Annexure-F

Revised Curriculum for MS Computer Science

DEPARTMENT OF COMPUTER SCIENCE
UNIVERSITY OF PESHAWAR
SESSION 2024

1 Introduction

The MS Computer Science program of the Department of Computer Science is a research-oriented program. The program has been designed in light of the guidelines/models enacted by authorized national bodies and meets global standards. It offers advanced courses in the emerging research areas of computer science followed by intensive research work which allows students to transform themselves into highly skilled researchers capable of working in industry and academia.

2 Rationale of Revision

Computer Science spans a wide range, from its theoretical and algorithmic foundations to cutting-edge developments in applied fields including machine learning, information management, World Wide Web, bioinformatics, and other exciting areas. Advanced principles, concepts, methods, approaches, and technologies continually evolve and intersect over time to address the ever-changing and diverse landscape of Computer Science. Therefore, the curriculum of a MS Computer Science program must be updated regularly to include the latest advancements and technologies, ensuring that students are equipped to meet the evolving demands of the field and software industry, thereby contributing to the country's economic growth. The following notable changes have been made in the existing MS Computer Science program:

1. List of specializations has been updated.
2. New courses have been added in different categories to train students in the latest technologies of Computer Science. Obsolete courses have been archived.
3. Course titles of the existing courses have been changed, where needed, to clearly reflect their contents.
4. Contents of existing courses have been revised to incorporate topics related to recent trends in Computer Science, to equip students with up-to-date information in Computer Science theory and research.
5. Text and reference books have been updated where needed.
6. New course codes have been allotted to the existing and new courses according to the UOP course code policy in the 700 series.
7. Core courses have been proposed as per the HEC curriculum.

3 List of Specializations/ Research Area

The specialization/Research Area of a research scholar will be decided by the Graduate Studies Committee (GSC) at the time of proposal defense. The following table shows the list of specializations in MS Computer Science at the Department of Computer Science:

S.No.	Name of Specialization/Research Area
1	Artificial Intelligence
2	Cloud Computing
3	Computer Networks
4	Computer Vision
5	Cyber Security
6	Data Science
7	Data Mining
8	Database Systems
9	Digital Transformation
10	Digital Humanism
11	Digital Inclusion
12	Educational Technology
13	E-Governance
14	Human Computer Interaction
15	ICT Accessibility
16	Image Processing
17	Information Retrieval
18	Machine Learning
19	Parallel Computing
20	Real Time Systems
21	Software Engineering
22	Web Engineering
23	Web Semantics
24	Wireless Networks
25	Wireless Sensor Networks

4 Course Details

4.1 Complete List of MS Courses with New Course Codes

S. No.	New Course Code	Old Course Code	Course Title	Credit Hours	Course Details
1	CS651	CS7101	Research Methods for Computer Science	1	Revised
2	CS701	CS7201	Theory of Computation	3	Revised
3	CS702	CS7202	Advanced Algorithm Analysis	3	Revised
4	CS703	CS7203	Advanced Operating Systems	3	Revised
5	CS704	CS7204	Advanced Computer Architecture	3	Revised
6	CS705	CS7205	Middleware Technologies for Distributed Systems	3	Revised
7	CS706	CS7206	Advanced Databases	3	Revised
8	CS707	CS7207	Data Warehousing	3	Revised
9	CS708	CS7208	Data Mining	3	Revised
10	CS709	CS7209	Database Security	3	Revised
11	CS710	CS7210	Distributed System Components	3	Revised
12	CS711	CS7211	Advanced Networking	3	Revised
13	CS712	CS7212	Cloud Security	3	Revised
14	CS713	CS7213	Opportunistic Networks	3	Revised
15	CS714	CS7214	Wireless Networks	3	Revised
16	CS715	CS7216	Semantic Web	3	Revised
17	CS716	CS7217	Web Mining	3	Revised
18	CS717	CS7218	Ontology Engineering	3	Revised
19	CS718	CS7226	Business Intelligence	3	Revised
20	CS719	CS7227	Advanced Wireless Network Security	3	Revised
21	CS720	CS7228	Wireless Sensor Networks	3	Revised
22	CS721	CS7229	Empirical Methods in Software Engineering Research	3	Revised

S. No.	New Course Code	Old Course Code	Course Title	Credit Hours	Course Details
23	CS722	CS7231	Emerging Technologies in Software Engineering	3	Revised
24	CS723	CS7232	Agile Software Development	3	Revised
25	CS724	CS7236	Real-Time Systems	3	Revised
26	CS725	CS7237	High Performance Computing	3	Revised
27	CS726	CS7238	Concurrency and Parallelism	3	Revised
28	CS727	CS7239	Advanced Data Analytics	3	Revised
29	CS728	CS7241	Software Engineering in Society	3	Revised
30	CS729	CS7242	Software Evolution and Reengineering	3	Revised
31	CS730	CS7243	Engineering Privacy in Software	3	Revised
32	CS731	CS7246	Real-time Stream Processing	3	Revised
33	CS732	CS7247	Linked Open Data	3	Revised
34	CS733	CS7249	Advanced Web Technologies	3	Revised
35	CS734	CS7250	Digital Libraries	3	Revised
36	CS735	CS7252	Wireless Ad hoc Networks	3	Revised
37	CS736	CS7253	Introduction to Computer Vision	3	Revised
38	CS737	CS7254	Advanced Digital Image Processing	3	Revised
39	CS738	CS7259	Pattern Recognition	3	Revised
40	CS739	CS7260	Technology Enhanced Learning	3	Revised
41	CS740	CS7261	Persuasive Technologies	3	Revised
42	CS741	CS7262	Interaction Design	3	Revised
43	CS742	CS7263	User Centered Research and Evaluation	3	Revised
44	CS743	CS7257	Advanced Machine Learning	3	Revised
45	CS744		Privacy Enhancing Technologies (PETs)	3	New
46	CS745		Intelligent Wireless Networks	3	New

