SCSE MPEs courses for AY22-23 Semester 1

CE/CZ4003 – Computer Vision

Academic Year	AY2022-2023	**Semester**	1	
Instructor(s)	Qian Kemao (mkmqian@ntu.edu.sg) Lu Shijian (shijian.lu@ntu.edu.sg)			
Course Code	CE/CZ4003			
Course Title	Computer Vision			
Pre-requisites	Study Year 3			
Pre-requisite for	NIL			
No of AUs	3			
Contact Hours	Lectures/TEL	26	Tutorials	13

Course Aims

This course aims to introduce you the basic concepts and technologies of computer vision, and develop skills to implement widely used algorithms to process real vision tasks. This course presents you with digital image acquisition, representation, processing, recognition, and 3D reconstruction, to gain understanding of algorithm/system design, analytical tools, and practical implementations of various computer vision applications. You will be equipped with fundamental knowledge, practical skills and the insights for future development in this area.

Intended Learning Outcomes (ILO)

Upon the successful completion of this course, students shall be able to:

1. Describe the fundamental computer vision concepts.
2. Explain the advantages and disadvantages of the common computer vision techniques.
3. Implement the basic computer vision algorithms.
4. Apply computer vision techniques to solve simple real problems.

SCSE MPEs courses for AY22-23 Semester 1

Overview of Course Content

	Topics
1	**Introduction to Computer Vision** Background and applications
2	**Principles of Camera Systems** Imaging systems, basic thin-lens optics, digitisation, image representation
3	**Image Enhancement in the Spatial Domain** Histogram operations, linear and nonlinear filtering
4	**Image Enhancement in the Frequency Domain** Fourier transform, low-pass, high-pass and band-pass filters
5	**Colour** Basics of colour
6	**Edge Processing** Edge representations, edge filtering, Canny edge detection, Hough transform
7	**Region Processing** Region representations, thresholding, texture-based segmentation
8	**Imaging Geometry** 3D Coordinate Systems, camera perspective projection, camera parameters and calibration
9	**3D Stereo Vision** Parallax and 2D triangulation, appearance-based matching and feature-based matching, 3D reconstruction
10	**Object Recognition** Supervised and unsupervised learning, bag-of-words model for general object recognition

Assessment (includes both continuous and summative assessment)

Component	Weightage	Team/Individual
1. Final Examination	60%	Individual
2. Project 1	20%	Individual
3. Project 2	20%	Individual
Total	100%	

SCSE MPEs courses for AY22-23 Semester 1

CE/CZ4010 – Applied Cryptography

Academic Year	AY2022-2023	**Semester**	1	
Instructor(s)	Tay Kian Boon (kianboon.tay@ntu.edu.sg)			
Course Code	CE/CZ4010			
Course Title	Applied Cryptography			
Pre-requisites	CE/CZ1011 or CE/CZ2100 Study Year 3			
Pre-requisite for	NIL			
No of AUs	3			
Contact Hours	Lectures/TEL	26	Tutorials	12

Course Aims

Summary: Cryptography is the foundational building block of Cybersecurity and Privacy. While the field of classical cryptography dealt with security and privacy of data in transit, the modern take on the subject has generalised the scope of its applications to ensuring security and privacy of all forms of digital communication, computation, automation, interaction, transaction and preservation. Thus, it is important to understand the technical aspects of cryptography to appreciate its applications in cybersecurity.

The Aim: This cryptography course in Computer Science and Engineering aims to develop your ability to understand how cryptographic algorithms work, to identify the problems associated with the application of cryptography in real-world scenarios, and explain the operation of various cryptographic mechanisms. This course will equip you to know deeply the fundamentals of symmetric key ciphers, hash functions and public key ciphers, enabling you to understand and develop secure cryptography solutions in real life cryptography. It will also introduce you to popular cryptographic libraries and APIs for hands-on implementation of security mechanisms, and some prominent cryptographic standards, guidelines and frameworks from the industry and government bodies.

Intended Learning Outcomes (ILO)

Upon the successful completion of this course, students shall be able to:

1. Explain and analyse the design and construction of fundamental cryptographic algorithms.
2. Discuss and explain the construction of cryptographic mechanisms based on the algorithms.
3. Design and develop basic security applications using open cryptographic libraries and APIs.
4. Analyse and argue the applicability of cryptographic schemes in certain real-world systems.
5. Examine and describe the importance of cryptographic standards, guidelines and frameworks in practice.

Overview of Course Content

	Topics
1	**Introduction to Cryptography** Network Security, Computer Security and System Security and the connection of Cryptology; Related concepts: Steganography, Cryptanalysis; Cryptography Terminology: Encrypt, decrypt, plaintext, ciphers, keys & keyspace, cryptography, cryptanalysis, cryptology; Historical Cryptography: Caesar (Monoalphabetic) Ciphers, Vigenere (Polyalphabetic) Ciphers, Electromechanical Encryptor e.g. ENIGMA; Random Numbers, pseudorandom number generators, NIST tests for randomness; Modern Cryptography
2	**Symmetric (Private) Key Cryptography** Concept of one-time pad; Introduction to stream ciphers –Ciphers based on Linear Feedback Shift Register, RC4 cipher; Introduction to Block Ciphers (DES, AES)-Secure Implementations of Symmetric Key Cryptosystems; Key Agreement & key Management; Modes of operation for Encryption (e.g. ECB, CBC modes) and Message Authentication (CBC-MAC, HMAC)
3	**Hash Functions (unkeyed)** Concept of checksum, message digest, digital signatures; Hash Function Concept (one way hash, collision resistance, birthday attack}, MD5, SHA1, SHA-256, KECCAK
4	**Symmetric Cryptography in Practice (e-learning)** E.g. Open Libraries (NaCl) and APIs (PKCS11, Microsoft CSP); Efficient implementation of File Encryption using the APIs/Libs.
5	**Asymmetric (Public) Key Cryptography** Concept of Public Key Cryptography; Design ideas based on Hard Problems (Factoring, Discrete Log); Diffie-Hellman Key Exchange; Design and construction of Public Key Encryption-RSA cryptosystem; Implementing RSA cryptosystem securely; Comparison of Key Lengths recommended for the constructions; Introduction to Elliptic Curve Cryptography (ECC)
6	**Digital Signatures** Concept of Digital Signature in asymmetric key cryptography; Design and construction of Digital Signature schemes (RSA, DSA)
7	**Other Cryptographic Mechanisms** Introduction to secret sharing schemes; Introduction to Side Channel Attacks
8	**Introduction to Quantum Cryptography & Post Quantum Crypto Algorithms** Key Exchange using quantum cryptography; Post quantum crypto algorithms-e.g. NTRU
9	**Cryptographic Standards/Topics** SSL/TLS Transport Layer Security protocol-Some Weak TLS Implementations of crypto algorithms & protocol in real world; Some Cryptographic algorithm standards (e.g. ISO/IEC, NIST); Industry standards/guidelines, e.g., Banking (ANSI, ISO, MAS); Security Frameworks like CCITT, ISO/IEC, IETF, PKCS, etc.
10	**Other Practical Concerns** Open Libraries (OpenSSL) and APIs (PKCS11, Microsoft CSP); Dealing with crypto vendors – need for crypto acceptance tests

