Subject Description Form

Subject Code	EIE570
Subject Title	Deep Learning with Photonics
Credit Value	3
Level	5
Pre-requisite/ Co-requisite/ Exclusion	N/A
Objectives	1. To introduce the fundamental concepts, and design principles in deep learning and optoelectronic devices. 2. To introduce the state-of-the-art modelling methods in deep learning and photonic devices. Rebuild photonic neural networks with the frontier papers of the scientific community.
Intended Learning Outcomes	Upon completion of the subject, students will be able to: Category A: Professional/academic knowledge and skills a. Understand and describe the physical-layer features of neural network structures. b. Understand the fundamental concepts/laws in photonics devices. c. Understand why the combination of the two disciplines will have great potentials for next generation information technology. Category B: Attributes for all-roundedness d. Communicate effectively. e. Think critically and creatively. f. Assimilate new technological development in related field.
Subject Synopsis/ Indicative Syllabus	1. Primer on Deep Learning (DL) 1-1 The overview and organization of the course 1-2 Matrix and Linear regression 1-3 Gradient descent 1-4 The cost function 1-5 Supervised Learning & Unsupervised Learning Exercise1: Install the DL environments Exercise2: Demonstration of file & matrix operation 2. Implementation of the neural network 2-1 Introduction of TensorFlow (TF) 2-2 Neural Networks Part 1: Setting up the Architecture 2-3 Neural Networks Part 2: Setting up the Data and the Loss pre-processing 2-4 Neural Networks Part 3: Learning and Evaluation 2-5 Neural Networks Part 4: Minimal Neural Network Case Study Exercise3: Install and Build the TF network Exercise4: Demonstrate handwriting number recognition 3. Primer on photonic devices 3-1 Fundamental optical laws

3-2 Diffractive grating and lens

3-3 Mach-Zhender Interferometer (MZI) array matrix

3-4 MicroRing Resonator (MRR) array matrix

3-5 Nonlinear devices

Exercise5: Simulation of the diffractive grating and lens

Exercise6: Simulation of MZI and MRR

4. Case study I: Inverse design for photonic devices

4-1 Inverse design principles

4-2 Direct Binary Search (DPS) method

4-3 Adjoined method

4-4 The forward & backward simulation

4-5 The prediction of optical waveguide modal information

Exercise7: Inverse design the beam splitter with DBS method

Exercise8: Inverse design the beam splitter with adjoin method

Exercise9: Demonstration of inverse design for optical waveguide design

5. Case study II: All-optical Diffractive Deep Neural Networks (D2NN)

5-1 The diffraction formula

5-2 The diffractive neural network configuration

5-3 The forward & backward propagation

5-4 The cost function

5-5 The training & validation procedure

Exercise10: Build the D2NN with TF

Exercise11: Demonstration of D2NN for handwriting number recognition

Teaching/Learning Methodology

The physical-layer characteristics of all-optical deep neural networks will be described and explained in lectures. Advantages of photonic computation will be presented in lectures. Modelling of photonic deep learning systems will be conducted during the class through the exercises. Students will also be required to study one photonic deep learning systems, share their findings with other classmates through presentations.

Teaching/Learning Methodology	Intended Subject Learning Outcomes					
	a	b	c	d	e	f
Lectures	✓	✓	✓		✓	
Exercises	✓	✓	✓	✓	✓	✓
Case study and presentation	✓	✓	✓	✓	✓	✓

Assessment Methods in Alignment with Intended Learning Outcomes

Specific assessment methods/tasks	% weighting	Intended subject learning outcomes to be assessed (Please tick as appropriate)					
		a	b	c	d	e	f
1. Assignments	20%	✓	✓			✓	
2. Exercises	30%	✓	✓	✓	✓	✓	✓
3. Mini projects	20%	✓	✓	✓		✓	
4. Tests	30%	✓	✓	✓		✓	✓
Total	100%						

	Explanation of the appropriateness of the assessment methods in assessing the intended learning outcomes: **Assignments:** let students review the taught materials, do further reading for deeper learning and understand better of the taught knowledge. Students may find these reading useful and will practice the obtained knowledge in the associated exercises and mini projects. **Exercises:** Exercises are designated based on projects to evaluate whether the students are proficient in the taught knowledge to solve the practical problem. Students need to bring a laptop to the classroom and may conduct literature research on the topics. Mutual discussions are encouraged in order to summarize the findings in a presentation. **Mini projects:** Students will need to finish the given mini projects during the class. Students can share their ideas and views about photonic neural networks through discussions. **Tests:** Tests will evaluate student's understanding and usage of deep learning with photonics.

Student Study Effort Expected	Class contact:	
	▪ Lectures/Tutorials	26 Hrs.
	▪ Case study and report	13 Hrs.
	Other student study effort:	
	▪ Further reading, doing homework/assignment and preparing for the subject.	66 Hrs.
	Total student study effort	105 Hrs.

Reading List and References	1. Prucnal, P. , Shastri, B. (2017) Neuromorphic Photonics. CRC Press, https://doi.org/10.1201/9781315370590. 2. Yao, K., Unni, R. & Zheng, Y. (2019). Intelligent nanophotonics: merging photonics and artificial intelligence at the nanoscale. Nanophotonics, 8(3), pp. 339-366. Retrieved 21 Mar. 2020, from doi:10.1515/nanoph-2018-0183 3. Ferreira de Lima, T., Shastri, B., Tait, A., et al. (2017). Progress in neuromorphic photonics. Nanophotonics, 6(3), pp. 577-599. Retrieved 21 Mar. 2020, from doi:10.1515/nanoph-2016-013 4. Molesky, S., Lin, Z., Piggott, A.Y. et al. Inverse design in nanophotonics. Nature Photonics 12, 659–670 (2018). https://doi.org/10.1038/s41566-018-0246-9