S. No.	New Course Code	Old Course Code	Course Title	Credit Hours	Course Details
47	CS746		Improving Deep Neural Networks	3	New
48	CS747		Large Language Models	3	New
49	CS748		Transformers in Machine Learning	3	New
50	CS749		Convolutional Neural Network	3	New
51	CS750		Web Security	3	New
52	CS751		Internet of Things Architecture, Protocols, and Standards	3	New
53	CS752		Blockchain Technologies	3	New

4.2 Details of Revised Courses

S. No.	Course Code	Course Title	Course Code Updated	Course Title Changed	Course Outline Updated	Reference Material Updated	Remarks
1	CS651	Research Methods for Computer Science	✓		✓	✓	Changed to non-Credit course as per HEC policy.
2	CS701	Theory of Computation	✓		✓		
3	CS702	Advanced Algorithm Analysis	✓		✓		
4	CS703	Advanced Operating Systems	✓		✓		
5	CS704	Advanced Computer Architecture	✓		✓	✓	
6	CS705	Middleware Technologies for Distributed Systems	✓	✓	✓	✓	

S. No.	Course Code	Course Title	Course Code Updated	Course Title Changed	Course Outline Updated	Reference Material Updated	Remarks
7	CS706	Advanced Databases	✓		✓		
8	CS707	Data Warehousing	✓				
9	CS708	Data Mining	✓				
10	CS709	Database Security	✓				
11	CS710	Distributed System Components	✓				
12	CS711	Advanced Networking	✓				
13	CS712	Cloud Security	✓				
14	CS713	Opportunistic Networks	✓	✓	✓	✓	
15	CS714	Wireless Networks	✓		✓		
16	CS715	Semantic Web	✓		✓		
17	CS716	Web Mining	✓		✓		
18	CS717	Ontology Engineering	✓		✓		
19	CS718	Business Intelligence	✓		✓		
20	CS719	Advanced Wireless Network Security	✓		✓	✓	
21	CS720	Wireless Sensor Networks	✓		✓		

S. No.	Course Code	Course Title	Course Code Updated	Course Title Changed	Course Outline Updated	Reference Material Updated	Remarks
22	CS721	Empirical Methods in Software Engineering Research	✓		✓	✓	
23	CS722	Emerging Technologies in Software Engineering	✓		✓	✓	
24	CS723	Agile Software Development	✓		✓	✓	
25	CS724	Real-Time Systems	✓		✓	✓	
26	CS725	High Performance Computing	✓	✓	✓	✓	
27	CS726	Concurrency and Parallelism	✓		✓	✓	
28	CS727	Advanced Data Analytics	✓	✓	✓	✓	
29	CS728	Software Engineering in Society	✓	✓	✓	✓	
30	CS729	Software Evolution and Reengineering	✓	✓	✓	✓	
31	CS730	Engineering Privacy in Software	✓		✓	✓	
32	CS731	Real-time Stream Processing	✓		✓	✓	
33	CS732	Linked Open Data	✓		✓		
34	CS733	Advanced Web Technologies	✓		✓		
35	CS734	Digital Libraries	✓		✓		

S. No.	Course Code	Course Title	Course Code Updated	Course Title Changed	Course Outline Updated	Reference Material Updated	Remarks
36	CS735	Wireless Ad hoc Networks	✓		✓		
37	CS736	Introduction to Computer Vision	✓		✓		
38	CS737	Advanced Digital Image Processing	✓		✓		
39	CS738	Pattern Recognition	✓		✓	✓	
40	CS739	Technology Enhanced Learning	✓		✓	✓	
41	CS740	Persuasive Technologies	✓		✓	✓	
42	CS741	Interaction Design	✓		✓	✓	
43	CS742	User Centered Research and Evaluation	✓		✓	✓	
44	CS743	Advanced Machine Learning	✓	✓	✓	✓	

4.3 List of Archived Courses

S. No.	Code	Course Title	Credit Hours
1	CS7102	Statistical Analysis	3
2	CS7103	Introduction to Mathematical Logic	3
3	CS7215	Network Performance Evaluation	3
4	CS7219	Description Logic	3
5	CS7220	Morphology of Natural Language	3
6	CS7221	Syntax of Natural Language	3

S. No.	Code	Course Title	Credit Hours
7	CS7222	Corpus Linguistics	3
8	CS7223	Machine Translation	3
9	CS7224	Mobile Ad Hoc Networking	3
10	CS7225	Network Management and QoS Provisioning	3
11	CS7230	Software Requirements Engineering	3
12	CS7233	Software System Quality	3
13	CS7234	Software Configuration Management	3
14	CS7235	Software Engineering Laboratory	3
15	CS7240	Smart Device Communications	3
16	CS7244	GPU Programming	3
17	CS7245	Parallel Algorithms Design and Analysis	3
18	CS7248	Virtual and Augmented Reality	3
19	CS7251	Information and Communication Technology (ICT) Accessibility	3
20	CS7255	Automatic Speech Recognition	3
21	CS7256	Image Compression	3
22	CS7258	Mathematics for Imaging	3

5 Core Courses

As per the HEC MC Computer Science curriculum 2017, MS scholars will have to take the following core courses:

1. CS701: Theory of Computation
2. CS702: Advanced Analysis of Algorithms
3. CS703: Advanced Operating Systems
4. CS704: Advanced Computer Architecture

MS scholars also need to pass the following course

1. Research Methods for Computer Science

(minor course of 1 credit hour)

6 Course Contents

Course Name:	Research Methods for Computer Science
Course Code:	CS651
Credit Hours:	1
Pre-requisites:	None

Course Introduction: This course helps students to understand how quantitative and qualitative research should be done.

