VINUNIVERSITY

CURRICULUM FRAMEWORK

PROGRAM CODE: 9480101

DOCTOR OF PHILOSOPHY IN COMPUTER SCIENCE

Applicable for the intake beginning in 2022 onward

This curriculum framework has been reviewed and validated by Cornell University

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PH.D. PROGRAM IN COMPUTER SCIENCE

Program name: Doctor of Philosophy in Computational Data Science

Degree: Doctor of Philosophy in Computer Science

Program code: 9480101

1. Training objectives

1.1. General objectives

To educate Ph.D. candidates in Computer Science to have a high level of expertise, practical and theoretical knowledge, and advanced theory in cutting-edge technological fields. Graduates will:

- have skills to synthesize and analyze information for discovering and creatively solving problems; have critical thinking skills, and be an independent researcher to create new knowledge;
- have skills in disseminating scientific knowledge and setting up research collaborations at national and international levels;
- show a creative capability to make expert conclusions and recommendations
- be able to train future undergraduate and graduate students.

1.2. Specific objectives

Upon completion of the Ph.D. in Computer Science program, students will have the ability to:

- Identify and solve scientific problems.
- Conduct self-directed learning, supervise, and lead research groups.
- Master tools and scientific theories in advanced research topics.
- Participate in the management and administration of research and development.
- Apply scientific methods to synthesize and enrich specialized knowledge.
- Conduct research to make expert conclusions and recommendations.
- Discover and present scientific findings in the form of articles, conference reports, undergraduate and graduate teaching.

2. Training time

For a Ph.D. candidate with a master's degree, the training period is three years. The training period for a Ph.D. candidate with a bachelor's degree will be four years.

3. Number of credits

The minimum academic load for a Ph.D. candidate with a master's degree is 90 credits.

In addition to the 90 credits (same as the candidate with a master's degree), Ph.D. candidates with a bachelor's degree need to take additional courses in each respective field (except foreign language courses and dissertation) to fulfill the output standards Level 7 of the national qualification framework and the requirements of the research field.

4. Admission candidates

Candidates refer to those who meet the following requirements:

a. Having graduated with a master's degree or a bachelor's degree with excellent grades or higher in the discipline of Computer Science or relevant disciplines, in particularly:
   - Disciplines of Computer Science:
     - Computer Science
     - Information Technology
     - Computer Engineering
     - Information System
     - Software Technology
     - Electronics and Telecommunication Engineering
     - Electrical Engineering
     - Mathematics Informatics
   - Close disciplines:
     - Applied Mathematics
     - Cryptographic Engineering
   - For other disciplines, the College Admissions Council will consider and decide.

b. Have research experience demonstrated through the master's thesis of a research-oriented training program, or published scientific articles and reports; or have worked for 02 years (24 months) or more as lecturers or researchers of training institutions, science and technology organizations;

c. Having an IELTS certificate of 6.5 (or equivalent) in English within two years (24 months) before the admission registration date or have a bachelor's or master's degree in English.

5. Training process, graduation recognition conditions

The training process is conducted on the credit base, which is in compliance with the organization and management regulations of the President of VinUniversity.

Research works publish (or accepted for publication) at least three articles in ISI-listed journals, including at least one Q1 article or in leading international conference proceedings.

6. Program content

6.1. Structure

The structure of the training program at the Ph.D. level includes the following parts:

Part	Content	The candidates who have a master's degree in the right and relevant discipline	The candidates who have bachelor's degree in the right and relevant discipline	The candidates who have a master's degree in the close discipline
1	Supplementary courses	0	30 credits in CS's Master program	More than 4 credits and less than 16 credits
	Ph.D. courses	16 credits		
2	Research works and Doctoral thesis	74 credits (24-25 credits/year)		

Note:

- The number of credits specified in the above table is the minimum number of credits a graduate candidate must complete.
- The instructor will propose the doctoral course from the master's and doctoral program to ensure the candidate can obtain the necessary knowledge to work on a specific research topic in the doctoral thesis.

6.2. Supplementary courses

Supplementary courses are intended to assist graduate students to learn sufficient knowledge and expertise to carry out research topics.

6.2.1. For the Ph.D. candidates without a master's degree

A Ph.D. candidate without a master's degree must complete 30 additional credits. The courses (equivalent level to a master's degree) are listed in the following table:

CONTENT	CODE	COURSE	CREDITS	DISTRIBUTION	
				Theory	Practice
Required graduate-level courses (24 credits)	**MGN5010**	Design thinking and Innovation Management	3	2	1
	MGN5020	Project Management for Innovation	3	2	1
	COMP5010	Algorithms and Data Structures	4	3	1
	MATH5010	Statistical Modeling	4	3	1
	COMP5020	Advanced Machine Learning	4	3	1
	CECS5020	Optimization: Models and Methods	4	3	1
Electives (select at	**MGN5030**	Strategic Management for Innovation	3	2	1

CONTENT	CODE	COURSE	CREDITS	DISTRIBUTION	
				Theory	Practice
least 6 credits)	**MGN5050**	Finance & Investment Management for Innovation	3	2	1
	MGN5040	Entrepreneurship & Innovation	3	2	1
	COMP5030	Computer Vision	4	3	1
	COMP5040	Natural Language Processing	4	3	1
	COMP5140	Text & Web Analytics	4	3	1
	CECS5050	Robotics	4	3	1
	CECS5090	Topics in Artificial Intelligence	1-2		

or any 30 credits listed in the following table:

CODE	COURSE	CREDITS	DISTRIBUTION	
			Theory	Practice
COMP5150	Artificial Intelligence	3	2	1
COMP5160	Applied Machine Learning	3	2	1
COMP5170	Trustworthy Machine Learning	4	3	1
COMP5180	Deep Learning for Computer Vision	4	3	1
COMP5190	Machine Learning	3	2	1
COMP5040	Natural Language Processing	4	3	1
COMP5200	Introduction to Bioinformatics	3	2	1
COMP5030	Computer Vision	4	3	1
COMP5210	Optimization in Computer Vision	4	3	1
COMP5220	Machine Learning for Signals	4	3	1
COMP5230	Deep Learning	4	3	1
COMP5240	Text Information Systems	3	2	1
COMP5250	Introduction to Data Mining	3	2	1
COMP5260	Data Mining Principles	4	3	1
COMP5070	Internet of Things	4	3	1
COMP5270	User Interface Design	4	3	1
COMP5280	Social Visualization	4	3	1

where these courses can be mapped to equivalent courses at UIUC or other partner universities. Other courses may be recommended by their supervisor.

6.2.2. For the Ph.D. candidate with a master's degree in a close discipline

The supplementary courses are selected from the modules list in Section 6.2.1. The number of credits for the supplementary courses is decided by the Scientific Council and instructor based on the candidate's mater courses. It must ensures the minimum and the maximum number of credits in the table in Section 6.1.

6.3. Study plan

6.3.1. For the Ph.D. candidates without a master's degree

Year	Courses, research	Number of credits	Expected outcomes
Year 1	CECS5010 Research communication	4	Passing grade
	Master courses	8-16	Passing grades
	Part 1 of the doctoral thesis	10-18	Passing the year 1 review session with PhD committee focusing on research questions, literature review, research methodology ...
Year 2	Master courses	8-14	Passing grades
	PhD courses	4 - 8	Passing grades
	Part 2 of the doctoral thesis	8-18	Passing the year 2 review session with PhD committee focusing on research progress and publications
Year 3	Master courses	Up to 14	Passing grades
	PhD courses	Up to 8	Passing grades
	Part 3 of the doctoral thesis	8-30	Passing the year 3 review session with PhD committee focusing on research progress and publications
Year 4 and remaining years	Last part of the doctoral thesis	30	Competion of the doctoral thesis and at least 3 publications (accumulated) Passing the thesis defense at the College level and at the university level.