Assessment (includes both continuous and summative assessment)

Component	Weightage	Team/Individual
1. Quiz	30%	Individual
2. Project	30%	Team and Individual
3. Final Examination	40%	Individual
Total	100%	

SCSE MPEs courses for AY22-23 Semester 1

CE/CZ4016 – Advanced Topics in Algorithms

Academic Year	AY2022-2023	**Semester**	1			
Instructor(s)	Zinovi Rabinovich (zinovi@ntu.edu.sg) He Ying (yhe@ntu.edu.sg)					
Course Code	CE/CZ4016					
Course Title	Advanced Topics in Algorithms					
Pre-requisites	CE/CZ2001: Algorithms Study Year 3					
Pre-requisite for	NIL					
No of AUs	3					
Contact Hours	Lectures/TEL	24	Tutorials	11	Quizzes	4

Course Aims

This course aims to develop your ability to identify key structural components in algorithms, problems and domains alike, and to exploit them to create provably computationally efficient solutions. This course builds on basic skills obtained in the prerequisite "Algorithms" course to broaden the range of analysis techniques that you use; provide you with intricate, elegant and actionable algorithmic design patterns; and develop your skill in exploiting salient problem features to facilitate computation.

Algorithms and designs presented in this course were at the beginning of multiple disciplines that now dominate the IT industry, and serve as a stepping stone for your further development for such roles as an algorithms engineer/developer or an applied researcher in computer technologies.

Intended Learning Outcomes (ILO)

Upon the successful completion of this course, students shall be able to:

1. Analyse, classify and compare algorithms and problems from the computational effort point of view.
2. Exploit recurring, dynamic and geometric problem structures to facilitate computation.
3. Recognise limitations of exact computational methods, and exploit the benefits of error tolerance.

Overview of Course Content

	Topics
0	**Overview** Brief overview of concepts and associated problems. Drivers and motivation, including practical links, for principles covered by the course.
1	**Analysis Techniques** Asymptotic bounds on performance of a given algorithm. Solving recurrences, substitution method, iteration method, master theorem for recurrence equations.
2	**Lower Bounds** Bounds on unspecified algorithms for a given problem. Lower bounds on search and sorting by comparison.
3	**NP-Completeness** Problem classes, and their associated computational complexity. P and NP, decision and optimisation problems, reductions and reducibility, NP-hardness and NP-completeness.
4	**Dynamic Programming** Exploiting problem sub-structure to facilitate computation. Optimal sub-structure and memorisation, sub-problem dependency graph. Dynamic programming instances as design patters: longest common subsequence, optimal matrix multiplication, rod-cutting-style variations.
5	**Search Techniques** Ad-hoc search methods and heuristics antecedent. Backtracking and branch-and-bound. Knapsack and assignment problem design pattern.
6	**Computational Geometry** Exploiting geometric embedding of a problem. Polygon triangulation, convex hulls in two dimensions, motion planning. Mathematical primer on convexity.
7	**Min-Cut/Max-Flow** Exploiting problem embedding as a commodity flow in a graph. Fold-Fulkerson method, and Edmonds-Karp variation. Maximum bipartite matching, additional applications as design patterns.
8	**Approximation Algorithms and Heuristics** Exploiting error tolerance to facilitate computation. Heuristic (ad-hoc) vs approximate (error bound) algorithms. Approximate solutions to TSP, set covering, knapsack and scheduling as design patterns.
9	**Randomised Algorithms** Monte Carlo and Las Vegas randomisation style of algorithms. Randomised Quicksort, hashing and Bloom filters, string matching.
10	**Material Review** Extended Q/A sessions, presentation of examples that require a combination of techniques.

Assessment (includes both continuous and summative assessment)

Component	Weightage	Team/Individual
1. Final Examination	50%	Individual
2. Written Quizzes (4x1h)	50%	Individual
Total	100%	

SCSE MPEs courses for AY22-23 Semester 1

CE/CZ4022 – Wireless and Mobile Networks

Academic Year	AY2022-2023	**Semester**	1	
Instructor(s)	Yeo Chai Kiat (asckyeo@ntu.edu.sg)			
Course Code	CE/CZ4022			
Course Title	Wireless and Mobile Networks			
Pre-requisites	CE3005 Computer Networks or CZ3006 Net Centric Computing Study Year 3			
Pre-requisite for	NIL			
No of AUs	3			
Contact Hours	Lectures/TEL	26	Tutorials	13

Course Aims

This course builds upon the foundation network knowledge gained from core courses on Computer Networks (CE3005) or Net Centric Computing (CZ3006). It aims to introduce to the realm of mobile communications made possible through wireless technologies. It provides a straightforward and broad survey of wireless voice and data network standards and technologies available today for personal communications. It is designed for those taking an entry-level wireless technology course or seeking better knowledge of wireless communications and networks. The topics include the technologies being harnessed in Bluetooth and Bluetooth Low Energy to Wifi to cellular telephony and mobile data to 5G wireless technologies to satellite communications. The course content thus span wireless personal networks (WPAN), wireless local area networks (WLAN) and wireless wide area networks (WWAN).