Course Objectives: The objectives of this course is as follows:

- Learn the philosophy and ethics of computer science research
- Improve technical writing and communication skills
- Design experiments to test hypotheses and evaluate results
- Understand both quantitative and qualitative research methods
- Discover how research is done at the M.S. and Ph.D. levels

Course Outline: This course provides an introduction to research methodology in computer science, covering the objectives and dimensions of research, tools, and techniques. Students will learn how to identify research problems, conduct literature reviews, and design experiments. The course also covers empirical methods of algorithm analysis, working with human subjects, qualitative and quantitative studies, and paper writing, reviewing, and publishing. Additionally, students will learn about starting research, PhD thesis expectations, finding good problems, and using online tools such as Google, CiteSeer, ACM Digital Library, and IEEE. The course also touches on grants, research proposals, and intellectual property. By the end of the course, students will understand how research is done at M.S. and Ph.D. levels and be able to conduct their own research in computer science.

Reference Material: The following is the recommended list of books (or their latest editions):

1. Khan, Koffka. Modern Research Methods in Computer Science, 13 Aug. 2023.
2. Dresch, Aline, et al. Design Science Research: A Method for Science and Technology Advancement, 1 Sep. 2014.
3. Fabb, How to write essays, dissertation, and thesis in literary studies, Publisher: Longman, Copyright: 1993
4. James E. Mauch, Jack W. Birch., Guide to the Successful Thesis and Dissertation, Publisher: Marcel Dekker, copy right 2003 Leedy, P. L., Practical Research, Planning and Design, Publisher: Prentice Hall, March 2004

Course Name:	Theory of Computation
Course Code:	CS701
Credit Hours:	3
Pre-requisites:	None

Course Introduction: This course emphasizes computability and computational complexity theory. Topics include regular and context-free languages, decidable and undecidable problems, reducibility, recursive function theory, time and space measures on computation, completeness, hierarchy theorems, inherently complex problems, oracles, probabilistic computation, and interactive proof systems.

Course Objectives: After the completion of this course a student will be able to have a clear understanding of:

- The processing mechanism of a computer system at abstract level
- What a computer can do and what it cannot do?
- What a computer can do more efficiently and what it can perform with less efficiency?
- The mechanism of different word processors (especially spell-checking facilities)
- The mechanism of different grammar checkers
- The mechanism of word generators
- How to develop more efficient spell-checkers and parsers?

Course Outline: Automata theory, formal languages, Turing machines, computability theory and reducibility, computational complexity, determinism, non-determinism, time hierarchy, space hierarchy, NP completeness, selected advanced topics.

Reference Material: The following is the recommended list of books (or their latest editions):

1. Cohen, Daniel. Introduction to Computer Theory. New York, Wiley, 1997.
2. Kelley, Dean. Automata and Formal Languages: an introduction. Prentice-Hall, Inc., 1995.
3. Sipser, Michael. Introduction to the Theory of Computation. Cengage Learning, 2013.
4. Esparza, Javier, and Michael Blondin. Automata Theory. MIT Press, 2023.

Course Name:	**Advanced Algorithm Analysis**
Course Code:	CS702
Credit Hours:	3
Pre-requisites:	None

Course Introduction: This is a graduate level course that focuses on the advanced topic related to analysis of algorithms

Course Objectives: The major objective of this course is providing comprehensive knowledge of modern computer algorithms and solving scientific and engineering problems efficiently and accurately. The students will be guided, how to analyze complex algorithms comparing efficiencies of these algorithms. Students will not only be taught the design of the existing algorithms but on the other hand it will be focused to teach them designing techniques using rigorous mathematical approaches. The students will be motivated to think about procedures solving real world problems optimally and correctly. Real world problem will be taken as examples to create feelings about the usefulness of this course.

Course Outline: Introduction; role of algorithms in computing, Analysis on nature of input and size of input Asymptotic notations; Big-O, Big Ω, Big Θ, little-o, little-ω, Sorting Algorithm

analysis, loop invariants, Recursion and recurrence relations; Algorithm Design Techniques, Brute Force Approach, Divide-and-conquer approach; Merge, Quick Sort, Greedy approach; Dynamic programming; Elements of Dynamic Programming, Search trees; Heaps; Hashing; Graph algorithms, shortest paths, sparse graphs, String matching; Introduction to complexity classes. Road Map Problem, Paths and Shortest Paths, Bellman-Ford Algorithm. Proof: Bellman Ford Algorithm, Shortest Paths in Directed Acyclic Graphs, Dijkstra's Algorithm: Problem Statement, Analysis, Correctness. 36 All-Pairs Shortest Paths, Shortest Paths and Matrix Multiplication. the Floyd-Warshall Algorithm, Johnson's Algorithm, Number Theoretic Algorithms: Definitions and Some Important Results, Number Theoretic Algorithms: GCD, Euclid's Algorithm, Groups and Rings. Groups and Rings, Chinese Remainder Theorem, RSA Cryptosystem. Fermat Theorem, Euler's Theorem, RSA Cryptosystem, String Matching Problem. String Matching: Naive Algorithm, Rabin-Karp Algorithm, String Match. with Finite Automata. Polynomials and Fast Fourier Transform: Representation of Polynomials, The DFT and FFT. NP Completeness: Circuit Satisfiability; Proof: Formula Satisfiability, 3-CNF; Clique