6.3.2. For the Ph.D. candidate with a master's degree

Year	Courses, research	Number of credits	Expected outcomes
Year 1	CECS5010 Research communication	4	Passing grade
	PhD courses	4 - 12	Passing grades
	Part 1 of the doctoral thesis	14-22	Passing the year 1 review session with PhD committee focusing on research questions, literature review, research methodology ...
Year 2	PhD courses	Up to 8	Passing grades

Year	Courses, research	Number of credits	Expected outcomes
	Part 2 of the doctoral thesis	22-30	Passing the year 2 review session with PhD committee focusing on research progress and publications
Year 3 and remaining years	Last part of the doctoral thesis	30	Competion of the doctoral thesis and at least 3 publications (accumulated) Passing the thesis defense at the College level and at the university level.

6.4. Ph.D. courses

6.4.1. List of Ph.D. courses

Ph.D. candidates need to complete CECS5010 and at least three other courses as listed in the following table:

No	CODE	COURSE	CREDITS	DISTRIBUTION	
				Theory	Practice
1	**CECS5010**	Research Communication	4	3	1
2	**COMP5020**	Advanced Machine Learning	4	3	1
3	**COMP5030**	Computer Vision	4	3	1
4	**COMP5040**	Natural Language Processing	4	3	1
5	**COMP5050**	Robotics	4	3	1
6	**COMP5060**	Ubiquitous Sensing and Intelligent Systems	4	3	1
7	**COMP5070**	Internet of Things	4	3	1
8	**COMP5080**	Blockchain Technologies	4	3	1
9	**COMP5090**	Cryptography	4	3	1
10	**COMP5100**	System, Network and Cloud Security	4	3	1
11	**COMP5110**	Big Data Analytics	4	3	1
12	**COMP5120**	Visualizations	4	3	1
13	**COMP5130**	Digital Forensics	4	3	1

6.4.2. Course description

CECS5010: Research Communication

4 credits

Course Description:

This course introduces and discusses practical aspects of research communication skills, including technical paper writing and oral presentation. Students will learn about effective scientific

communications through extensive practical training including written, spoken, and individual exercises.

COMP 5020: Advanced Machine Learning

4 credits

Pre-requisites: Introduction to Programming (Python), Algorithms and Data Structures, AI & Introduction to Machine Learning, Probability & Statistics, Linear Algebra

Course Description:

Machine learning is the data-driven process of constructing mathematical models that can make predictions about future situations, or take actions in a future situation to optimize some outcomes. Neural Networks (one form of ML methods) are unstructured and expressive models that can be used for function approximation and classification. In this course, we will study a range of Deep Learning tools that allow for the efficient construction of very complex Neural Network models. We will also study methods for model evaluation. In our homework and project work, we will make use of everal python-based tools, including PyTorch, Tensorflow and Keras.

Additionally, the course will cover advanced modeling techniques, such as ensemble learning, extended linear models, probabilistic graphical models, mixture and latent variable models, and matrix factorization. First, the theoretical foundations of these techniques will be presented and augmented with in-class examples and homework problems. Second, the state of-the-art research related to these techniques will be presented and augmented with paper reviews that highlight the practical applications of these advanced data mining techniques. Applications of the models will be presented in popular domains, including social computing and health informatics.

COMP 5030: Computer Vision

4 credits

Pre-requisites: Advanced Machine Learning

Course Description:

Computer Vision is the area of engineering and computer science concerned with the use of artificial vision tools to collect and process information in order to provide automatic systems with some autonomy. The objective of this course is to present an insight into the world of machine vision that goes beyond image processing algorithms and traditional computer vision approaches. Students will acquire a knowledge and an understanding of artificial vision from a practical implementation perspective and gain the capability to design physical vision systems. Various aspects will be examined, as time permits, and some of the main approaches currently found in the literature will be discussed, opening the door to many research themes.

COMP 5040: Natural Language Processing

4 credits

Pre-requisites: Advanced undergraduates and graduates with a background in formal language and automata theory. Programming experience is necessary for the assignments. The required programming language for all assignments is Python 3.5. Prior exposure to linguistics is not required.

Course Description:

This course covers the introduction to natural language processing (NLP), the goal of which is to enable computers to use human languages as input, output, or both. It examines NLP in context of including machine translation, automatic conversational assistants and Internet search. Possible topics include summarization, machine translation, sentiment analysis and information extraction as well as methods for handling the underlying phenomena (e.g., syntactic analysis, word sense disambiguation, discourse analysis, their shortcomings and solutions).

COMP 5050: Robotics

4 credits

Pre-requisites: Control Systems

Course Description:

The course will cover: components of robotic systems; selection of coordinate frames; homogeneous transformations; solutions to kinematic equations; velocity and force/torque relations; manipulator dynamics in Lagrange's formulation; digital simulation of manipulator motion; trajectory planning; obstacle avoidance; controller design using the computed torque method; and different controllers for manipulators.

COMP 5060: Ubiquitous Sensing and Intelligent Systems

4 credits

Pre-requisites: Undergraduate level in Computer Science or Electrical Engineering program with minimum grade of C

Course Description:

This course aims to provide student with an overview and the foundation of multidisciplinary research field of next generation of computing. It covers the sensing technology, mechanism behind sensing data, embedded computing, and methods to analyze sensing data.

COMP 5070: Internet of Things

4 credits

Pre-requisites: Networks or Equivalent

Course Description:

This course covers the main cybersecurity principles and technologies motivated by the evolving ecosystem of Internet of Things (IoT): smart devices, sensors, operating systems, data storage, networking, communication protocols, and system services. The topics include IoT device and system security threats, privacy issues, open challenges, and countermeasure techniques.

COMP 5080: Blockchain Technologies

4 credits

Pre-requisites: Networks or Equivalent

Course Description:

This course covers the topics related to blockchain technologies. It discusses distributed systems and alternative consensus mechanisms, as well as cryptoeconomic and proof-of-stake. The topics include: Altcoins, Bitcoin transactions, consensus protocols, cryptocurrency, elliptic curves, hash functions, mining strategies and incentives, Zerocoin, zerocash. Fundamental uses of bitcoin and blockchain technology are examined, including enterprise blockchain systems, adopting blockchain, and the governmental and societal regulation and control of the blockchain technology.

COMP 5090: Cryptography

4 credits

Pre-requisites: Algorithm Design or Equivalent

Course Description:

This course gives an introduction to the theory and practice of cryptographic techniques. The key topics are encryption (secret-key and public-key), message integrity, digital signatures, user authentication, key management, cryptographic hashing, network security protocols (SSL, IPsec), public-key infrastructure, digital rights management, and zero-knowledge protocols.

COMP 5100: System, Network and Cloud Security

4 credits

Pre-requisites: Networks, Operating Systems or Equivalent

Course Description:

The course gives an overview of security topics for operating systems, networks and Cloud. It covers the main operating systems in the market and gives the overview of securing their main elements according to a variety of usage scenarios. It also discusses network security, setting up secure network environments and responding to security threats in a networked environment. Finally, it considers approaches to securing Cloud and distributed systems and data, with a special focus on data privacy.