Intended Learning Outcomes (ILO)

Upon the successful completion of this course, students shall be able to:

1. Describe, explain and evaluate the fundamental components and technologies of wireless mobile communication systems.
2. Describe, explain, discuss and analyse the requirements of, as well as issues and challenges on mobile communication systems.
3. Describe, explain, discuss and analyse the effects of mobility on the communication system and how the impacts and impairments can be alleviated and resolved.
4. Factor, analyse and evaluate the various issues, techniques and technologies in the design and development of mobile applications and communication networks.

Overview of Course Content

	Topics
1	**Fundamentals of Wireless Mobile Communications** Fundaments of wireless communication systems: enabling concepts and challenges; components of a wireless communication system; radio frequency transmission, data and carrier signal components; channel bandwidth and data rate; signal propagation (SNR, attenuation, multipath distortion, noise), data transmission (modulation, common channel models, fading mitigation, spread spectrum, multiple access – FDMA, TDMA, CDMA).
2	**Overview of Mobile Networks** Introduction to different types of mobile networks e.g. WPAN, WLAN, WWAN, Ad Hoc networks, MANETS, Meshed networks, vehicular networks, sensor networks etc.
3	**Wireless Personal Area Networks (WPAN)** Bluetooth technology: applications, classes, network topology, standards, transmission; Bluetooth Low Energy (BLE); Introduction to ZigBee, Near Field Communication (NFC), Wearable Technologies.
4	**Wireless Local Area Networks (WLAN)** IEEE 802.11 standards; WLAN modes; Media Access Control; MAC Layer Operations; Transmission Technology; Wireless Propagation Problems; Wifi Mesh System, Wifi Range Extender, Applications.
5	**Wireless Wide Area Networks (WWAN)** Cellular communications network: network components; Switching Technology; Organisation; Channel reuse; Mobility Management, Handoff; Roaming; Generations of Cellular Technologies. 5G networks. Satellite communications network: Transmission, Service and Type, Satellite Systems, Satellite internet; Applications e.g. GPS, DGPS, Wifi in flight.
6	**Revision**

Assessment (includes both continuous and summative assessment)

Component	Weightage	Team/Individual
3. Tests	80%	Individual
4. Assignment	20%	Individual
Total	100%	

CE/CZ4023 – Advanced Computer Networks

Academic Year	AY2022-2023	**Semester**	1	
Instructor(s)	Dusit Niyato (niyato@ntu.edu.sg) Tan Rui (tanrui@ntu.edu.sg)			
Course Code	CE/CZ4023			
Course Title	Advanced Computer Networks			
Pre-requisites	CE3005: Computer Networks or CZ3006: Net-Centric Computing Study Year 3			
Pre-requisite for	NIL			
No of AUs	3			
Contact Hours	Lectures/TEL	26	Tutorials	10

Course Aims

Building upon earlier courses (CE3005 or CZ3006), this subject aims to bring students into the realm of real inter-networking. The subject consists of two complementary components. On one hand, several application layer protocols are to be explained, along with their requirements on the underlying networks. One the other hand, practical network design and management methodologies will be introduced; they aim at meeting the application requirements. Emphasis is mostly placed on the practical use and construction of networks, with a bias toward multimedia applications. Advanced materials, such as, peer-to-peer networking will also be covered to prepare the students well for the future career in advanced computer networks.

Intended Learning Outcomes (ILO)

Upon the successful completion of this course, students shall be able to:

1. Identify and explain several application layer protocols and what they may demand from the underlying networks.
2. Identify and explain networks design and management to satisfy various application requirements
3. Conduct quick protocol performance analysis and making critical design decisions
4. Design a network to support a given set of requirements
5. Review new technologies and perform literature review related to advanced and emerging computer network technologies

Overview of Course Content

	Topics
1	**Top-Down View of Computer Networks** Recapitulate the concepts, emphasising on the Internet structure (edge, core, access), as well as multiplexing, fragmentation, and delay.
2	**Application Layer Protocols** Concepts of Application layer protocols; Application layer protocols such as HTTP and SMTP; Network management architecture and protocols (e.g., SNMP); Peer-to-protocols.
3	**Multimedia Networking** Multimedia applications; Voice-over-IP; Session protocols (e.g. SIP and H.323); Real-Time Streaming Protocol (RTSP), Real-Time Protocol (RTP) and Real-Time Control Protocol (RTCP).
4	**Advanced Network Protocols** Multi-protocol Label Switching (MPLS) protocols; IP Multicasting architecture and protocols.
5	**QoS and Traffic Management** Quality of Services (QoS) requirements, Best-effort service, Integrated services, Differentiated services. Introduction to traffic management techniques, Connection Admission Control, Traffic Shaping and Policing, and Scheduling.
6	**Network Deployment and Design** Practical issues in designing commonly used computer networks, ranging from home network to enterprise networks. Some focuses will be given to design wireless networks or hybrid wired-wireless networks.