Reference Material: The following is the recommended list of books (or their latest editions):

1. Cormen, Thomas, et al. Introduction to Algorithms. 4th Edition. The MIT Press, 2022
2. Kleinberg, Jon, and Tardos, Eva. Algorithm Design. Pearson, 2005.
3. Sedgewick, Robert, and Wayne, Kevin. Algorithms. 4th Edition. Addison-Wesley Professional, 2011.

Course Name:	**Advanced Operating Systems**
Course Code:	CS703
Credit Hours:	3
Pre-requisites:	None

Course Introduction: The course covers advanced topics in computer operating systems with a special emphasis on distributed computing, and the services provided by distributed operating systems. Important topics include naming, security, remote procedure call, networks, concurrency, transactions, parallel computing, shared memory, message passing and scale.

Course Objectives: The objectives of this course are as follows:

- To provide in-depth coverage of modern operating system issues.
- To provide insight in the design principles of distributed systems.
- To focus on a high level functionality of operating systems, such as, file systems, security, and naming mechanisms.
- To provide experience in reading and evaluating research papers.

Course Outline: Characterization of Modern Operating Systems; file systems, memory management techniques, Process scheduling and resource management, System Models Architectural models, Inter-process Communication, Issues of Security in Distributed Systems (Partial coverage), Distributed File System, Concurrency Control in Distributed Systems, Problems of coordination and agreement in Distributed Systems, Replication, advantages and requirements, Fault-tolerant services, Mobile and Ubiquitous Computing.

Reference Material: The following is the recommended list of books (or their latest editions):

1. Silberschatz, Abraham, Henry Korth, and S. Sudarshan. *Operating System Concepts*. 10th ed., John Wiley & Sons, 2021.
2. Tanenbaum, Andrew S., and Herbert Bos. *Modern Operating Systems*. 5th ed., Pearson, 2022.

Course Name:	**Advanced Computer Architecture**
Course Code:	CS704
Credit Hours:	3
Pre-requisites:	None

Course Introduction: This course forms a strong foundation in the understanding and design of modern computing systems. Building on a computer organization base, this course explores techniques that go into designing a modern microprocessor.

Course Objectives: The objectives of this course are as follows:

- To understand the advance hardware and software issues of computer architecture
- To understand the multi-processor architecture & connection mechanism
- To understand multi-processor memory management

Course Outline: Computer Architecture and Importance for Computer Science Graduates, Instruction Set Architectures(ISA), Complex Instruction Set Computing (CISC), Reduced Instruction Set Computing (RISC), Operations of the Computer Hardware, Assembly Language, Registers, Data and Instruction Representation, Different Types of Instructions, Loops and IF Statements in Assembly, Supporting Procedures/Functions in Computer Hardware, Supporting Different Data Types in Hardware, Immediate and Addresses in Instructions, Compiling and Linking Processes to Convert a C/Java Program into Assembly and Converting that into Machine Code, Review of Number Systems, Signed and Unsigned Data Types, Arithmetic Operations (Subtraction, Multiplication, Division) in Hardware, Float Data Types and Arithmetic Operations on Float, Evaluating Performance of a System, Latency, Response Time, and Throughput, CPU Execution Time, Calculating CPU Execution Time for a Program, Benchmarks and Amdahl's Law, Processor Design, Building a 32-bit ALU, Processor Data path, Designing a Processor to Execute Instructions and Include Control Unit, Pipelining and Hazards in Pipelining and Solutions, Memory Hierarchy, Caches, Measuring and Improving Cache Performance, Direct Mapped Cache, Fully Associative Caches and Cache Optimizations, Virtual Memory, Virtual Machines. Storage and other I/O topics, Multiprocessors, Multi-cores and Clusters. Data Level Parallelism, Vector Processing, Support for Multimedia Applications, Graphics Processing Units, Request Level Parallelism.

Reference Material: The following is the recommended list of books (or their latest editions):

1. 1. John L. Hennessy and David A. Patterson, Computer Architecture: A Quantitative Approach, 6th Edition, Morgan Kaufmann Publishers, 2020.
2. 2. John Hennessy and David Patterson, Computer Organization and Design: The Hardware/ Software Interface, 6th Edition, Morgan Kaufman Publishers, 2020.

Course Name:	Middleware Technologies for Distributed Systems
Course Code:	CS705
Credit Hours:	3
Pre-requisites:	None

Course Introduction: This course provides an in-depth study of middleware technologies that support distributed systems and applications. Students will learn about the architecture, design patterns, and implementation of middleware solutions, exploring their applications in enterprise systems, cloud computing, and IoT.

Course Objectives: By the end of the course, students should be able to:

- Design and implement middleware solutions for various distributed applications.
- Address challenges related to security, scalability, and interoperability in middleware
- systems.
- Integrate middleware with emerging technologies such as cloud computing and IoT.
- Conduct research and development in advanced middleware technologies.