COMP 5110: Big Data Analytics

4 credits

Pre-requisites: Advanced Machine Learning

Course Description:

The aim of this course is to provide practical knowledge for working as a Data Scientist or a Machine Learning Engineer in an industrial environment. Students will learn how to apply Machine Learning at a large scale, driving an AI product to production, and collaborating in a team.

COMP 5120: Visualizations

4 credits

Pre-requisites: Statistics and Probability (R), Data Mining, Web Programming, JavaScript, Python

Course Description:

Visual media are increasingly generated, manipulated, and transmitted by computers. When well designed, such displays capitalize on human facilities for processing visual information and thereby improve comprehension, memory, inference, and decision making. Yet the digital tools for transforming data into visualizations still require low-level interaction by skilled human designers. As a result, producing effective visualizations can take hours or days and consume considerable human effort.

In this course, we will study techniques and algorithms for creating effective visualizations based on principles and techniques from graphic design, visual art, perceptual psychology, and cognitive science. The course is targeted both towards students interested in using visualization in their own work, as well as students interested in building better visualization tools and systems. In addition to participating in class discussions, students will have to complete several short programming and data analysis assignments as well as a final programming project.

COMP 5130: Digital Forensics

4 credits

Pre-requisites: Software Construction or Equivalent

Course Description:

The course covers the area of digital forensics including collecting evidence extracting information from software and hardware systems. It discusses forensics of networks, live systems, mobile phones and other device forensics. It provides insight into the areas of covert analysis and intruder artifacts. Students participate in a project where they take a role of a forensic examiner and use existing tools to understand digital forensics cases. Special attention is given to the area of data recovery and analytics as part of the digital forensics process.

6.4. Research works and Ph.D. thesis

Research work is a major, mandatory stage in the process by which a doctoral thesis is performed. This is the stage where Ph.D. students can reach new knowledge or new solutions, form the most important basis for writing a doctoral thesis.

Ph.D. students must actively perform scientific research tasks and research results must be officially published in scientific articles in accordance with the provisions of the Doctoral Training Regulations. Scientific research topics and published articles must be in line with the objectives of the thesis, ensuring truthfulness, science and novelty. The content of articles must not overlap and reflect the main content of the thesis. Articles, inventions and inventions that are research results must be under the name of VinUniversity.

Ph.D. student is responsible for the truthfulness, accuracy and novelty of the thesis's research results, and abides by Vietnam's and international intellectual property regulations.

Requirements for a doctoral thesis:

- The doctoral thesis is a scientific research result of a Ph.D. student, which contains new theoretical and practical contributions in the professional field, valuable in developing and increasing scientific knowledge and completely solve the problem posed by the thesis topic.
- Comply with the law on protection of intellectual property rights, in particular:
  - Fully citing and indicating sources of reference to the research results of other authors (if any);
  - In case the thesis uses the scientific work content of the collective where the Ph.D. student is a co-author, there must be a written consent of other co-authors to allow the Ph.D. student to use the group's research results;
  - Compliance with other provisions of intellectual property law.
- Meeting the publication requirements for the thesis: The Ph.D. student has published at least 3 articles in the ISI-listed journal, including at least 1 article in Q1 or in the leading international conference proceedings.

7. Course Outlines

7.1. Research Communication

Course Code	**CECS5010**
Course Title	**Research Communication**
Catalogue Description	This course introduces and discusses practical aspects of research communication skills, including technical paper writing and oral presentation. Students will learn about effective scientific communications through extensive practical training including written, spoken, and individual exercises.
Credit Value	4
Required or elective	
Pre-requisite/ Co-requisite/ Exclusion	None
Textbook(s) and other required materials	TBD by VinUni Faculty. Sample texts include: 1. Paul V. Anderson (2013), *Technical Communication. A Reader-centered Approach*, 8e (Wadsworth). 2. Gerald J. Alred, Charles T. Brusaw, Walter E. Oliu (2020), *Handbook of Technical Writing, 12th edition.*Strunk and White, The Elements of Style (free download book available)
Course Learning Goals	Students will: 1. analyze the structure of the best research articles in their fields; 2. learn how to write a good research article; 3. learn how to give a good oral presentation of research results.
Course Learning Objectives	Upon completion of the course, students will be able to: 1. identify the key elements of clear effective communication in the research process; 2. recognize and reproduce the structure of excellent research articles; 3. organize and present data in different formats including graphs, charts, tables, etc. appropriate for various purposes; 4. write a good research article that maximizes clarity and understanding; 5. craft and deliver an oral presentation of technical information effectively.

Topics Covered/ Indicative Syllabus	• Publication Basics
	  ○ Building scientific knowledge
	  ○ The peer-review process
	  ○ Research publication landscape
	  ○ Communication Ethics
	• Manuscript Writing
	  ○ Literature reading and problem finding
	  ○ Manuscript structure and narrative
	  ○ Words, sentences, and paragraphs

	○ Infographics ○ Titles, abstracts, and cover letters ○ Edit and revise manuscripts • Oral Presentation ○ Communication in an era of global science ○ How to prepare a scientific presentation ○ How to deliver a scientific presentation ○ Preparing and giving conference posters • Public Communication
Class/Laboratory Schedule	NA
Contribution of course to meeting the professional component	After taking this course, students should be able to produce well-written research papers and deliver effective oral presentations.
Assessment Methods in Alignment with Intended Learning Outcomes	• Assignments: 40% • Presentation: 30% • Exam: 30%
Course Webpage	TBD
Rationale for Offering	
Date/Person Prepared	
Ethical Behavior Statement	Each student in this course is expected to abide by the Vin University Code of Academic Integrity. Any work submitted by a student in this course for academic credit will be the student's own work (with the acknowledgment that many projects are carried out in groups in which participants will contribute equally). The Code is available on the web at (insert website). Violations are taken seriously.

7.2. Advanced Machine Learning

Course Code	**COMP5020**
Course Title	**Advanced Machine Learning**
Catalogue Description	Machine learning is the data-driven process of constructing mathematical models that can 1. Make predictions about future situations, or 2. Take actions in a future situation to optimize some outcomes. Neural Networks (one form of ML methods) are unstructured and expressive models that can be used for function approximation and classification.

	In this course, we will study a range of Deep Learning tools that allow for the efficient construction of very complex Neural Network models. We will also study methods for model evaluation. In our homework and project work, we will make use of several python-based tools, including PyTorch, Tensorflow and Keras. Additionally, the course will cover advanced modeling techniques, such as ensemble learning, extended linear models, probabilistic graphical models, mixture and latent variable models, and matrix factorization. First, the theoretical foundations of these techniques will be presented and augmented with in-class examples and homework problems. Second, the state of-the-art research related to these techniques will be presented and augmented with paper reviews that highlight the practical applications of these advanced data mining techniques. Applications of the models will be presented in popular domains, including social computing and health informatics. You are expected to independently finish machine problems and collaborate with your team members in the final course project. Basic mathematics background is also required. Since this is a graduate-level course, you are supposed to know basic concepts of calculus (e.g., derivative and integral), probability (e.g., Bayes's theorem, conditional probability, basic probability distributions), linear algebra (e.g., vector, matrix and inner product) and optimization (e.g., gradient-based methods). Good knowledge in mathematics will help you gain in-depth understanding of the methods discussed in the course and develop your own idea for new solutions
Credit Value	4
Required or elective	R
Pre-requisite/ Co-requisite/ Exclusion	Introduction to Programming (Python), Algorithms and Data Structures, AI & Introduction to Machine Learning, Probability & Statistics, Linear Algebra
Textbook(s) and other required materials	TBD by VinUni Faculty. Sample texts include: 1. *Mining Text Data*. Springer, 2014. 2. Alpaydin, Ethem. *Introduction To Machine Learning*. MIT Press, 2020. 3. John Hearty, *Advanced Machine Learning with Python*. Packt Publishing, 2016.
Course Learning Goals	Students will: 1. understand the basics behind each data mining method as well as the respective cons and pros. 2. understand how information in real-world applications can be formulated and represented as different genres of data, such as matrices, sequences, data streams, graphs/networks select, combine, and etc. 3. apply specific data mining techniques for certain data types and challenges. 4. understand, explain, and interpret the obtained results. 5. identify recent trends and open directions in the field of data mining.

