Artificial Intelligence and Machine Learning: Advanced Applications of Neural Networks and Deep Learning

LMH Summer Programmes are provided by Lady Margaret Hall, a college in the University of Oxford

Course:	Artificial Intelligence and Machine Learning: Advanced Applications of Neural Networks and Deep Learning
Available:	Programme Session 2: 17th July to 4th August 2023
Lectures:	18 Hours
Seminars:	12 Hours
Tutorials:	3 Hours
Independent Study:	Approximately 120 Hours
Recommended Credit:	15 CATS / 7.5 ECTS / 4 US Credits

About this Course:	In our age of burgeoning smart technology and automation we are already seeing the transformative potential of Artificial Intelligence and Machine Learning in fields as diverse as finance, medicine, and manufacturing. In this course students who are already familiar with the key theoretical foundations of Artificial Intelligence and Machine Learning will dive deeper into the exciting capabilities of this area of research and its applications in three streams. First, you will explore Generative Deep Learning and, working with the MNIST and CIFAR-10 datasets, train networks to produce new synthetic samples which appear to belong to the datasets. Secondly, you will learn to design and train Graph Neural Networks, a class of deep learning methods designed to be applied to structured data on irregular grids, such as social network data. Finally, you will look at applications of Reinforcement Learning, a method utilised when you do not have data, but do have access to the data generation process, such as when training a robot to interact with its environment and achieve an objective. This course provides students with an introduction to these advanced topics of Artificial Intelligence and Machine Learning, and provides a solid foundation for future advanced study in the field.
Course Overview:	Generative Deep Learning • Definitions of Generative and Autoregressive Models. • Autoencoders and variational autoencoders. • Generative Adversarial Networks. • Diffusion Models.

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	Graph Neural Networks
	• Definitions of Graph Machine Learning.
	• Classic Machine Learning on Graphs:
	  ○ Random Walk
	  ○ PageRank
	• Graph Neural Networks:
	  ○ Permutation Invariance/Equivariance
	  ○ Neural Message Passing
	  ○ Training Neural Networks
	  ○ Graph Sampling
	• PyTorch Geometric:
	  ○ Hands-on Graph Neural Networks
	  ○ Node Classification with Graph Neural Networks
	  ○ Graph Classification with Graph Neural Networks
	Reinforcement Learning
	• The fundamentals of Reinforcement Learning and Planning in sequential decision problems.
	• Dynamic Programming
	  ○ Policy Iteration
	  ○ Value Iteration.
	• Markov Decision Processes
	• Sample-Based Learning Algorithms (eg (double) Q-Learning, SARSA).
	• Deep Reinforcement Learning.

Key Texts:	Bishop, C.M., *Pattern Recognition and Machine Learning*, 2006, New York. Goodfellow, I., Bengio, Y., and Courville, A., *Deep Learning*, 2016, Cambridge MA.
Learning Outcomes:	By studying this course you will: • Be able to assess appropriate Machine Learning techniques and methodologies to be applied to diverse and complex problems. • Understand how to use Generative Deep Learning tools to train networks to produce synthetic samples of a dataset. • Learn to design and train Graph Neural Networks. • Understand varied applications of Reinforcement Learning.
Admissions Requirements:	LMH Summer Programmes are designed for students who want to gain and develop knowledge in their chosen subject area. LMH Summer Programmes are intensive courses of study aimed at undergraduates who have completed one, two, or three years of their degree, or entry level postgraduate students. We will consider each applicant's academic ability and expect successful applicants to have a minimum grade point average equivalent to 2:1 level on the British grading scale. For example, this would mean at least a 3.2 GPA on the 4.0 grading scale in the United States, and 80% in China. **This course would suit students who are already familiar with the key theoretical foundations of Artificial Intelligence and Machine Learning and wish to expand and further their knowledge and experience. Students must have a good understanding of:** • **Neural Networks** • **Convolutional Neural Networks** • **Deep Learning Libraries** • **Optimization**

	• **Numerical Linear Algebra** **Students who take *Artificial Intelligence and Machine Learning: Theory and Practice* in Session 1 will be prepared to take this course in Session 2.** To participate fully in the programme all students will need to have proficiency in English. English language requirements for students who are not native English speakers: • Overall TOEFL score of 85; • or IELTS score of 6.5 (no less than 6.0 in each component); • or CET-4 at 550 or CET-6 at 520. If the language of instruction in your home institution is English you do not need to provide evidence of your English proficiency.
Teaching Methods:	Core syllabus material will be covered in lectures. Students attend four lectures each week and each lecture lasts 90 minutes. Seminars in smaller groups offer students space to discuss and debate, to dig deeper into difficult concepts, and to explore their own ideas. Student contribution to seminars is vital, and tutors will ensure everyone takes part in discussions. Seminars last 2 hours and students will take part in two seminars each week. Independent study is a crucial part of an LMH Summer Programme and of the Oxford teaching model. Tutors will recommend important reading to do between lectures and seminars that will enable students to come to class equipped to understand the information presented and prepared to take part in discussion and debate. Each week students will have an assignment of independent work to complete and submit in advance of the tutorial. There is an appropriate amount of space in the timetable to complete the necessary reading, preparation, and assignments. Students should expect to do around 40 hours of independent study each week. The final class each week is a tutorial, a very small class typically including only 2-4 students and central to the teaching methods used by the University of Oxford and on LMH Summer Programmes. Guided by their tutor, students will receive feedback on their assignments and be challenged to defend, justify, or even rethink their work and ideas. These rigorous academic discussions help develop and facilitate learning in a way that cannot be done with lectures and seminars alone.
Assessment:	On a three-week LMH Summer Programme students produce one piece of assessed work every week, which is submitted to the tutor and then discussed in a tutorial. At the end of each week students will receive a percentage grade for their submitted work. Each week's work counts for a third of the final percentage grade, so the final grade is an average of the mark received for each piece of work. Students who stay for six or nine weeks will receive a separate grade for each 3-week course.
Academic Credit:	Lady Margaret Hall will provide a transcript of students' assessed work, and can send this directly to your home institution if required. LMH Summer Programmes are designed to be eligible for academic credit, and we will communicate with home institution to facilitate this as needed. As a guide, we recommend the award of 15 CATS / 7.5 ECTS / 4 US Credits for each 3-week course.