Course Outline: Introduction to Middleware: Overview of middleware concepts and significance in distributed systems. Key components and architecture of middleware solutions. Middleware Architectures and Design Patterns: Exploration of middleware architectures, including service-oriented architecture (SOA) and microservices. Common design patterns and best practices in middleware development.
Communication and Messaging Middleware: Study of communication protocols and messaging systems. Analysis of message-oriented middleware (MOM) and enterprise service bus (ESB).
Data Management and Integration Middleware: Techniques for data integration and transformation in distributed systems. Role of middleware in supporting database connectivity and data synchronization..
Middleware Security and Performance: Security challenges and solutions for middleware systems. Strategies for optimizing middleware performance and scalability.
Middleware for Cloud and IoT: Middleware solutions for cloud computing and IoT applications., Case studies of middleware integration in cloud and IoT environments.
Middleware Platforms and Technologies: Examination of popular middleware platforms such as Apache Kafka, RabbitMQ, and Spring Boot. Comparison of different middleware technologies and their use cases.
Middleware for Mobile Applications: Role of middleware in supporting mobile application development and deployment. Integration of middleware with mobile platforms and services.
Future Trends and Innovations: Emerging trends and research directions in middleware technologies. Opportunities for innovation and development in middleware solutions.

Reference Material: The following is the recommended list of books (or their latest editions):

1. Ghosh, Ratan K., and Hiranmay Ghosh. *Distributed Systems: Theory and Applications*. John Wiley & Sons, 2023.
2. Hohpe, Gregor, and Bobby Woolf. *Enterprise integration patterns: Designing, building, and deploying messaging solutions*. Addison-Wesley, 2012.
3. Munz, Frank. *Middleware and Cloud Computing: Oracle on Amazon Web Services*

(AWS), Rackspace Cloud and RightScale. munz & more publishing, 2011.

Course Name:	**Advanced Databases**
Course Code:	CS706
Credit Hours:	3
Pre-requisites:	None

Course Introduction: The main objective of this course includes an overview of the selected advanced topics in databases. A student should have studied databases at master's level that provides foundation for this course. A student should study recent research work going on in the area of databases.

Course Objectives: The objective of this course is that a student should learn the advanced level technology information in databases. A student should know different database connections available for different programming languages and learn how data is converted from a database management system to other formats and vice versa. A student should study recent research work in database technology.

Course Outline:
Review of relational databases SQL in the real world: embedded SQL, data passing, status, cursor, connection, transaction, stored procedure; dynamic SQL, parameter, descriptor; JDBC; SQLJ; ODBC. Relational calculus; DB services XML databases, description and query of semi-structured, nested, complex data; XML basics, XML schema, XLST. Stylesheet, templates, evaluation. XQuery: FLWR expression, evaluation, built-in functions, user defined functions, aggregation, quantification. More XQuery: data and types; Xquery and XML schema; proj, sel, construction, group, join, recursive functions, wildcard types, XqueryX; XPath and XQuery, Materialized views.

Reference Material: The following is the recommended list of books (or their latest editions):

1. Lewis, Philip M., Arthur Bernstein, and Michael Kifer. Database and Transaction Processing: An Application-Oriented Approach. Addison Wesley, 2002. Print. ISBN 978-0-201-70872-4.
2. Ray, Chhanda. Advanced Database System. Oct 1, 2020. Print.
3. Coronel, Carlos, and Steven Morris. Database Systems: Design, Implementation, & Management. Jan 1, 2018. Print.
4. Edet, Theophilus. Advanced SQL Programming: Techniques for Efficient Data Management. Mastering Database Management Series, Jun 15, 2024. Print.
5. Rathi, Preeti, and Ruchika Bhakhar. Advanced Database Systems: Principles, Techniques, and Applications. Apr 8, 2024. Print.

Course Name:	**Data Warehousing**
Course Code:	CS707
Credit Hours:	3
Pre-requisites:	None

Course Introduction: This course will explore the principles and practices essential for designing, building, and managing large-scale data storage systems.

Course Objectives: The objective of this course is that a student should learn the fundamentals of data warehousing. A student should know what state-of-the-art techniques are available and how dimensional modeling is performed in data warehousing? A student should learn the design process of a data warehouse after finishing this course. The study of recent research papers is another primary objective of this course.

Course Outline:
Introduction to Data Warehousing: Heterogeneous information; the integration problem; the Warehouse Architecture; Data Warehousing; Warehouse DBMS.
Aggregations: SQL and aggregations; aggregation functions; grouping.
Data Warehouse Models and OLAP Operations: Decision support; Data Marts; OLAP vs OLTP; the Multi-Dimensional data model; Dimensional Modelling; ROLAP vs MOLAP; Star and snowflake schemas; the MOLAP cube; roll-up, slicing, and pivoting.
Some Issues in Data Warehouse Design: monitoring; wrappers; integration; data cleaning; data loading; materialized views; warehouse maintenance; OLAP servers; metadata.

Reference Material: The following is the recommended list of books (or their latest editions):

1. M. Jarke, M. Lenzerini, Y. Vassiliou, P. Vassiliadis (ed.), Fundamentals of Data Warehouses, Springer-Verlag, 1999.
2. Ralph Kimball, The Data Warehouse Toolkit, Wiley 1996.

Course Name:	**Data Mining**
Course Code:	CS708
Credit Hours:	3
Pre-requisites:	None

Course Introduction: The Data Mining course for MS students provides an in-depth understanding of the techniques and tools used to uncover patterns and insights from large datasets.