Course Learning Objectives	Upon completion of the course, students will be able to: 1. be familiar with the background and foundation of machine learning. 2. implement standard machine learning methods without the use of pre-packaged machine learning software. 3. make informed decisions about which machine learning methods are appropriate for different real-world problems. 4. use the mathematical and computer science tool to solve the machine learning problem. 5. acquire background knowledge to apply new machine learning and data mining methods.
Topics Covered/ Indicative Syllabus	• Introduction to statistical machine learning • Linear and logistic regression, decision trees • Kernel methods and support vector machine • Dimensionality reduction • Graphical models • K-means clustering, hierarchical clustering, spectral graph clustering • Deep Learning: Neural networks, convolutional neural networks • Student presentation
Class/Laboratory Schedule	
Contribution of course to meeting the professional component	
Assessment Methods in Alignment with Intended Learning Outcomes	• Student presentation (50%) • Final Exam (50%)
Course Webpage	
Rationale for Offering	
Date/Person Prepared	
Ethical Behavior Statement	Each student in this course is expected to abide by the VinUni Code of Academic Integrity. Any work submitted by a student in this course for academic credit will be the student's own work (with acknowledgement that many projects are carried out in groups in which participants will contribute equally). The Code is available on the web at (insert website). Violations are taken seriously.

7.3. Computer Vision

Course Code	**COMP5030**
Course Title	**Computer Vision**
Catalogue Description	Computer Vision is the area of engineering and computer science concerned with the use of artificial vision tools to collect and process information in order to provide automatic systems with some autonomy. The objective of this course is to present an insight into the world of machine vision that goes beyond image processing algorithms and traditional computer vision approaches. Students will acquire a knowledge and an understanding of artificial vision from a practical implementation perspective and gain the capability to design physical vision systems. Various aspects will be examined, as time permits, and some of the main approaches currently found in the literature will be discussed, opening the door to many research themes.
Credit Value	4
Required or elective	R
Pre-requisite/ Co-requisite/ Exclusion	Advanced Machine Learning
Textbook(s) and other required materials	TBD by VinUni Faculty. Sample texts include: 1. Trucco, Emanuele, and Alessandro Verri. *Introductory Techniques for 3-D Computer Vision*. Prentice Hall, 2006. 2. Prince, Simon J. D. *Computer Vision: Models, Learning, and Inference*. Cambridge University Press, 2012. 3. Forsyth, David, and Jean Ponce. *Computer Vision: a Modern Approach*. Pearson, 2012. 4. Davies, E. R. *Computer Vision: Principles, Algorithms, Applications, Learning*. Academic Press, 2018. 5. Bradski, Gary, and Adrian Kaehler. *Learning OpenCV*. O'Reilly Media, 2015.
Course Learning Goals	Students will: 1. use mathematical modelling tools to represent digital images. 2. perform transformations and filtering operations in the time and frequency domains to achieve desired outputs such as edge detection, noise removal, line and corner detection, and image smoothing. 3. apply morphological operations for shape recognition and template matching 4. use advanced algorithms such as support vector machines and artificial neural networks and deep learning techniques for object recognition and classification. 5. use stereo vision techniques and optical flow methods to study motion. 6. use contemporary numerical and simulation tools to implement methods and algorithms.

	7. communicate effectively in written and oral forms, and document and present results.
Course Learning Objectives	Upon completion of the course, students will be able to: 1. understand and master basic knowledge, theories and methods in image procesing and computer vision. 2. identify, formulate and solve problems in image procecssing and computer vision. 3. analyse, evaluate and examine existing practical computer vision systems. 4. communicate effectively and work in teams to develop a working computer vision system. 5. critically review and assess scientific literature in the field and apply theoretical knowledge to identify the novelty and practicality of proposed methods. 6. design and develop practical and innovative image processing and computer vision applications or systems. 7. conduct themselves professionally and responsibly in the areas of computer vision image processing and deep learning.
Topics Covered/ Indicative Syllabus	• Camera and optics • Light and color • Image filtering • Image processing • Feature detection and matching • Image compression • Multiple views and stereo • Recognition • Segmentation • Color imaging • Introduction to spectral imaging • Introduction to machine learning • Applications, including for example the following; o Face detection o Face recognition o OCR o Industrial applications o Medical imaging o Image stitching
Class/Laboratory Schedule	➢ Basics of computer vision ○ Nature of images. ○ Homogeneous transformations ○ Image acquisition ○ Geometrical and optical image formation ○ Perspective projection ○ Camera technologies ○ Vision systems design. ➢ Basics of image processing

	○ Filtering ○ Edge detection ○ Features detection ○ Contours, segmentation ○ Morphological operators. ➢ Calibration ○ Camera model ○ Intrinsic and extrinsic camera parameters ○ Camera calibration. ➢ Motion ○ Motion detection ○ Optical flow ○ Object tracking ○ Motion capture. ➢ Three-dimensional imaging ○ Epipolar geometry ○ Stereoscopic vision Active range imaging ○ Structured lighting. • Modelingandregistration ○ Modeling techniques for autonomous systems ○ Data fusion ○ Uncertainty mapping ○ Registration, pose estimation. • Applications ○ Quality control ○ Visual feedback ○ Mapping and robot guidance ○ Activity monitoring ○ Motion estimation ○ Autonomous systems ○ Biomedical imaging devices.
Contribution of course to meeting the professional component	This course serves as the foundational course in the computer vision field. It helps students to develop and apply computer vision techniques for solving practical problems. After this course, student be able to choose appropriate image processing methods for image filtering, image restoration, image reconstruction, segmentation, classification and representation.
Assessment Methods in Alignment with Intended Learning Outcomes	• Assignments: 10% • Presentation: 15% • Project: 25% • Midterm quiz: 20% • Exam: 30%

Course Webpage	TBD
Rationale for Offering	Computer Vision is an important field of Artificial Intelligence concerned with questions such as "how to extract information from image or video, and how to build a machine to see". Recent explosive growth of digital imaging technology, advanced computing, and deep learning makes the problems of automated image interpretation even more exciting and much more relevant than ever.
Date/Person Prepared	May 2021
Ethical Behavior Statement	Each student in this course is expected to abide by the Vin University Code of Academic Integrity. Any work submitted by a student in this course for academic credit will be the student's own work (with the acknowledgment that many projects are carried out in groups in which participants will contribute equally). The Code is available on the web at (insert website). Violations are taken seriously.