Assessment (includes both continuous and summative assessment)

Component	Weightage	Team/Individual
1. Term Paper	30%	Individual
2. Quiz 1 (Part 1)	35%	Individual
3. Quiz 2 (Part 2)	35%	Individual
Total	100%	

SCSE MPEs courses for AY22-23 Semester 1

CE/CZ4031 – Database System Principles

Academic Year	AY2022-2023	**Semester**	1 & 2	
Instructor(s)	Long Cheng (c.long@ntu.edu.sg) Sourav S Bhowmick (ASSourav@ntu.edu.sg)			
Course Code	CZ4031			
Course Title	Database System Principles			
Pre-requisites	CZ2007: Introduction to Databases Study Year 3			
Pre-requisite for	CZ4033: Advanced Data Management			
No of AUs	3			
Contact Hours	Lectures/TEL	26	Tutorials	13

Course Aims

Database management systems (DBMS) are designed to manage large and complex data sets. The fundamentals of the implementation of database management systems must be understood by all Computer Science students. This will help students to develop and design software systems utilising databases, and equip students with the knowledge of managing data of large scale. Moreover, this should be understood by current and future business leaders so that they can offer strategic guidance based on an informed understanding of database business capabilities. This course provides the basis for achieving this goal.

Intended Learning Outcomes (ILO)

Upon the successful completion of this course, students shall be able to:

1. Discuss the importance of, and uses for, databases within organisations.
2. Explain how a relational database is implemented.
3. Describe the principles behind commercial databases and how to manage a relational database system.
4. Communicate knowledgeably about data management using professional language.

Overview of Course Content

	Topics
1	**Overview of Database Management Systems (DBMS)** DBMS Architecture, Relational DBMS
2	**Storage of Relational Data** Memory Hierarchy, Disks, Representing Relations in Disks, Using Secondary Storage Effectively, How to Move Data to Memory
3	**Indexing Techniques** Indexes on Sequential Files, Secondary Indexes, B-Trees, Hashing, Multi-dimensional Indexes (R-Trees, kD Trees)
4	**Query Processing** One-Pass Algorithms, Nested-Loop Joins, Two-Pass Algorithms based on Sorting and Hashing, Index-Based Algorithms, Algebraic Laws
5	**Query Optimisation** Introduction to Physical Query Plan Operators, Logical Query Plans, Physical Query Plans, Join Ordering
6	**Failure Recovery** Modelling Resilient Operations, Undo/Redo Logging, Checkpoint, Recoverability, Recovery process
7	**Transaction Management and Concurrency Control** Transactions, Serial and Serialisable Schedules, Conflict-Serialisability, Locking, Resolving Deadlocks

Assessment (includes both continuous and summative assessment)

Component	Weightage	Team/Individual
1. Quizzes (Three)	60%	Individual
2. Projects (Two)	40%	Team and individual
Total	100%	

SCSE MPEs courses for AY22-23 Semester 1

CZ4032 – Data Analytics and Mining

Academic Year	AY2022-2023	**Semester**	1				
Instructor(s)	Cong Gao (gaocong@ntu.edu.sg) Lin Guosheng (gslin@ntu.edu.sg)						
Course Code	CZ4032						
Course Title	Data Analytics and Mining						
Pre-requisites	CE/CZ2001-Algorithms Study Year 3						
Pre-requisite for	NIL						
No of AUs	3						
Contact Hours	Lectures/TEL	26	Tutorials	11	Student Presentations	4	

Course Aims

In the era of big data, large quantities of data are being accumulated. The amount of data collected is said to double every nine months. Seeking knowledge from massive data is one of the most desired attributes of Data Mining. In general, there is a huge gap from the stored data to the knowledge that could be construed from the data. This transition will not occur automatically, that is where Data Mining comes into picture. In Exploratory Data Analysis, some initial knowledge is known about the data, but Data Mining could help in a more in-depth knowledge about the data. Courses on Database systems give methods to extract information, but they fail to extract knowledge that is actionable.

Manual data analysis has been around for some time now, but it creates a bottleneck for large data analysis. Fast developing computer science and engineering techniques and methodology generates new demands. Data mining techniques are now being applied to all kinds of domains, which are rich in data. Although data mining is partly based on statistical methods, data mining methods give a lot more than the statistical methods. Data mining methods are to a large extent based on machine learning methods. The difference is data mining is meant for huge data whereas machine learning is usually done over relatively small-sized data. Huge data brings completely a new set of problems to be solved.

This course aims to introduce you to the exciting and ever-evolving world of data analytics and mining.

Intended Learning Outcomes (ILO)

Upon the successful completion of this course, students shall be able to:

1. Discuss basic concepts and general knowledge of data analytics, data mining and the KDD process, using professional language associated with data analytics and data mining
2. Pre-process the data so that it can be analysed further using sophisticated data analytics and mining algorithms
3. Discuss several major data mining tasks (including classification, clustering, and association rule mining, etc) and related algorithms to solve them
4. Apply data mining techniques to tackle real-world big data applications, to perform core data
5. analytics & mining tasks with large amount of data.

Overview of Course Content

	Topics
1	**Introduction of Data Analytics & Mining** Overview of data mining and knowledge discovery, MapReduce and Spark.
2	**Data Cleaning and Integration** Data Warehouse, data cleaning, integration, entity resolution, discretisation, similarity measures
3	**Association Rule Mining** Frequent itemset generation, Association Rule, A-priori algorithm, FP-Growth algorithm, Sequential pattern mining, Rule based classification methods
4	**Classification** Decision tree, Ensemble Classification
5	**Recommendation Systems** Applications of Recommendation Systems, Content-Based, Collaborative Filtering, Latent Factor Models
6	**Locality-Sensitive Hashing**
7	**Clustering and Anomaly Detection** Clustering algorithms (choose from: K-means, k-mean++, BFR, CURE, Dbscan, etc) and anomaly detection algorithms
8	**Graphs Mining** Pagerank/random walk, Clustering/partitioning of Graphs, Discovery of Communities
9	**Graph Representation Learning and GNN** High-level introduction to deep learning, graph representation techniques, GNN
10	**Data Stream Mining** Filtering, querying
11	**Advanced Topic** One of the following topics: Computational advertising, Time series mining, Spatial temporal data mining

