 3. 建立系統性的分析方法思維，為進一步研究與應用機器學習奠定堅實的理論與數學分析基礎。(Establish a systematic analytical methodology and mindset that provides a solid theoretical and mathematical foundation for further research and applications in machine learning.)
教科書及參考資料 (Textbooks and Reference)	1. Mehryar Mohri, Afshin Rostamizadeh, and Ameet Talwalkar, Foundations of Machine Learning, MIT Press, 2nd Edition, 2018. 2. Shai Shalev-Shwartz and Shai Ben-David, Understanding Machine Learning: From Theory to Algorithms, Cambridge University Press, 2014.

課程大綱(Course Syllabus)		大約分配時數 (Approximate Number of Hours)	核心能力 (Core Capabilities)
單元主題(Topic)	內容綱要(Content)	講授 (Lecture)	
1. Introduction	Introduction to machine learning theory	3	☑ 1.1 ☑ 1.2 ☑ 1.3 □ 2.1 □ 2.2 ☑ 2.3 ☑ 3.1 □ 3.2 ☑ 3.3 □ 4.1 □ 4.2
2. Mathematical Tools for Analysis	Review of linear algebra, convex optimization, probability, and inequalities.	3	☑ 1.1 ☑ 1.2 ☑ 1.3 □ 2.1 □ 2.2 ☑ 2.3 ☑ 3.1 □ 3.2 ☑ 3.3 □ 4.1 □ 4.2

3. Analysis of Learnability	Notion of learnability, probably approximately correct learning, sample complexity, and examples.	6	☑ 1.1 ☑ 1.2 ☑ 1.3 □ 2.1 □ 2.2 ☑ 2.3 ☑ 3.1 □ 3.2 ☑ 3.3 □ 4.1 □ 4.2
4. Analysis of Complexity	Vapnik-Chervonenkis dimension, Natarajan dimension, Rademacher complexity, growth function, and examples.	7	☑ 1.1 ☑ 1.2 ☑ 1.3 □ 2.1 □ 2.2 ☑ 2.3 ☑ 3.1 □ 3.2 ☑ 3.3 □ 4.1 □ 4.2
5. Analysis of Generalization Bounds	Generalization error upper bounds, generalization error lower bounds, empirical risk minimization, and examples.	7	☑ 1.1 ☑ 1.2 ☑ 1.3 □ 2.1 □ 2.2 ☑ 2.3 ☑ 3.1 □ 3.2 ☑ 3.3 □ 4.1 □ 4.2
	Midterm Exam	3	☑ 1.1 ☑ 1.2 ☑ 1.3 □ 2.1 □ 2.2 □ 2.3 ☑ 3.1 □ 3.2 □ 3.3 □ 4.1 □ 4.2
6. Analysis of Stability	Infinite VC dimension, perturbation sensitivity, uniform stability, relationship between stability and learnability, relationship between stability and generalization.	6	☑ 1.1 ☑ 1.2 ☑ 1.3 □ 2.1 □ 2.2 ☑ 2.3 ☑ 3.1 □ 3.2 ☑ 3.3 □ 4.1 □ 4.2
7. Analysis of Consistency	Bayes' optimal classifier, surrogate function, separation mechanism, and examples.	7	☑ 1.1 ☑ 1.2 ☑ 1.3 □ 2.1 □ 2.2 ☑ 2.3 ☑ 3.1 □ 3.2 ☑ 3.3 □ 4.1 □ 4.2
8. Analysis of Convergence	Deterministic optimization, stochastic optimization, gradient descent, convergence rate, and iteration complexity.	6	☑ 1.1 ☑ 1.2 ☑ 1.3 □ 2.1 □ 2.2 ☑ 2.3 ☑ 3.1 □ 3.2 ☑ 3.3 □ 4.1 □ 4.2
9. Other Advanced Topics (Optional/ 彈性教學主題)	Online learning, batch learning, regret, regret bounds, full information, bandits, and other advanced topics.	6	☑ 1.1 ☑ 1.2 ☑ 1.3 □ 2.1 □ 2.2 ☑ 2.3 ☑ 3.1 □ 3.2 ☑ 3.3 □ 4.1 □ 4.2

備註(Notes)：
本課程大綱為目前之規劃內容，可能因國定假日、不可預期之停課、演習或其他特殊情況而調整；相關異動將另行公告，並以實際上課公告為準。授課教師將視情況提供適切之課程安排與教學內容。(This syllabus reflects the current course plan and may be adjusted due to national holidays, unforeseen class suspensions, drills, or other special circumstances. Any changes will be announced through official course channels. The instructor will make appropriate adjustments to course arrangements and instructional content as needed.)