7.4. Natural Language Processing

Course Code	**COMP5040**
Course Title	**Natural Language Processing**
Catalogue Description	This course covers the introduction to natural language processing (NLP), the goal of which is to enable computers to use human languages as input, output, or both. It examines NLP in context of including machine translation, automatic conversational assistants and Internet search. Possible topics include summarization, machine translation, sentiment analysis and information extraction as well as methods for handling the underlying phenomena (e.g., syntactic analysis, word sense disambiguation, discourse analysis, their shortcomings and solutions).
Credit Value	4
Required or elective	
Pre-requisite/ Co-requisite/ Exclusion	Advanced undergraduates and graduates with a background in formal language and automata theory. Programming experience is necessary for the assignments. The required programming language for all assignments is Python 3.5. Prior exposure to linguistics is not required.
Textbook(s) and other required materials	TBD by VinUni Faculty. Sample texts include: 1. Jurafsky, Daniel, and James H. Martin. *Speech and Language Processing: An Introduction to Natural Language Processing, Computational Linguistics, and Speech Recognition*. 2nd ed., Prentice Hall, 2009. ISBN 978-0130950697.

	2. Jacob Eisenstein. *Introduction to Natural Language Processing (Adaptive Computation and Machine Learning series)*, The MIT Press, 2019. ISBN 978-0262042840.
Course Learning Goals	Students will: 1. understand the research questions and methods used in different areas of natural language processing. 2. implement simple natural language processing algorithms and applications. 3. understand and evaluate original research papers in natural language processing that build on and go beyond the textbook material covered in class.
Course Learning Objectives	On completion of the course, students will be able to: 1. understand approaches to discourse, generation, dialogue, and summarization within NLP. 2. Understand approaches to syntax and semantics in NLP. 3. explain the advantages and disadvantages of different NLP technologies and their applicability in different research domains. 4. explore the usage of different NLP technologies. 5. understand the leading trends and systems in NLP.
Topics Covered/ Indicative Syllabus	• Introduction and Overview • Regular Expression and Tokenization • Syntax and Parsing: Constituencies and Dependencies • Language Modeling • Part of Speech Tagging, Sequence Labeling, and Hidden Markov Models • Logistic Regression for NLP • Distributional similarities and Vector Semantics • Machine Translation • Discourse Processing • Dialogue Systems
Class/Laboratory Schedule	
Contribution of course to meeting the professional component	
Assessment Methods in Alignment with Intended Learning Outcomes	• Homework assignments (25%). • Midterm exam (25%). • Final exam (25%). • Research project or Literature survey (25%)
Course Webpage	
Rationale for Offering	
Date/Person Prepared	
Ethical Behavior Statement	Each student in this course is expected to abide by the VinUni Code of Academic Integrity. Any work submitted by a student in this course for academic credit will

	be the student's own work (with acknowledgement that many projects are carried out in groups in which participants will contribute equally). The Code is available on the web at (insert website). Violations are taken seriously.

7.5. Robotics

Course Code	**COMP 5050**
Course Title	**Robotics**
Catalogue Description	The course will cover: components of robotic systems; selection of coordinate frames; homogeneous transformations; solutions to kinematic equations; velocity and force/torque relations; manipulator dynamics in Lagrange's formulation; digital simulation of manipulator motion; trajectory planning; obstacle avoidance; controller design using the computed torque method; and different controllers for manipulators.
Credit Value	4 [Theory: 3, Practice: 1]
Required or elective	Required
Pre-requisite/ Co-requisite/ Exclusion	Pre-requisites: Control Systems Co-requisites: None
Textbook(s) and other required materials	TBD by VinUni faculty. Recommended text: 1. **Craig John J**, *Introduction to Robotics: Mechanics and Control*, 4th Edition, Pearson, 2017. Supplementary texts: 2. **A.J. Koivo,** *Fundamentals for Control of Robotic Manipulators*, J. Wiley & Sons, Inc., 1989, ISBN No. 0-471-85714-9.
Course Learning Goals	Students will: 1. Learn the Components of robotics systems 2. Learn the coordinate transformation, Selection of coordinate frames, the transform arithmetic. 3. Understand the kinematics and trajectory planning. 4. Learn the Velocities, Forces, Torques in Joint and Base Coordinates. 5. Learn Dynamic Modelling, Lagrange's energy expressions for a manipulator 6. Learn the sensors and devices in a robotics system. 7. Design PID-controller and Force-torque control strategy
Course Learning Objectives	Upon completion of the course, students will be able to: 1. Identify the basic components of robot, select the right coordinate system for particular manipulator movement, and perform position transformation between different coordinates. 2. Characterize the kinematics in static and dynamic situations, calculate and solve the kinematics problems

	3. Calculate a trajectory for the desired motion of a manipulator in multidimensional space; Calculate Forces and Torques in the Joints and Arms of the robot 4. Implement dynamic modelling, Lagrange's energy expression and equation of motion 5. Describe the sensors and devices in a robotics system and robotic applications 6. Calculate the parameters of controllers.
Topics covered/ Indicative Syllabus	• Introduction to Robotics • Coordinate Transformation • Kinematics • Trajectory Planning • Control Techniques • Sensors and Devices • Robot Applications
Class/Laboratory Schedule	Lectures: Two 75 min lectures per week Homework: Weekly assignments Exams: One midterm exams and one final exam. Design Project: The course has a design project that will last throughout the semester.
Contribution of course to meeting the professional component	This course serves as a graduate course in Master in CS and Ph.D. in CS programs. It contributes to the students' understanding of a broad range of topics in robotics with an emphasis on basics of manipulators, coordinate transformation and kinematics, trajectory planning, control techniques, sensors and devices, and robot applications
Assessment Methods in Alignment with Intended Learning Outcomes	Course outcomes are primarily assessed through homework assignments, project, and exams: Homework (10%), Midterm Exam (30%), Project (20%), and Final Exam (40%).
Course Webpage	TBD by VinUni Faculty
Rationale for offering	This course provides students with both basic and advanced knowledge of a robot motions including kinematics and dynamics, as well as control techniques and sensor systems. This course fits into the program mission and complements the existing program curriculum because it covers a broad range of topics in robotics with an emphasis on basics of manipulators, coordinate transformation and kinematics, trajectory planning, control techniques, sensors and devices, robot applications and economics analysis. This course is unique and does not overlap with any existing courses, thereby complementing the area/subarea offerings. This course will enhance graduates' education from the control system area and will support students' career in the control system applications, especially in robotics.
Person preparing this description and date	Do Tho Truong, 4/2020

Ethical behavior statement	Each student in this course is expected to abide by the Vin University Code of Academic Integrity. Any work submitted by a student in this course for academic credit will be the student's own work (with the acknowledgment that many projects are carried out in groups in which participants will contribute equally). The Code is available on the web at (insert website). Violations are taken seriously.