Assessment (includes both continuous and summative assessment)

Component	Weightage	Team/Individual
1. Final Examination	50%	Individual
2. Course Written Report and Presentation	50%	Team
Total	100%	

SCSE MPEs courses for AY22-23 Semester 1

CE/CZ4041 – Machine Learning

Academic Year	AY2022-2023	**Semester**	1			
Instructor(s)	Sinno Jialin Pan (sinnopan@ntu.edu.sg) Kelly Ke Yiping (ypke@ntu.edu.sg)					
Course Code	CE/CZ4041					
Course Title	Machine Learning					
Pre-requisites	CE/CZ1011 or CE/CZ1004 & CE/CZ2100 CE/CZ1007 Study Year 3					
Pre-requisite for	NIL					
No of AUs	3					
Contact Hours	Lectures/TEL	22	Tutorials	10	Student Presentations	6

Course Aims

This course provides an introductory but broad perspective of machine learning fundamental algorithms, and is relevant for anyone pursuing a career in AI or Data Science. It aims to provide you with the essential concepts and principles of algorithms in machine learning so that you can use various machine learning techniques to solve real-world application problems.

Intended Learning Outcomes (ILO)

Upon the successful completion of this course, students shall be able to:

1. Explain the motivations and principles behind various machine learning algorithms.
2. Apply or even design specific machine learning algorithms to solve real-world application problems.
3. Identify some state-of-the-art machine learning techniques.
4. Conduct research on machine learning.

Overview of Course Content

	Topics
1	**Introduction to Machine Learning** Overview of machine learning, supervised learning, unsupervised and applications
2	**Bayesian Classifiers** Bayesian decision theory, Naïve Bayes, Bayesian Brief Networks
3	**Decision Tree** Tree induction, prediction-based trees, generalisation errors
4	**Artificial Neural Networks** Perceptron, Multi-layer perceptron, backpropagation algorithm
5	**Support Vector Machines (SVMs)** Induction of SVMs, linear SVMs, Kernelised SVMs
6	**Regression Models** Linear regression, Kernelised regression
7	**K-Nearest Neighbor Classifiers (KNN)** KNN with majority voting, KNN with distance-weighted voting
8	**Ensemble Learning** Boosting, bootstrapping, model average
9	**Clustering** K-means clustering, hierarchical clustering, performance evaluation for clustering, applications
10	**Density Estimation** Parametric and non-parametric density estimation approaches
11	**Dimension Reduction** Principal component analysis (PCA), linear discriminant analysis (LDA)
12	**Application and Advanced Research Topics** Through course project on a predefined list of applications or research topics

Assessment (includes both continuous and summative assessment)

Component	Weightage	Team/Individual
1. Final Examination	60%	Individual
2. Course Project Presentation	10%	Team
3. Course Project Report	30%	Team
Total	100%	

SCSE MPEs courses for AY22-23 Semester 1

CE/CZ4042 – Neural Networks and Deep Learning

Academic Year	AY2022-2023	**Semester**	1	
Instructor(s)	Jagath Rajapakse (asjagath@ntu.edu.sg) Loy Chen Change (ccloy@ntu.edu.sg)			
Course Code	CE/CZ4042			
Course Title	Neural Networks and Deep Learning			
Pre-requisites	CE1007, CE1011, CE1012 (AY19-20 and earlier cohort) or CZ1007, CZ1011, CZ1012 (AY19-20 and earlier cohort) or CE1107, CE1104 (AY20-21 cohort) or CZ1007, CZ1104, (AY20-21 cohort) or CZ1007, MH2802 (DSAI cohort) or CZ1107, MH2802 (DSAI AY20-21 Cohort); Study Year 3			
Pre-requisite for	NIL			
No of AUs	3			
Contact Hours	Lectures/TEL	26	Tutorials	12

Course Aims

This course aims to provide you with a basic but comprehensive foundation of neural networks and deep learning, including underlying principles, architectures, and learning algorithms of various types of deep neural networks that are essential for future applications of artificial intelligence and data science.

Intended Learning Outcomes (ILO)

Upon the successful completion of this course, students shall be able to:

1. Interpret artificial neuron as an abstraction of biological neuron and explain how it can be used to build deep neural networks that are trained to perform various tasks such as regression and classification.
2. Identify the underlying principles, architectures, and learning algorithms of various types of neural networks.
3. Select and design a suitable neural network for a given application.
4. Implement deep neural networks that can efficiently run on computing machines.

Overview of Course Content

	Topics
1	**Introduction to Neural Networks** Biological neural networks, artificial neuron, activation functions, history of neural networks
2	**Regression** Gradient descent learning, stochastic gradient descent learning, linear neuron, linear regression, perceptron, perceptron learning algorithm
3	**Classification** Pattern recognition, discrete perceptron, discrete perceptron learning, logistic regression, learning a logistic neuron
4	**Neuron Layers** Softmax layer, softmax learning algorithm, perceptron layers, learning algorithms
5	**Feedforward Networks** Feedforward neural networks, multilayer perceptron, backpropagation algorithm, deep feedforward neural networks
6	**Model Selection and Overfitting** Holdout method, K-split resampling technique, K-fold cross-validation, three-way data splits, overfitting and underfitting of neural networks, early stopping, regularisation and weight decay, drop-outs
7	**Convolution Neural Networks (CNN)** Feature extraction by convolution, pooling of feature maps, convolutional neural networks, deep CNN, learning with momentum
8	**Recurrent Neural Networks (RNN)** Recurrent neural networks with hidden recurrence (Elman type) and with output recurrence (Jordan type), learning deep RNN
9	**Gated Recurrent Networks (GRN)** Vanishing and exploding gradient problem in RNN, memory cells and gating, long short-term memory (LSTM) units, gated recurrent units (GRU), sequence-to-sequence models
10	**Autoencoders** Learning of autoencoders, denoising autoencoders, sparse autoencoders, building stacked and deep autoencoders
11	**Generative Adversarial Networks** Generative models, discriminator and generator minmax game, training GAN, DCGAN, cGAN
12	**Revision**