Course Objectives: With the unprecedented rate at which data is being collected today in almost all fields of human endeavor, there is an emerging economic and scientific need to extract useful information from it. Data mining is the process of automatic discovery of patterns, changes, associations and anomalies in massive databases. This course will provide an introduction to the main topics in data mining and knowledge discovery, with a special emphasis on Data mining & Web mining

Course Outline: Introducing Data Mining: Why data mining?; What is data mining?; A View of the KDD Process; Problems and Techniques; Data Mining Applications; Prospects for the Technology.
The CRISP-DM Methodology: Approach; Objectives; Documents; Structure; Binding to Contexts; Phases, Task, Outputs.

Data Mining Inputs and Outputs: Concepts, Instances, Attributes; Kinds of Learning; Providing Examples; Kinds of Attributes; Preparing Inputs. Knowledge Representations; Decision Tables and Decision Trees; Classification Rules; Association Rules; Regression Trees and Model Trees; Instance-Level Representations.
Data Mining Algorithms: One-R; Naïve Bayes Classifier; Decision Trees; Decision Rules; Association Rules; Regression; K-Nearest Neighbour Classifiers.
Evaluating Data Mining Results: Issues in Evaluation; Training and Testing Principles; Error Measures, Holdout, Cross Validation; Comparing Algorithms; Taking Costs into Account; Trade-Offs in the Confusion Matrix

Reference Material: The following is the recommended list of books (or their latest editions):

1. Witten and E. Frank, Data Mining: Practical Machine Learning Tools and Techniques with Java Implementations, Morgan Kaufman, 1999.
2. J. Han and M. Kamber, Data Mining: Concepts and Techniques, Morgan Kaufman, 2000.
3. D. Hand, H. Mannila and P. Smyth. Principles of Data Mining, MIT Press, 2001.
4. M. H. Dunham. Data Mining: Introductory and Advanced Topic. Prentice Hall, 2003.

Course Name:	**Database Security**
Course Code:	CS709
Credit Hours:	3
Pre-requisites:	None

Course Introduction: The Database Security course for MS students focuses on the strategies and technologies used to protect databases from threats and vulnerabilities.

Course Objectives: The objective of this course is that a student should learn the state-of-the-art in database security. Different database security models and data access control mechanisms are taught in this course. A student should practically implement different database security techniques using a database management software. The study of recent research papers in database security is another objective of this course.

Course Outline: Data protection: basic concepts. Access control policies: discretionary access control policies; mandatory access control policies; role-based access control (RBAC); Chinese wall access control policies. Administration policies.
Access control in relational database systems: Grant and Revoke statements; grant operation and delegation; revoke operations recursive revocation with timestamps and without timestamps; non-cascading revoke operations; views and content-based authorization; RBAC. Advanced access control models: temporal authorization models; temporal RBAC; the BFA model for workflow systems; access control and integrity for XML data; the Author-X system; XACML and SAML; access control for web services.
Trust negotiation systems: preliminary concepts; TrustBuilder; Trust-X.

Reference Material: The following is the recommended list of books (or their latest editions):

1. Hassan A. Afyouni, Database Security and Auditing: Protecting Data Integrity and Accessibility, Publisher: Course Technology 2005.
2. Silvana Castano, Database Security, Publisher Addison-Wesley 1995

3. B. Fernandez, Rita C. Summers, Christopher Wood, Database Security and Integrity, Publisher: Addison-Wesley Longman Publishing Co, Inc. 1881

Course Name:	**Distributed System Components**
Course Code:	CS710
Credit Hours:	3
Pre-requisites:	None

Course Introduction: The Distributed System Components course for MS students delves into the architecture, design, and functionality of systems that distribute processing across multiple interconnected components.

Course Objectives: The objectives of this course are as follows:

- Present the principles underlying the functioning of distributed systems;
- Create an awareness of the major technical challenges in distributed systems design and implementation;
- Expose students to modern and classic technology used in distributed systems and their software;
- Expose students to past and current research issues in the field of distributed systems;

Course Outline: Components of a distributed systems, Distributed systems, End to End Protocols and Networking. Distributed Operating system, Distributed databases, Communication Mechanism, Message Passing, Stream oriented communications, Remote procedure call, Remote Method Invocation, DCE RPC, Java RMI, SOAP, Naming, Clock Synchronization, Process Synchronization, Distributed Processes, Code Migration. Content distribution, Distributed Object systems, CORBA, DCOM - .NET, Distributed Coordination, Fault Tolerance, Distributed Systems Security.

Reference Material: The following is the recommended list of books (or their latest editions):

1. Van Steen, Maarten, and Andrew S. Tanenbaum. Distributed Systems. Leiden, The Netherlands: Maarten van Steen, 2017.
2. Hwang, Kai, J. J. Dongarra, and Geoffrey C. Fox. Distributed and Cloud Computing: Clusters, Grids, Clouds, and the Future Internet. Morgan Kaufmann, 2011.
3. Joshi, Unmesh. Patterns of Distributed Systems. Addison Wesley, 2023.

Course Name:	**Advanced Networking**
Course Code:	CS711
Credit Hours:	3
Pre-requisites:	None

Course Introduction: The Advanced Networking course for MS students provides an in-depth exploration of the complex concepts and technologies that underpin modern networked systems.

Course Objectives: Aim of the course is to understand the principles of networking and the protocols in the different layers, and their interactivity between each other. Students should understand the problem in the current Internet architecture new study new QoS architectures such as Integrated services and Differential services. Also students should know the problem with the IPv4 and need for IPv6 protocols.
Additionally students will be expected to read all of the papers assigned for the course others may be added based on class interest. Students will have to write of papers provide during the class. Students submitting reviews for a paper will be expected to be active in the discussion of that paper.