7.6. Ubiquitous Sensing and Intelligent Systems

Course Code	**COMP 5060**
Course Title	**Ubiquitous Sensing and Intelligent Systems**
Catalogue Description	This course aims to provide student with an overview and the foundation of multidisciplinary research field of next generation of computing. It covers the sensing technology, mechanism behind sensing data, embedded computing, and methods to analyze sensing data.
Credit Value	4
Required or elective	An elective course for Master and Ph.D. program in Computer Science.
Pre-requisite/ Co-requisite/ Exclusion	Pre-requisites: Undergraduate level in Computer Science or Electrical Engineering program with minimum grade of C
Textbook(s) and other required materials	TBD by VinUni Faculty. Sample texts include: 1. Mechatronic Systems, Sensors, and Actuators : Fundamentals and Modeling, Robert H. Bishop, CRC Press, 2017. 2. ARM® v7-M Architecture Reference Manual 3. G. Buttazzo, *Hard Real-Time Computer Systems: Predictable Scheduling Algorithms and Applications*, 3rd Edition, Springer, 2011. 4. Ubiquitous Computing Fundamentals (1st ed.). Chapman & Hall/CRC
Course Learning Goals	Upon completion of the course, students will be able to: 1. Understand the fundamental physical/chemical sensor & actuator mechanism 2. Analyze mechanism behind sensing data 3. Acquire knowledge of embedded computing 4. Learn about the standard methods and techniques of analyzing measure sensing data 5. Hand-on experiment with intelligent system including (sensor and analysis)
Topics Covered/ Indicative Syllabus	• Physical/chemical types of sensors • Types of actuators • Embedded computing • Overview of wearable computing

	• Sensor data analysis including applied machine learning • Sensor fusion techniques • Privacy in mobile and ubiquitous computing • Real world applications: implications and challenges
Class/Laboratory Schedule	Lectures: Two 75-min lectures per week Design Project: The course has a design project that will last throughout the semester.
Contribution of course to meeting the professional component	This course provides the knowledge of real-world ubiquitous computing system that students will face in future career. It contributes to the students' skills in applying and integrating the knowledge from other courses to design, analyze and interface with a physical system. In addition, students will learn the values and tradeoffs between theory, simulation, and physical implementations. This course also contributes to student's hands-on skills on design, prototyping, implementation, and control of a real-time intelligent system.
Assessment Methods in Alignment with Intended Learning Outcomes	Course outcomes will be assessed through in-class quizzes (20%), homework assignments (20%), and final project report and presentation (60%).
Course Webpage	Canvas website
Rationale for Offering	The world is moving to the third generation of computing where Internet of Things and intelligent systems are pervasive and ubiquitous. This course aims to support students' skills in designing a physical system that meets future practical requirements through projects.
Date/Person Prepared	Cuong Do, 4/2021
Ethical Behavior Statement	Each student in this course is expected to abide by the Vin University Code of Academic Integrity. Any work submitted by a student in this course for academic credit will be the student's own work. Violations are taken seriously.

7.7. Internet of Things

Course Code	**COMP5070**
Course Title	**Internet of Things (IoT)**
Catalogue Description	This course covers the main cybersecurity principles and technologies motivated by the evolving ecosystem of Internet of Things (IoT): smart devices, sensors, operating systems, data storage, networking, communication protocols, and system services. The topics include IoT device and system security threats, privacy issues, open challenges, and countermeasure techniques.
Credit Value	4
Required or elective	

Pre-requisite/ Co-requisite/ Exclusion	Networks or Equivalent
Textbook(s) and other required materials	TBD by VinUni Faculty. Sample texts include: 1. *The Internet of Things*, by Samuel Greengard, ISBN: 9780262527736 2. *Internet of Things: Architectures, Protocols, and Standards*, by Simon Cirani, Marco Picone, and Luca Veltri 3. *Internet of Things: Principles and Paradigms*, by Rajkumar Buyya and Amir Vahid Dastjerdi
Course Learning Goals	Students will: 1. understand the core technology in IoT, including embedded systems, smart devices, communication protocols, and data processing techniques. 2. understand and explain the core IoT cybersecurity principles and technologies. 3. examine and explain security threats and data trustworthiness issues in IoT based applications.
Course Learning Objectives	Upon completion of the course, students will be able to: 1. understand and describe concepts in IoT technology, design principles of IoT systems, and IoT application development. 2. analyze IoT devices and systems from a cybersecurity perspective. 3. identify appropriate security and privacy solutions for IoT. 4. explain open challenges and issues related to IoT applications.
Topics Covered/ Indicative Syllabus	• Introduction to IoT systems: definitions, applications, and technologies. • IoT cybersecurity principles and technologies. • Security threats and techniques in IoT. • Data trustworthiness and privacy in IoT. • IoT in healthcare: Interoperability and security issues. • IoT in smart home: Security risks. • Open issues, challenges, and countermeasures.
Class/Laboratory Schedule	
Contribution of course to meeting the professional component	
Assessment Methods in Alignment with Intended Learning Outcomes	• Assignments: 10% • Presentation: 15% • Project: 25% • Midterm: 20% • Exam: 30%

Course Webpage	
Rationale for Offering	
Date/Person Prepared	
Ethical Behavior Statement	Each student in this course is expected to abide by the Vin University Code of Academic Integrity. Any work submitted by a student in this course for academic credit will be the student's own work (with the acknowledgment that many projects are carried out in groups in which participants will contribute equally). The Code is available on the web at (insert website). Violations are taken seriously.

7.8. Blockchain Technologies

Course Code	**COMP 5080**
Course Title	**Blockchain Technologies**
Catalogue Description	This course covers the topics related to blockchain technologies. It discusses distributed systems and alternative consensus mechanisms, as well as cryptoeconomic and proof-of-stake. The topics include: Altcoins, Bitcoin transactions, consensus protocols, cryptocurrency, elliptic curves, hash functions, mining strategies and incentives, Zerocoin, zerocash. Fundamental uses of bitcoin and blockchain technology are examined, including enterprise blockchain systems, adopting blockchain, and the governmental and societal regulation and control of the blockchain technology.
Credit Value	4
Required or elective	
Pre-requisite/ Co-requisite/ Exclusion	Networks or Equivalent
Textbook(s) and other required materials	TBD by VinUni Faculty. Sample texts include: 1. *The Basics of Bitcoins and Blockchains*, by Antony Lewis. 2. *Blockchain Revolution*, by Don and Alex Tapscott. 3. *Blockchain and the Law: The Rule of Code*, by Primavera De Filippi, and Aaron Wright.
Course Learning Goals	Students will: 1. understand the blockchain technology's fundamental concepts and its implementation. 2. acquire a range of skills to assess and work effectively with blockchain technology in different fields. 3. explain the limitations, challenges and opportunities associated with blockchain technology.
Course Learning Objectives	Upon completion of the course, students will be able to:

	1. understand the concept of blockchain technology, challenges, gaps, and problems. 2. understand and explain the business needs and the connection to blockchain technology. 3. evaluate blockchain solutions and their economic impact. 4. understand how blockchain is applied to different aspects of the business.
Topics Covered/ Indicative Syllabus	Topics to be covered: An introduction to blockchain technology • Decentralized ledger system • Integrity, security, and privacy issues of a decentralized system • The importance of blockchain technology Cryptocurrency, platforms, and blockchain technology • Introduction to cryptocurrency (Bitcoin, Ethereum, etc.) • Cryptographic elements (public key, private key, digital signature, and hash value) • Classification of blockchain platforms (Ethereum, IBM Blockchain, OpenChain, etc.) Blockchain philosophy and cryptonomics • Philosophical contemplation of blockchain technology • Towards a decentralized society • The economics of new age Blockchain Applications and Use Cases • Business drivers of blockchain • Selection criteria for blockchain applications • Digital currency and finance • Supply chain transfer • Healthcare • Ownership and property rights • Governance and compliance Blockchain limitations, opportunities, and challenges • Limitations • Security risks • Privacy issues • The future of blockchain • Legal and regulatory problems
Class/Laboratory Schedule	
Contribution of course to meeting the	

professional component	
Assessment Methods in Alignment with Intended Learning Outcomes	• Participation and Readings - 20% • Case studies - 50% (25% each) • Reflection paper - 30%
Course Webpage	
Rationale for Offering	
Date/Person Prepared	
Ethical Behavior Statement	Each student in this course is expected to abide by the Vin University Code of Academic Integrity. Any work submitted by a student in this course for academic credit will be the student's own work (with the acknowledgment that many projects are carried out in groups in which participants will contribute equally). The Code is available on the web at (insert website). Violations are taken seriously.