Assessment (includes both continuous and summative assessment)

Component	Weightage	Team/Individual
1. Final Examination	40%	Individual
2. Assignment (Programming)	25%	Individual
3. Project	35%	Team, scaled with Peer review for individual
Total	100%	

SCSE MPEs courses for AY22-23 Semester 1

CE/CZ4045 – Natural Language Processing

Academic Year	AY2022-2023	**Semester**	1	
Instructor(s)	Sun Aixin (axsun@ntu.edu.sg)			
Course Code	CE/CZ4045			
Course Title	Natural Language Processing			
Pre-requisites	CE/CZ2001 Algorithms Study Year 3			
Pre-requisite for	NIL			
No of AUs	3			
Contact Hours	Lectures/TEL	26	Tutorials/Example Classes	13

Course Aims

Natural language processing is becoming a very hot topic in both industrial practices and academic research. It finds many real-world applications such as information extraction, sentiment analysis, machine translation, question answering, and summarisation. Hence, it is an important subject to prepare you to cope with the huge amount of unstructured information in text, for example, in web pages and business documents. This subject covers the basic concepts and computational methods for natural language processing. Techniques covered should be biased toward those generally accepted established traditional practices recommended by practitioners.

This course will equip you with the basic concepts and techniques in natural language processing on different levels including words, syntax, and semantics. You will be able to apply the techniques to real-world problems and conduct evaluations of your solutions.

Intended Learning Outcomes (ILO)

Upon the successful completion of this course, students shall be able to:

1. Identify and analyse the linguistic characteristics of written English.
2. Design and develop an NLP system to analyse and process a general corpus.
3. Troubleshoot for domain-specific NLP applications.

SCSE MPEs courses for AY22-23 Semester 1

Overview of Course Content

	Topics
1	**Regular Expressions and Word-Level Analysis** Introduction to NLP, Finite State Automata (Deterministic and Non-deterministic), Stemming, Tokenising, Segmentation, Spelling Checking
2	**N-gram Language Model** Word Prediction, N-gram Language Models (Counting and basic concepts), Evaluation, Smoothing for Language Models
3	**Word Classes and Part-of-speech Tagging** Word classes, POS tagging, Hidden Markov Model and its Application to Part-of-speech Tagging, the Viterbi Algorithm
4	**Formal Grammars** Constituency, grammatical relations, subcategorisation, phrase structure, dependency structure, context free grammar (CFG), dependency grammar
5	**Syntactic Parsing** Top-down parsing, bottom-up parsing, parse tree, CKY algorithm, Earley algorithm, syntactic ambiguities, probabilistic CFG, treebank, attachment ambiguities, lexicalised CFG
6	**Computational Semantics** First-order logic, model-theoretic semantics, representing linguistic concepts, semantic augmentation to CFG, compositional semantic analysis
7	**NLP Applications** Introduction to Classification Methods, Evaluation, Introduction to Sentiment Analysis (Concept and Basic Methods). Information extraction. Word sense disambiguation
8	**Machine Translation** Introduction to Machine translation (Alignment Models, Decoding)
9	**Review**

Assessment (includes both continuous and summative assessment)

Component	Weightage	Team/Individual
1. Final Examination	50%	Individual
2. Midterm Quiz	15%	Individual
3. Assignment	35%	Team
Total	100%	

SCSE MPEs courses for AY22-23 Semester 1

CE/CZ4062 – Computer Security

Academic Year	AY2022-2023	**Semester**	1 & 2	
Instructor(s)	Tay Kian Boon (kianboon.tay@ntu.edu.sg) Zhang Tianwei (tianwei.zhang@ntu.edu.sg)			
Course Code	CE/CZ4062			
Course Title	Computer Security (System Security)			
Pre-requisites	CE/CZ2005 Study Year 3			
Pre-requisite for	NIL			
No of AUs	3			
Contact Hours	Lectures/TEL	26	Tutorials	13

Course Aims

Currently been updated

Intended Learning Outcomes (ILO)

1. *Currently been updated*

Overview of Course Content

Currently been updated

Assessment (includes both continuous and summative assessment)

Component	Weightage	Team/Individual
1. Quizzes(two)	64%	Individual
2. Presentation	36%	Team and individual
Total	100%	

SCSE MPEs courses for AY22-23 Semester 1

CE/CZ4064 – Security Management

Academic Year	AY2022-2023	**Semester**	1			
Instructor(s)	Anwitaman Datta (Anwitaman@ntu.edu.sg) Kang Meng Chow (mengchow@ntu.edu.sg)					
Course Code	CE/CZ4064					
Course Title	Security Management					
Pre-requisites	CE/CZ2006: Software Engineering Study Year 3					
Pre-requisite for	NIL					
No of AUs	3					
Contact Hours	Lectures/TEL	23	Tutorials	4	Student Presentations	12

Course Aims

This course aims to develop your ability to identify the problems associated with (cyber and information) security management and understand using case studies that to effectively address them, one needs to design solutions that encompass multiple dimensions, including technology, people, processes and (internal as well as external) regulations.

This course provides an introductory but broad perspective of cyber and information security, and is relevant for anyone pursuing a career in the IT/ICT industry – including those in product design and development, security engineering, penetration testing, network/system administration, as well as, given the proliferation of IT in all walks of our lives, in executive roles across industries and government.

Intended Learning Outcomes (ILO)

Upon the successful completion of this course, students shall be able to:

1. Explain the need for effective security management.
2. Identify the typical problems associated with security management.
3. Describe and debate the ways in which various organisations solve these problems.
4. Analyse real world and (possibly) new security incidents or problems, and propose and evaluate possible mitigations.

