Subject Description Form

Subject Code	EIE6207
Subject Title	Theoretical Fundamental and Engineering Approaches for Intelligent Signal and Information Processing
Credit Value	3
Level	6
Pre-requisite / Co-requisite/ Exclusion	The student is expected to have background knowledge of University Mathematics in his/her 1st and/or 2nd year of undergraduate studies. In particular, s/he is expected to have a fundamental understanding of basic statistics, calculus, signals and linear systems.
Objectives	The subject covers mathematical techniques and application examples applicable to electronic and information engineering, particularly in the areas of image and video technology, speech and audio processing, pattern recognition, telecommunications, opto-electronics, acoustics, and electronic circuits. After the completion of this subject, the student should acquire some good engineering approaches, mathematical and optimization techniques to carry out academic research and hi-tech R&D work in the above areas.
Intended Learning Outcomes	**Upon completion of the subject, students will be able:** Category I: Professional/academic knowledge and skills 1. to understand the theories behind the subject materials and be able to apply them for research and practical applications, including (i) matrix fundamentals, analysis and applications, (ii) probability and statistical signal processing, and (iii) engineering approaches for optimization, classifications, and estimation. 2. to master these advanced/essential techniques for modern engineering or research work, and 3. to develop efficient realization algorithms or systems for electronic and information engineering applications, which enable them to accept modern design/realization challenges in the future. Category II: Attributes for all-roundedness 4. to present ideas and findings effectively. 5. to think critically. 6. to learn independently.

Subject Synopsis/ Indicative Syllabus	**1. Matrix Analysis** • Overview of linear algebra • Eigenvalues and eigenvectors • Diagonalization of matrices • Change of basis and similarity transformations • Generalized eigenvectors/eigenvalues • Exponential function of matrix • Pseudo-inverse for non-square matrix • Singular value decomposition • Jordan canonical, Quadratic and Hermitian forms • Matrix norms and their properties • Functions of matrices • State-space representation • Solution of the state equation • Controllability and observability **2. Applications of Matrix Analysis** • Network/traffic flow analysis • Leontief input-output model analysis • Matrix fundamentals for election analysis. • Transformation, data fitting and data compression using singular value decomposition. • The controller designs using state-space methods. **3. Probability and Stochastic Processes** • Functions of random variables • Multivariate Gaussian distributions • Power spectral density • Wide-sense stationarity, strict sense stationarity. **4. Estimation and Prediction** • Maximum likelihood and Bayesian estimation. • Minimum mean square error (MMSE) estimation. • Kalman filtering **5. Machine Learning and Deep Learning** • Constrained Optimization o Equality and inequality constraints o Duality o Lagrange multipliers o Support vector machines • Clustering o K-means algorithm o Gaussian mixture models o EM Algorithm • Subspace Modeling o Principal component analysis o Linear discriminant analysis o Factor analysis • Bayesian Methods o Bayes theorem o Bayesian inference o Bayes classifiers • Deep Learning and deep neural networks o Deep neural networks o Convolutional neural networks o Stochastic gradient descent and backpropagation o Feature learning o Recurrent neural networks and LSTM

Teaching/Learning Methodology

Lectures:

Matrix analysis, probability, statistical signal processing, optimization, machine learning and deep learning are delivered to students.

Tutorials:

Students will be able to clarify concepts and to have a deeper understanding of the lecture material via tutorial questions; problems and application examples are given and discussed.

Lab Exercises:

In the lab exercises, students will have the chance to apply the deep learning concepts they learn in lectures to build AI systems. In particular, they will construct and evaluate a handwritten digit recognition system using the Nvidia Jetson TX2 Developer Kit. Students will also use the kit and a webcam to perform real-time object recognition and handwritten digit recognition. Students need to submit a lab report to discuss their findings and observations.

Teaching/Learning Methodology	Intended Subject Learning Outcomes					
	1	2	3	4	5	6
Lectures	✓	✓	✓		✓	✓
Tutorials	✓	✓	✓		✓	✓
Labs	✓	✓	✓	✓	✓	✓

Assessment Methods in Alignment with Intended Learning Outcomes

Specific assessment methods/ tasks*	% weighting	Intended subject learning outcomes to be assessed (Please tick as appropriate)					
		1	2	3	4	5	6
1. Test	20%	✓	✓			✓	✓
2. Examination	60%	✓	✓			✓	
3. Lab	20%	✓	✓	✓	✓	✓	✓
Total	100%						

Student Study Effort Expected

Class contact:	
▪ Lecture	26 Hours
▪ Tutorial	10 Hours
▪ Lab	3 Hours
Other student study effort:	
▪ Self-study and write-up	63 Hours
Total student study effort	102 Hours

Reading List and References	**References:** 1. M.W. Mak and J.T. Chien, *Machine Learning for Speaker Verification*, Cambridge University Press, 2020. 2. S.Y. Kung, M.W. Mak and S.H. Lin, *Biometric Authentication: A Machine Learning Approach*, Prentice Hall, 2005. 3. C. Bishop, *Pattern Recognition and Machine Learning*, Springer, 2006. 4. S.J.D. Prince, *Computer Vision: Models Learning and Inference*, Cambridge University Press, 2012. 5. M.W. Mak, "Lecture Notes on Factor Analysis and I-Vectors", *Technical Report and Lecture Note Series*, Department of Electronic and Information Engineering, The Hong Kong Polytechnic University, Feb. 2016. http://www.eie.polyu.edu.hk/~mwmak/papers/FA-Ivector.pdf 6. Sheldon Ross, *A First Course in Probability*, 6th Edition, Prentice Hall, 2002. (chapters 2 & 4-8) 7. R. D. Yates & D. J. Goodman, *Probability and Stochastic Processes: A Friendly Introduction for Electrical and Computer Engineers*, Prentice Hall, ISBN 0471178373. (chapters 6 & 10) 8. M. H. Hayes, *Statistical Digital Signal Processing and Modeling*, Wiley, 1996. ISBN-0-471-59431-8 (chapter 7.1-7.3) 9. M.J. Zaki and W. Meira Jr., *Data Mining and Analysis*, Fundamental Concepts and Algorithms, Cambridge University Press, 2014. 10. V. Britanak, P. Yip and R. Rao, *Discrete Cosine and Sine Transforms*, Academic Press, Inc., 2007. 11. G. Strang, *Introduction to linear algebra*, Vol. 3. Wellesley, MA: Wellesley-Cambridge Press, 1993. G. Strang, Introduction to Linear Algebra, 2009. 12. G. Strang, Computational Science and Engineering, 2007. 13. David C. Lay, Linear Algebra and its Applications, Fourth Edition, Pearson/Addison-Wesley, 2011. ISBN-13: 978-0321385178. 14. Roger A. Horn and Charles R. Johnson, Matrix Analysis, 2nd Edition, Cambridge University Press, 2012. 15. Selected reading from recent issues of IEEE Transactions on Image Processing, Pattern Analysis and Machine Intelligence, Circuits and System for Video Technology, Signal Processing; Pattern Recognition, Proceedings of ICASSP, ICIP, CVPR and IRE Proceedings.