7.9. Cryptography

Course Code	**COMP 5090**
Course Title	**Cryptography**
Catalogue Description	This course gives an introduction to the theory and practice of cryptographic techniques. The key topics are encryption (secret-key and public-key), message integrity, digital signatures, user authentication, key management, cryptographic hashing, network security protocols (SSL, IPsec), public-key infrastructure, digital rights management, and zero-knowledge protocols.
Credit Value	4
Required or elective	
Pre-requisite/ Co-requisite/ Exclusion	Algorithm Design or Equivalent
Textbook(s) and other required materials	TBD by VinUni Faculty. Sample texts include: *1.* D. Boneh, and V. Shoup, *A Graduate Course in Applied Cryptography*. 2. Niels Ferguson, Bruce Schneier, and Tadayoshi Kohno. *Cryptography Engineering.* Wiley, Indianapolis, IN, 2010. ISBN 978-0-470-47424-2. 3. J. Katz and Y. Lindell, *Introduction to Modern Cryptography*, 3rd edition.
Course Learning Goals	Students will: 1. understand the important to enhance security connected with data storage, communication, and various electronic transactions.

	2. understand basic cryptographic concepts and methods, a good knowledge of some commonly used cryptographic primitives and protocols. 3. explain the basics of computational number theory, the constructions and security issues of various cryptosystems, such as symmetric encryption schemes (stream cipher and block cipher), digital signature schemes, and cryptography protocols.
Course Learning Objectives	Upon completion of the course, students will be able to: 1. explain how theories, principles, and techniques based on cryptology can be used to achieve data security. 2. understand and explain the theories underpinning standard cryptographic methods, such as different types of hash-functions, symmetric and asymmetric ciphers, digital signatures, and random numbers. 3. analyze, use, and implement such methods and reflect on their limits and applicability.
Topics Covered/ Indicative Syllabus	Topics to be covered: Basic Symmetric-Key Encryption • One Time Pad • Stream Cipher • Block Cipher Public-key Cryptography • Arithmetic modulo primes • Cryptography using arithmetic modulo primes • Public key encryption • Arithmetic modulo composites Digital Signatures • Digital signatures: definitions and applications • More signature schemes and applications • Cryptographic Protocols Protocols • Identification protocols • Authenticated key exchange and SSL/TLS session setup • Zero-knowledge protocols
Class/Laboratory Schedule	
Contribution of course to meeting the professional component	
Assessment Methods in Alignment with	• Assignments: 10% • Presentation: 15% • Project: 25%

Intended Learning Outcomes	• Midterm: 20% • Exam: 30%
Course Webpage	
Rationale for Offering	
Date/Person Prepared	
Ethical Behavior Statement	Each student in this course is expected to abide by the Vin University Code of Academic Integrity. Any work submitted by a student in this course for academic credit will be the student's own work (with the acknowledgment that many projects are carried out in groups in which participants will contribute equally). The Code is available on the web at (insert website). Violations are taken seriously.

7.10. System, Network and Cloud Security

Course Code	**COMP 5100**
Course Title	**System, Network and Cloud Security**
Catalogue Description	The course gives an overview of security topics for operating systems, networks and Cloud. It covers the main operating systems in the market and gives the overview of securing their main elements according to a variety of usage scenarios. It also discusses network security, setting up secure network environments and responding to security threats in a networked environment. Finally, it considers approaches to securing Cloud and distributed systems and data, with a special focus on data privacy.
Credit Value	4
Required or elective	
Pre-requisite/ Co-requisite/ Exclusion	Networks, Operating Systems or Equivalent
Textbook(s) and other required materials	TBD by VinUni Faculty. Sample texts include: 1. Charles P. Pfleeger and Shari Lawrence Pfleeger. *Analyzing Computer Security: A Threat/Vulnerability/Countermeasure Approach*. Prentice Hall, Upper Saddle River, NJ, 2011. ISBN 978-0-13-278946-2. 2. William Stallings (2016). *Cryptography and Network Security - Principles and Practices,* 7th Edition, Prentice Hall.
Course Learning Goals	Students will: 1. describe the security design principles of the operating systems, networks, and Cloud infrastructure. 2. understand the impacts of known threats, risks, vulnerabilities, and privacy issues to organization. 3. explore the guiding security design patterns, applied technologies, and skills relating to IT services' safeguards and countermeasures.

	4. apply approaches to securing Cloud and distributed systems and data, with a special focus on data privacy.
Course Learning Objectives	Upon completion of the course, students will be able to: 1. explain the concepts of confidentiality, availability, and integrity (CIA) in the context of information assurance. 2. understand the fundamentals of the operating system, network, and Cloud computing architectures based on current standards, protocols, and best practices. 3. understand the concepts and guiding principles for designing and implementing appropriate safeguards and countermeasures for IT services. 4. design secure environments to assure isolation of physical and logical infrastructures. 5. identify the known threats, risks, vulnerabilities, and privacy issues associated with the operating system, network, and cloud-based services. 6. understand the industry security standards, regulatory, audit policies, and compliance requirements for the operating system, network, and cloud-based infrastructures.
Topics Covered/ Indicative Syllabus	Topics to be covered: • Basic security principles • Incidents for security breaches. • System-level security and analysis • Network protocols and security • Cloud security • Data security and storage • Access and authentication control • Security risks evaluation
Class/Laboratory Schedule	
Contribution of course to meeting the professional component	
Assessment Methods in Alignment with Intended Learning Outcomes	• Assignments: 10% • Presentation: 15% • Project: 25% • Midterm: 20% • Exam: 30%
Course Webpage	
Rationale for Offering	
Date/Person Prepared	

Ethical Behavior Statement	Each student in this course is expected to abide by the Vin University Code of Academic Integrity. Any work submitted by a student in this course for academic credit will be the student's own work (with the acknowledgment that many projects are carried out in groups in which participants will contribute equally). The Code is available on the web at (insert website). Violations are taken seriously.

7.11. Big Data Analytics

Course Code	**COMP5110**
Course Title	**(Data Mining and) Big Data Analytics**
Catalogue Description	The aim of this course is to provide practical knowledge for working as a Data Scientist or a Machine Learning Engineer in an industrial environment. Students will learn how to apply Machine Learning at a large scale, driving an AI product to production, and collaborating in a team.
Credit Value	4
Required or elective	Elective (Required for focus Data Science Analytics)
Pre-requisite/ Co-requisite/ Exclusion	Advanced Machine Learning and Data Mining
Textbook(s) and other required materials	TBD by VinUni Faculty. Sample texts include: 1. Amit Nandi, *The Spark for Python Developers*, Packt Publishing, 2015. ISBN: 978-1784397371. 2. Glen J. Myat, *Making Sense of Data*, John Wiley & Sons, 2007. ISBN:978-0470074718.
Course Learning Goals	Students will: 1. distinguish between many forms of data, how data vary by scholarly discipline, and how they are used throughout the scholarly life cycle. 2. learn some professional criteria for selecting and appraising data. 3. explain technologies for Big Data analytics, such as statistical analysis, text mining, and machine learning. 4. describe the ethics, governance, and sustainability challenges relating to Big Data.
Course Learning Objectives	Upon completion of the course, students will be able to: 1. understand the big data characteristics and challenges. 2. learn various open questions over big data. 3. familiarize with the existing big data processing platforms/tools. 4. understand big data collection, integration, and storage. 5. learn the core techniques of processing big data, including data cleansing, and various aspects of data analytics and visualization. 6. apply big data analytic methods on real life problems.