Course Outline: Review of basic concepts: The OSI Model, packet and circuit switching, network topology, ISDN,. The TCP/IP protocol stack: IP, ARP, TCP and UDP, DNS, ICMP, Internet Addressing, Routing, IP multicast, RSVP, Differential Services. Next generation IP-ipng, Wireless: Radio basics, satellite systems, WAP, current trends, Issues with wireless over TCP. Congestion control: control vs. Avoidance. Algorithms, congestion in Internet. Mobile IP, Voice over IP (VoIP), VPNs Network Security. Management: Quality of Service (QoS). Network vs. Distributed Systems management protocols, web based management. OPNET.

Reference Material:
The following is the recommended list of books (or their latest editions):

1. James F. Kurose and Keith W. Ross. Computer Networking- A top-Down Approach Featuring the Internet. Addison Wesley. January 2004
2. Coulouris, Dollimore, Kindberg. Distributed Systems- Concepts and Design. Addison Wesley. 4th edition May 20, 2005
3. William Stallings, Data and Computer Communication, Prentice-Hall- Seventh Edition 2004 (for those who wants to review the basics of networking.)

Course Name:	**Cloud Security**
Course Code:	CS712
Credit Hours:	3
Pre-requisites:	None

Course Introduction: Cloud computing infrastructure have become a mainstay of the IT industry, opening the possibility for on-demand, highly elastic and infinite compute power with scalability and supporting the delivery of mission-critical secure enterprise applications and services. This course provides the ground-up coverage on the high-level concepts of cloud landscape, architectural principles, techniques, design patterns and real-world best practices applied to Cloud service providers and consumers and delivering secure Cloud based services. The course will describe the Cloud security architecture and explore the guiding security design principles, design patterns, industry standards, applied technologies and addressing regulatory compliance requirements critical to design, implement, deliver and manage secure cloud based services. The course delves deep into the secure cloud architectural aspects with regards to identifying and mitigating risks, protection and isolation of physical & logical infrastructures including compute, network and storage, comprehensive data protection at all OSI layers, end-to-end identity management & access control, monitoring and auditing processes and meeting

compliance with industry and regulatory mandates. The course will leverage cloud computing security guidelines set forth by ISO, NIST, ENISA and Cloud Security Alliance (CSA).

Course Objectives: Students successfully completing this course should be able to:

- Understand fundamentals of cloud computing architectures based on current standards, protocols, and best practices intended for delivering Cloud based enterprise IT services and business applications.
- Identify the known threats, risks, vulnerabilities and privacy issues associated with Cloud based IT services.
- Understand the concepts and guiding principles for designing and implementing appropriate safeguards and countermeasures for Cloud based IT services
- Design cloud services that meets essential Cloud infrastructure characteristics – on demand computing, shared resources, elasticity and measuring usage.
- Design security architectures that assures secure isolation of physical and logical infrastructures including compute, network and storage, comprehensive data protection at all layers, end-to-end identity and access management, monitoring and auditing processes and compliance with industry and regulatory mandates

Course Outline: Fundamentals of Cloud Computing and Architectural Characteristics, Cloud deployment models Public, ,Cloud Computing Roles Risks and Security Concerns, Guiding Security design principles for Cloud Computing, Secure Isolation Comprehensive data protection, End-to-end access control Monitoring auditing, Quick look at CSA, NIST and ENISA guidelines for Cloud Security, Common attack vectors and threats, Data protection for Confidentiality and Integrity , Common attack vectors and threats , Encryption, Data Redaction, Tokenization, Obfuscation, PKI and Key , Management, Assuring data deletion , Data retention, deletion and archiving procedures for tenant data, Data Protection Strategies, Enforcing Access Control for Cloud Infrastructure based Services, Monitoring, Auditing and Management, Introduction to Identity Management in Cloud Computing, Cloud Computing Security Design Patterns, Policy, Compliance & Risk Management in Cloud Computing.

Reference Material: The following is the recommended list of books (or their latest editions):

1. Winkler, Vic JR. Securing the Cloud: Cloud computer Security techniques and tactics. Elsevier, 2011.
2. Erl, Thomas, Robert Cope, and Amin Naserpour. Cloud computing design patterns. Prentice Hall Press, 2015.
3. Salman, Zainab, and Mustafa Hammad. "Securing cloud computing: A review." International Journal of Computing and Digital Systems 10 (2021): 545-554.

Course Name:	**Opportunistic Networks**
Course Code:	CS713
Credit Hours:	3
Pre-requisites:	None

Course Introduction: The purpose of the course is to expose students to emerging networking protocols and technologies in the field of opportunistic and challenged networks.

Course Objectives: The primary objective of this course is to:

- Expose graduate students to the exciting new research topics in networking.
- Motivate graduate students to take up research work in the new and exciting areas in networking.

Course Outline: Overview of packet switching networks and devices, route lookup algorithms, signaling protocols, Delay Tolerant Networks (DTN), DTN routing, DTN protocol stack, DTN architecture, DTN protocols, Bundle Layer, Bundle Protocol, Vehicular Adhoc Networks (VANETs), VANETs architecture, VANETs protocol stack, VANETs routing, VANETs security, WAVE, Dedicated Short Range Communication (DSRC). QOS in DTN, QOS in VANETs, Intelligent Transport System (ITS), ITS applications, ITS architecture, ITS protocol stack, ITS security.