Overview of Course Content

	Topics
1	**Introduction** Concepts and terminology. Drivers and motivations for security management (what is security, and why is it necessary.) Discourse various related concepts of security, including data security, information security, technology risk, information risk, and Cyber security.
2	**Information Security, Governance, and the Law** Principles and practices of information security governance, policy, and programme. Laws and regulations affecting information security governance, policy, and programme.
3	**Model, Framework, and Approach** Systems, models, and frameworks pertaining to security management. Information classification. Industry standards, best practices, and certifications (e.g., ISO/IEC 27001). Performance measurement. Economics of information security.
4	**Organisation and People** Organisation and reporting structure. People aspects of security management, including third-party personnel, and temporary employees. Information owner and custodian. Security awareness, training, and competency. Security communications.
5	**Risk Analysis and Assessments** Principles, methods and practices of risk analysis and assessments, including common problems and resolutions. Managing information security risks in outsourcing and other business alliances.
6	**Security Operations** Operations management, effectiveness and efficiency. Incident handling. Change management. Vulnerability management.
7	**Internal Control, Audit, and Security** Principles and practices of Internal Control and Audit in organisations. How Internal Control and Audit relates to Security in practice. Common challenges and resolutions.
8	**Contingency Planning and Management** Principles and practices relating to incident management, crisis management, business continuity planning and management, and disaster recovery planning and management.

Assessment (includes both continuous and summative assessment)

Component	Weightage	Team/Individual
1. First Quiz	30%	Individual
2. Second Quiz	30%	Individual
3. Case Study Written Report	15%	Team + Individual
4. Case Study Oral Presentation	25%	Team + Individual
Total	100%	

SCSE MPEs courses for AY22-23 Semester 1

CE/CZ4069 – Concepts and Techniques for Malware Analysis

Academic Year	AY2022-2023	**Semester**	1			
Instructor(s)	Ho Sing Cherng (HO_Sing_Cherng@csa.gov.sg)/ Lam Fhong Sheng (lam_fhong_sheng@csa.gov.sg) Tay Kian Boon (kianboon.tay@ntu.edu.sg)					
Course Code	CE/CZ4069					
Course Title	Concepts and Techniques for Malware Analysis					
Pre-requisites	CE/CZ1006 – Computer Organisation and Architecture CE/CZ2005 – Operating Systems Study Year 3					
Pre-requisite for	NIL					
No of AUs	3					
Contact Hours	Lectures/TEL	26	Tutorials	13	Laboratories	-

Course Aims

Malware analysis is a specialisation within cyber security. Malware attacks are often detrimental to companies or organisations. When malware breaches an organisation's defences, the security team needs to act quickly to cure current infections and prevent it from re-occurring. Understanding the capabilities of the malware is critical to an organisation's ability to quickly create a signature to prevent the widespread of the malware across the network, to block further communications from the attacker. This understanding could also be translated to valuable knowledge in identifying existing security gaps within an organisation's system and fortify defences. This course aims to build a strong foundation to perform triage on malicious software using a variety of system and network monitoring utilities, a disassembler, a debugger and many other freely available tools.

Intended Learning Outcomes (ILO)

Upon the successful completion of this course, students shall be able to:

2. Set up a safe virtual environment to analyse malware.
3. Determine and discuss the various capabilities of malware, the spread of malware and the communication with the attacker.
4. Explain techniques for malware analysis
5. Perform a quick triage to extract network signatures and host-based indicators.
6. Use key analysis tools such as IDA Pro, x64Dbg and CFF explorer that are commonly known to the industry.
7. Identify basic malware patterns and techniques and discuss on how to circumvent some of them.

Note:

- This course is capped at 100 students maximum.
- Priority will be given to Year 4 SCSE students to register for this course.
- Student is advised to take Computer Security at the same time.
- x86 assembly language will be studied in this course

SCSE MPEs courses for AY22-23 Semester 1

Overview of Course Content

	Topics
1	**Introduction** The goals of malware analysis. Overall process and methodology of analysing malware. Types of malware categories. Dos and Don'ts for malware analysis.
2	**Basic Static Techniques** (i) Antivirus scanning (ii) Introduction of PE format (iii) Gleaning information from a file's strings, PE attributes and resources
3	**Basic Dynamics Analysis** (i) Using a malware sandbox (ii) How to set up a virtual environment that is suitable for analysis (iii) Behavioural analysis a. Detonating of malware b. Using monitoring tools like procmon, Process Explorer, RegShot, FakeNet and Wireshark c. Interpreting analysis results
4	**Fundamentals of x86 Disassembly** An introduction to x86 assembly language, which provides the fundamentals for reverse engineering and in-depth analysis of malware. Recognising C Code constructs in assembly such as for-loop, if-else statements.
5	**Advance Static Technique – Reverse Engineering** Cover a wide range of windows-specific concepts that are necessary for understanding malicious windows program.
6	**Advance Dynamic Technique – Debugging** (i) Introduction of a basic debugger – x64dbg (ii) Concept of breakpoints (iii) Modifying code execution with a debugger
7	**Common Malware Functionalities and Techniques** Explore common malware functionality when analysing malware. (i) Downloaders and Launchers (ii) Backdoors (iii) Credentials stealers and keyloggers (iv) Hash Dumping (v) Malware persistence

Assessment (includes both continuous and summative assessment)

Component	Weightage	Team/Individual
1. Final Examination	40%	Individual
2. Assignments	60%	Individual
Total	100%	

SCSE MPEs courses for AY22-23 Semester 1

CE/CZ4070 – Cyber Threat Intelligence

Academic Year	AY2022-2023	**Semester**	1	
Instructor(s)	Lim Yi Hao (yihao.lim@ntu.edu.sg)			
Course Code	CE/CZ4070			
Course Title	Cyber Threat Intelligence			
Pre-requisites	Study Year 3			
Pre-requisite for	NIL			
No of AUs	3			
Contact Hours	Lectures/TEL	26	Tutorials	13

Course Aims

This course aims to introduce Cyber Threat Intelligence as a concept and teach students the approach and different techniques for managing and processing Cyber Threat Intelligence – from collections to prioritisation of assets and to better leverage tactical, operational, and strategic-level threat intelligence as well as to better comprehend, synthesise, and leverage cyber threat intelligence to respond to different cyber situations.