教育目標
(Educational Objectives)

1.專業基礎知識. 使學生擁有扎實的專業基礎知識，成為資訊及相關領域的專業人才(Professional Foundation Knowledge: Equip students with a solid foundation in their field, preparing them to become professionals in information technology and related disciplines.)

2.培養創造能力. 使學生具有運用所學到的各種專業知識與理論以科學的方法解決問題與創新(Cultivate Creative Abilities: Enable students to apply the knowledge and theories they have learned to solve problems and innovate using scientific methods.)

3.自我挑戰能力與終身學習. 讓學生習於自我挑戰、獨立思考，學會思維創新、領導及組織團隊、有效溝通、終身學習之能力(Self-Challenge and Lifelong Learning: Encourage students to embrace challenges and independent thinking, and to develop skills in innovative thinking, leadership, team organization, effective communication, and lifelong learning.)

4.社會人文素養與國際視野. 讓學生具備關懷社會的情操與人文素養，並具國際觀，奉獻社會國家及人類(Social and Cultural Literacy with a Global Perspective: Instill in students a caring attitude towards society and a strong cultural literacy, while fostering an international outlook that empowers them to contribute to their communities, nation, and humanity.)

核心能力
(Core Competencies)

1. 具有資訊工程相關基礎知識之吸收與了解的能力(Capability to grasp foundational knowledge in computer science.)
2. 具有運用資訊工程理論及應用知識，分析與解決相關問題的能力(Capability to use computer science theory and application knowledge to analyze and solve related problems.)
3. 在資訊工程的許多領域中，具有至少某一項專業能力，例如：硬體、軟體、多媒體、系統、網路、理論等(Professional in at least one area, including hardware, software, multimedia, system, networking, and theory.)
1. 具有資訊工程實作技術及使用計算機輔助工具的能力(Capability to perform computer science implementations and use computer-aided tools.)
2. 具有設計資訊系統、元件或製程的能力(Capability to design computer systems, components, or processes.)
3. 具有科技寫作與簡報的能力。(Capability to write and present technical materials.)
1. 具有除了已有的應用領域之外，亦可以將自己的專業知識應用於新的領域或跨多重領域，進行研發或創新的能力。(Capability to apply one's professional knowledge to a new application domain or across multiple different application domains.)
2. 具有領導或參與一個團隊完成一項專案任務的能力並且具有溝通、協調與團隊合作的能力。(Capability to lead or participate in group projects, with effective communication, coordination, and teamwork.)
3. 具有因應資訊科技快速變遷之能力，培養自我持續學習之能力。(Capability to adapt to rapidly changing computer science technology and to develop self-learning capabilities.)
1. 具有社會責任、人文素養及奉獻精神。(The awareness of social responsibilities, humanity, and contribution.)
2. 具有工程倫理、宏觀能力、國際觀及前瞻視野。(The awareness of engineering ethics, broad capabilities, and global and contemporary vision.)

教學要點概述 (Teaching Key Points Overview)	
教材編選 (Teaching Materials)	☑自製簡報(Self-prepared presentation slides) ☑課程講義(Lecture handouts) ☑其他(Others)
教學方法 (Teaching Methods)	☑講述(Blackboard-based and slide-based instruction) ☑其他(Others)
評量工具 (Evaluation Tools)	☑上課點名(Attendance) 10% ☑隨堂作業(Assignments) 30% ☑期中考(Midterm Exam) 30% ☑期末報告(Final Report) 30% (書面報告/Written Report)
教學資源 (Teaching Resources)	☑課程網站(Course website) ☑教材電子檔供下載(Digital materials for download)

教師 相關訊息 (Instructor’s Information)	全英文授課。 (This course will be taught in English.) 請學生尊重智慧財產權及使用正版教科書。 (Students should respect intellectual property rights and use authorized textbooks.)
教學相關配合事項 (Course Relative Information)	所有作業、考試及報告均禁止抄襲。任何學生若被發現有抄襲行為，將自動視為課程不及格。 (Plagiarism is strictly prohibited for all homework, exams, and assignments. Any student found engaging in plagiarism will automatically fail the course.)