Topics Covered/ Indicative Syllabus	• Overview of Big Data. • Introduction to Hadoop Ecosystem. • Introduction to Spark 2.0. • Language processing with Spark 2.0. • Analysis of Streaming Data with Spark 2.0. • Applications of Spark ML Library. • Statistical Process Control. • Data Visualization and Translation. • Assessing Quality of Big Data Analysis.
Class/Laboratory Schedule	
Contribution of course to meeting the professional component	
Assessment Methods in Alignment with Intended Learning Outcomes	• Homework: 20% • Assignment: 30% • Midterm Exam: 20% • Final Exam: 30%
Course Webpage	
Rationale for Offering	
Date/Person Prepared	
Ethical Behavior Statement	Each student in this course is expected to abide by the Vin University Code of Academic Integrity. Any work submitted by a student in this course for academic credit will be the student's own work (with the acknowledgment that many projects are carried out in groups in which participants will contribute equally). The Code is available on the web at (insert website). Violations are taken seriously.

7.12. Visualization

Course Code	**COMP5120**
Course Title	**Visualization**
Catalogue Description	Visual media are increasingly generated, manipulated, and transmitted by computers. When well designed, such displays capitalize on human facilities for processing visual information and thereby improve comprehension, memory, inference, and decision making. Yet the digital tools for transforming data into visualizations still require low-level interaction by skilled human designers. As a result, producing effective visualizations can take hours or days and consume considerable human effort.

	In this course, we will study techniques and algorithms for creating effective visualizations based on principles and techniques from graphic design, visual art, perceptual psychology, and cognitive science. The course is targeted both towards students interested in using visualization in their own work, as well as students interested in building better visualization tools and systems. In addition to participating in class discussions, students will have to complete several short programming and data analysis assignments as well as a final programming project.
Credit Value	4
Required or elective	
Pre-requisite/ Co-requisite/ Exclusion	Statistics and Probability (R), Data Mining, Web Programming, JavaScript, Python
Textbook(s) and other required materials	TBD by VinUni Faculty. Sample texts include: 1. Tufte, Edward R. *The Visual Display of Quantitative Information*. Graphics Press, 2009. 2. Tufte, Edward Rolf. *Envisioning Information*. Graphics Press, 2017. 3. Ward, Matthew, et al. *Interactive Data Visualization: Foundations, Techniques, and Applications*. CRC Press, 2015. 4. Thomas, James J. *Illuminating the Path:* IEEE, 2005.
Course Learning Goals	Students will: 1. explore how to design and create data visualization based on data available and tasks to be achieved. 2. Understand data and image modeling, exploratory data analysis, and visualization design. 3. learn how to create and analyze their data visualizations by using open source data visualization tools.
Course Learning Objectives	Upon completion of the course, students will be able to: 1. understand the key concepts about visualization techniques and visual analytics. 2. identify and evaluate the key issues in the application of data visualization techniques. 3. use appropriate visualization tools effectively for data analysis.
Topics Covered/ Indicative Syllabus	• The Purpose of Visualization: • Data and Image Models • Visualization Design • Exploratory Data Analysis • Perception • Interaction • Introduction to D3 • D3 Tutorial • Using Space Effectively: 2D

	• Visual Explainers • Deconstructing Visualizations • Color • Graph Layout • Network Analysis • Animation
Class/Laboratory Schedule	
Contribution of course to meeting the professional component	ExCel
Assessment Methods in Alignment with Intended Learning Outcomes	● Class Participation: (10%) ● Assignment 1: Visualization Design (10%) ● Assignment 2: Exploratory Data Analysis (15%) ● Assignment 3: Creating Interactive Visualization Software (25%) ● Final Project (40%)
Course Webpage	
Rationale for Offering	
Date/Person Prepared	
Ethical Behavior Statement	Each student in this course is expected to abide by the Vin University Code of Academic Integrity. Any work submitted by a student in this course for academic credit will be the student's own work (with the acknowledgment that many projects are carried out in groups in which participants will contribute equally). The Code is available on the web at (insert website). Violations are taken seriously.

7.13. Digital Forensics

Course Code	**COMP 5130**
Course Title	**Digital Forensics**
Catalogue Description	The course covers the area of digital forensics including collecting evidence extracting information from software and hardware systems. It discusses forensics of networks, live systems, mobile phones and other device forensics. It provides insight into the areas of covert analysis and intruder artifacts. Students participate in a project where they take a role of a forensic examiner and use existing tools to understand digital forensics cases. Special attention is given to the area of data recovery and analytics as part of the digital forensics process.
Credit Value	4

Required or elective	
Pre-requisite/ Co-requisite/ Exclusion	Software Construction or Equivalent
Textbook(s) and other required materials	TBD by VinUni Faculty. Sample texts include: 1. E. Casey *Digital Evidence and Computer Crime, third edition*, Academic Press, 2011. 2. Bill Nelson, Amelia Phillips, Christopher Steuart (2015). *Guide to Computer Forensics and Investigations*, Fifth Edition, ISBN-13: 978-1285060033. Cengage Learning
Course Learning Goals	This course exposes students to the forensics tools, methods, and procedures used to investigate computers, data recovery techniques, evidence collection, evidence protection, expert witness skills, and computer crime investigation techniques. It emphasizes the importance of digital forensics and prepares students to conduct a digital investigation in an organized and systematic way. Students will learn different techniques and procedures to collect forensic data, analyze, compile, and report on forensics data obtained from digital media.
Course Learning Objectives	Upon completion of the course, students will be able to: 1. Apply knowledge of various forensic tools and techniques employed by computer forensics experts on digital media. 2. Explain and adequately document the process of digital forensics analysis. 3. Understand the tradeoffs and differences between various forensic tools. 4. Describe the representation and organization of data and metadata within modern computer systems. 5. Describe the current research in computer forensics.
Topics Covered/ Indicative Syllabus	Topics to be covered: • Overview of digital investigation and digital evidence • Investigation processes • Data Acquisitions • Processing Crime and Incident Scenes • File System Analysis & file recovery • Information hiding & steganography • Time, registry & password recovery • Email & database forensics
Class/Laboratory Schedule	
Contribution of course to meeting the professional component	
Assessment Methods in Alignment with	• Homework: 30%

Intended Learning Outcomes	• Research Project: 20% • Midterm Exam: 20% • Final Exam: 30%
Course Webpage	
Rationale for Offering	
Date/Person Prepared	
Ethical Behavior Statement	Each student in this course is expected to abide by the Vin University Code of Academic Integrity. Any work submitted by a student in this course for academic credit will be the student's own work (with the acknowledgment that many projects are carried out in groups in which participants will contribute equally). The Code is available on the web at (insert website). Violations are taken seriously.