Intended Learning Outcomes (ILO)

Upon the successful completion of this course, students shall be able to:

1. Discuss and explain the concept of cyber threat intelligence, the need for cyber threat intelligence, the cyber threat intelligence cycle and how it can be applied at tactical, operational and strategic levels to augment existing security measures in the organisation.
2. Discuss and explain various cyber threat actors' profiles, sorted according to espionage, cyber-criminals and hacktivists, their different motivations and modus operandi; and explain how these characteristics can help to determine potential targets, which data or assets are valuable to them, and how they will carry out their attacks.
3. Design and develop cyber threat intelligence requirements, to prioritise assets to protect and sort assets by various classification such as personal information, intellectual property, confidential business information, credentials and systems information.
4. Discuss and explain concepts of threat models and how it can be used, and demonstrate ways to counter analytic bias and convert raw threat data or information into actionable intelligence.

SCSE MPEs courses for AY22-23 Semester 1

Overview of Course Content

	Topics
1	**Introduction to Cyber Threat Intelligence** What is cyber threat intelligence; Why use cyber threat intelligence; Types of cyber threat intelligence
2	**Cyber Threat Intelligence Operations** Introduction to the cyber-attack lifecycle; Analyst Tradecraft; Cognitive Bias
3	**Analytic Skills** Applying Bias to Cyber Threat Intelligence; Structural Analysis Techniques; Quantitative Analysis; Determining Confidence
4	**Cyber Artifacts** Introduction to Indicators of Compromise; Host-based indicators; Network-based indicators; Threat hunting
5	**Develop OSINT Intel Collection Techniques** Introduction to VirusTotal; OSINT collection techniques; Introduction to Criminal Cyber Underground
6	**Develop Raw Data into Cyber Threat Intelligence** Introduction to threat intelligence requirements; Understand how to classify and identify stakeholders; Understand the need for and how to evaluate sources
7	**Develop Raw Data into Cyber Threat Intelligence** Case study – Strategic Intelligence; Case study – Operational Intelligence; Case study – Tactical Intelligence
8	**Group Presentations – Threat Landscape Brief**

Assessment (includes both continuous and summative assessment)

Component	Weightage	Team/Individual
1. Quiz	20%	Individual
2. Group Presentation	20%	Team and Individual
3. Team Assignment	20%	Team and Individual
4. Final Examination	40%	Individual
Total	100%	

SCSE MPEs courses for AY22-23 Semester 1

CE/CZ4153 – Blockchain Technology

Academic Year	AY2022-2023	**Semester**	1			
Instructor(s)	Li Yi (yi_li@ntu.edu.sg) Wen Yonggang (ygwen@ntu.edu.sg)					
Course Code	CE/CZ4153					
Course Title	Blockchain Technology					
Pre-requisites	MH1812 Discrete Mathematics CE/CZ1007 Data Structures CE/CZ2001 Algorithms Study Year 3					
Pre-requisite for	NIL					
No of AUs	3					
Contact Hours	Lectures/TEL	20	Tutorials	12	Seminars	7

Course Aims

Summary: Blockchain Technology has taken the world by storm with its proliferation in an astoundingly diverse array of applications. Cryptocurrencies and a plethora of business use-cases paved the way for inclusive decentralisation through innovative incentives and smart contracts. In its modern incarnation, Blockchain offers the promise of immutability, consistency, attribution, authenticity and automation of record-keeping as well as computations within an inherently decentralised operating environment.

The Aim: This elective course in Computer Science and Engineering aims to introduce you to the core technical framework of Blockchain Technology and Cryptocurrencies, encompassing distributed systems, consensus protocols, incentive mechanisms and decentralised applications. You will also learn the major anonymity, security, privacy, scalability and interoperability issues in modern Blockchain, in addition to the relevant enterprise platforms, solutions, applications and regulatory aspects of the technology.

Intended Learning Outcomes (ILO)

Upon the successful completion of this course, students shall be able to:

1. Recognise and identify the various consensus protocols in distributed systems.
2. Discuss and explain Bitcoin blockchain, its technical mechanisms, and protocols.
3. Discuss and explain Ethereum blockchain, its smart contracts, DApps, and tokens.
4. Design and develop decentralised applications using tokens and smart contracts.
5. Analyse and argue anonymity, security, and privacy issues in modern blockchain.
6. Analyse and argue scalability and interoperability of current blockchain platforms.
7. Examine and create enterprise solutions and applications of blockchain technology.

SCSE MPEs courses for AY22-23 Semester 1

Overview of Course Content

	Topics
1	**Motivation and Introduction** Distributed Systems, Consensus and Blockchain
2	**The Bitcoin Blockchain** Bitcoin Blockchain and the Nakamoto Consensus; Deep-dive to the Technical Mechanisms of Bitcoin; Protocol Optimisations and Variations in AltCoins
3	**The Ethereum Blockchain** Ethereum Virtual Machine and Smart Contracts; DApps, Tokens and Cryptocurrency Eco-System; Design and Development of Ethereum DApps
4	**Practical Aspects of Blockchain** Anonymity and De-Anonymisation in Blockchain; Security and Privacy in Blockchain Frameworks; Scalability and Interoperability of Blockchain
5	**Blockchain in Practice** Enterprise Blockchain Platforms and BaaServices; Enterprise Blockchain Solutions and Applications; Blockchain Laws, Regulations and Governance

Assessment (includes both continuous and summative assessment)

Component	Weightage	Team/Individual
1. Quizzes	40%	Individual
2. Development	30%	Team + Individual
3. Term Paper	30%	Team + Individual
Total	100%	