課程目標與教育核心能力相關性 (Relationship between Course Objectives and Core Educational Competencies)	
請勾選：☑ 1.1 ☑ 1.2 ☑ 1.3 ☐ 2.1 ☐ 2.2 ☑ 2.3 ☑ 3.1 ☐ 3.2 ☑ 3.3 ☐ 4.1 ☐ 4.2	
1.1	具有資訊工程相關基礎知識之吸收與了解的能力(Capability to grasp foundational knowledge in computer science.)
	為何有關(Why Relevant)： 機器學習理論是一個建立在資訊工程基礎知識之上的領域。掌握這門課的理論基礎知識能夠幫助學生理解人工智慧領域中涉及的數學原理與理論工具，例如可學習性、模型複雜度及泛化界等概念。此外，這項能力對於深入學習和應用機器學習理論至關重要，可為未來或研究所階段從事更高階的研究與專業實踐打下堅實的基礎。(Machine learning theory builds on core modern computer science knowledge. Mastering its theoretical fundamentals enables students to grasp essential mathematical principles and tools, such as learnability, model complexity, and generalization bounds, underpinning artificial intelligence. This competency is crucial for advanced research and professional practice.)
	達成指標(Achievement Indicators)： 成績由作業、期中考試與期末報告決定。研究生必須取得70分以上，而大學部學生必須超過60分才能及格。(Grades are determined by assignments, midterm exam, and the final (project) report. Graduate students must achieve a score of over 70, and undergraduates must exceed 60 to pass.)
	評量方法： 隨堂作業、期中考與期末報告。 等級5：考試成績達到80分以上。 等級4：考試成績達到70分以上。 等級3：考試成績達到60分以上。 等級2：考試成績達到50分以上。 等級1：考試成績未達50分。 Assessment Methods： Assessment Criteria for Assignments, Midterm Exam, and the Final (Project) Report: • Level 5: Submission of 80% of assignments and an anticipated semester grade of 80 points or above, or a report grade of 80 points or above. • Level 4: Submission of 60% of assignments and an anticipated semester grade of 70 points or above, or a report grade of 70 points or above. • Level 3: Submission of 40% of assignments and an anticipated semester grade of 60 points or above, or a report grade of 60 points or above. • Level 2: Submission of 20% of assignments and an anticipated semester grade of 50 points or above, or a report grade of 50 points or above. • Level 1: No assignment submissions or an anticipated semester grade of less than 50 points, or a report grade of less than 50 points.
	具有運用資訊工程理論及應用知識，分析與解決相關問題的能力(Capability to use computer science theory and application knowledge to analyze and solve related problems.)

	為何有關(Why Relevant)： 本課程聚焦於機器學習的核心理論與基礎數學原理，其數學分析方法與關鍵概念能夠使學生更有效地利用所學之數學工具進行深入的理論推導與實證分析，為日後在解決實際機器學習問題時提供必要的方法論與技術基礎。(This course covers the core theories of machine learning and its foundational mathematics. It equips students with analytical methods to rigorously derive and empirically analyze key concepts, providing essential methodologies for tackling real-world challenges in the future.)
1.2	達成指標(Achievement Indicators)： 學生在作業、期中考試及期末報告中展示運用理論及數學工具探索機器學習問題的分析能力。評量標準將以作業、考試和報告成績為依據，研究生需達70分以上，大學部學生需達60分以上。(Students will demonstrate their ability to analyze machine learning problems using theoretical and mathematical tools through assignments, a midterm exam, and a final report. Evaluation is based on these components, with graduate students needing at least 70 and undergraduates at least 60 to pass.)
	評量方法(Assessment Methods)： 同核心能力1.1中之評量方法(Same as the Assessment Criteria outlined in Core Competencies 1.1.)
1.3	在資訊工程的許多領域中，具有至少某一項專業能力，例如：硬體、軟體、多媒體、系統、網路、理論等。(Professional in at least one area, including hardware, software, multimedia, system, networking, and theory.)
	為何有關(Why Relevant)： 在機器學習理論分析中，具備資訊工程的理論頗析專業能力與數學量化分析知識，並有助於跨領域知識應用，從而有效解決複雜近代AI學科問題。(In machine learning theoretical analysis, possessing specialized theoretical skills in computer science facilitates the application of interdisciplinary knowledge, thereby effectively solving complex contemporary AI problems.)
	達成指標(Achievement Indicators)： 同核心能力1.1中之達成指標(Same as the Achievement Indicators outlined in Core Competencies 1.1.)
	評量方法(Assessment Methods)： 同核心能力1.1中之評量方法(Same as the Assessment Criteria outlined in Core Competencies 1.1.)
2.3	具有科技寫作與簡報的能力(Capability to write and present technical materials.)
	為何有關(Why Relevant)： 學生必須提交一份期末專題報告。報告主題可依教師提供的方向選定，或聚焦於當代與前沿機器學習理論分析的某一小子題，透過研讀與比較討論，練習提出獨到見解。報告需以英文科技寫作撰寫。本任務旨在培養學生的科技寫作能力，促進跨領域知識整合，並提升其獨立進行專題研究與解決複雜問題的核心能力。(Students are required to submit a final project report. The report topic may be chosen based on teacher-provided guidelines or focus on a specific subtopic within contemporary and cutting-edge machine learning theoretical analysis, allowing for in-depth study and comparative discussion to foster original insights. The report must be written in technical English. This assignment is designed to cultivate students' technical writing skills, promote the integration of interdisciplinary knowledge, and enhance their core competencies in independently conducting research projects and solving complex problems.)
	達成指標(Achievement Indicators)： 同核心能力1.1中之達成指標(Same as the Achievement Indicators outlined in Core Competencies 1.1.)
	評量方法(Assessment Methods)： 同核心能力1.1中之評量方法(Same as the Assessment Criteria outlined in Core Competencies 1.1.)
	具有除了已有的應用領域之外，亦可以將自己的專業知識應用於新的領域或跨多重領域，進行研發或創新的能力(Capability to apply one's professional knowledge to a new application domain or across multiple different application domains.)

3.1	為何有關(Why Relevant)： 在學習機器學習理論與數學分析的過程中，學生掌握資訊工程與人工智慧的核心技術，並在期末報告中探討如何將理論分析與數學原理應用於醫療、金融、製造、教育等新興領域。透過跨領域整合，學生提出創新解決方案，推動技術創新。(In studying machine learning theory and mathematical analysis, students master core techniques in computer science and artificial intelligence and explore in their final report how to apply theoretical analysis and mathematical principles to emerging fields such as healthcare, finance, manufacturing, and education. Through interdisciplinary integration, they propose innovative solutions that drive technological innovation.)
	達成指標(Achievement Indicators)： 同核心能力1.1中之達成指標(Same as the Achievement Indicators outlined in Core Competencies 1.1.)
	評量方法(Assessment Methods)： 同核心能力1.1中之評量方法(Same as the Assessment Criteria outlined in Core Competencies 1.1.)
3.3	具有因應資訊科技快速變遷之能力，培養自我持續學習之能力(Capability to adapt to rapidly changing computer science technology and to develop self-learning capabilities.)
	為何有關(Why Relevant)： 隨著資訊科技快速發展，本課程強調堅實理論基礎和系統性分析方法，使學生能迅速掌握技術趨勢和新興概念，並應用機器學習理論於深度學習理論之數學分析，以保持競爭力。(In the rapidly evolving field of information technology, this course emphasizes a solid theoretical foundation and systematic analytical methods, enabling students to quickly grasp technological trends and emerging concepts, and to apply machine learning theory to deep learning analysis to maintain competitiveness.)
	達成指標(Achievement Indicators)： 同核心能力1.1中之達成指標(Same as the Achievement Indicators outlined in Core Competencies 1.1.)
	評量方法(Assessment Methods)： 同核心能力1.1中之評量方法(Same as the Assessment Criteria outlined in Core Competencies 1.1.)