Reference Material: The following is the recommended list of books (or their latest editions):

1. Vasilakos, Athanasios, Yan Zhang, and Thrasyvoulos Spyropoulos. Delay tolerant networks. Boca Raton, FL, USA: CRC press, 2016.
2. Hartenstein, Hannes, and Kenneth Laberteaux, eds. VANET: vehicular applications and inter-networking technologies. John Wiley & Sons, 2009.

Course Name:	**Wireless Networks**
Course Code:	CS714
Credit Hours:	3
Pre-requisites:	None

Course Introduction: This course covers fundamental techniques in design and operation of cellular networks including GSM, 3G, 4G, 5G and 6G wireless networks, multiple access techniques, radio propagation models, channel capacity with MIMO and massive MIMO, error control techniques, communication challenges in HetNets, power control, radio resource and network management, wireless LANs standards, bluetooth, machine type communication networks, LoRa and LoRaWAN techniques and significance.

Course Objectives: The objectives of this course is as follows:

- To introduce the fundamentals of wireless communication
- To discuss radio propagation issues and diversity gain
- To improve understanding of the use of OFDM/OFDMA based techniques in broadband wireless systems

Course Outline: This course covers fundamental techniques in design and operation of first, and third generation wireless networks: cellular systems, medium access techniques, radio propagation models, error control techniques, handoff, power control, common air protocol (AMPS, IS-95, IS-136, GSM, GPRS, EDGE, WCDMA, CDMA 2000 etc), Wireless LANs Standards, wireless LANs, Wi-Fi, WiMAx, Bluetooth, sensor networks, physical layer

specifications in wireless LANs, radio resource and network management. As an example for third generation interfaces, WCDMA is discussed in detail since is intended for graduate students who have some background on computer networks.

Reference Material: The following is the recommended list of books (or their latest editions):

1. Rappaport, Theodore S. Wireless Communications: Principles and Practice. 3rd ed., Pearson, 2024.
2. Molisch, Andreas F. Wireless Communications: From Fundamentals to Beyond 5G. IEEE Press, 2022.
3. Bejarano, Oscar. Wireless: A Total Beginner's Guide to Modern Wireless Communication Technologies. Independently Published, 2023.
4. Goldsmith, Andrea. Wireless Communications. Cambridge University Press, 2005.
5. Haupt, Randy L. Wireless Communications Systems: An Introduction. IEEE Press, 2019.

Course Name:	**Semantic Web**
Course Code:	CS715
Credit Hours:	3
Pre-requisites:	None

Course Introduction: As the volume of Web resources grows exponentially, researchers from industry, government, and academia are now exploring the possibility of creating a Semantic Web in which meaning is made explicit, allowing machines to process and integrate Web resources intelligently. How will this Web of the future be effectively built? This course attempts to address this problem by covering most of the proposed approaches. This course provides a succinct account of this new Web, its principles, concepts, and related tools. Its main contribution lies in the ability to demonstrate how Semantic Web technologies may be integrated and realized in several application domains.

Course Objectives: According to the general objective, students should be able:

- To understand the limitations of the present web and the importance of metadata in solving the problem
- To identify and resolve real world problems by applying these technologies successfully
- To build systems in different domains (for instance, knowledge management, biomedicine, e-commerce, e-learning, etc.) and applications for those areas
- To integrate applications developed with semantic web technologies with other software and hardware systems
- To assimilate technological changes

Course Outline: Semantic Web introduction, vision and Layer Cake, Web Documents and XML, Resource Description Framework, RDF Schema and RDF Simple Entailment, SPARQL, Ontologies, Web Ontology Language OWL, Topic Maps, Logic and Inference Rules, RuleML, SWRL, Relations between Semantic Web Languages, Semantic Web Vocabularies and

Applications, Web Services and Semantic Web Services, Agents on the Web, Semantic Web Applications, Ontology Engineering.

Reference Material:
The following is the recommended list of books (or their latest editions):

1. Grigoris Antoniou and Frank van Harmelen, A Semantic Web Primer, MIT Press, 2004.
2. Dieter Fensel, James A. Hendler, Henry Lieberman, and Wolfgang Wahlster, Spinning the Semantic Web - Bringing the World Wide Web to Its Full Potential, MIT Press, 2002.
3. Breitman, K.K., Casanova, M.A., Truszkowski, W., Semantic Web: Concepts, Technologies and Applications. NASA Monographs in Systems and Software Engineering Series, Springer 2007.

Course Name:	**Web Mining**
Course Code:	CS716
Credit Hours:	3
Pre-requisites:	None

Course Introduction: The accessibility and ubiquity of content on the WWW has changed how we perceive information. Web mining aims to discover useful information or knowledge from Web hyperlinks, page contents and usage data. Due to the richness and diversity of information and other Web specific characteristics, Web mining is not just an application of data mining. Web mining has developed many of its own methods, ideas, models and algorithms. This course provides an in-depth coverage of how to extract and discover information within the Web and how we use the Web.

Course Objectives: • To introduce Web mining technology from a practical point of view and to obtain a solid grasp of how techniques in Web mining technology can be applied to solve problems in real-world applications
• To provide students with a sound basis in Web data mining tasks and techniques
• To ensure that students are able to read, and critically evaluate Web mining research papers
• To ensure that students are able to implement and to use some of the important Web mining algorithms
• To design and develop a large scale web crawler and a mini search engine

Course Outline: Data Mining and Knowledge Discovery, Web Usage Mining, Privacy Issues, Web Content Mining, Web Structure Mining and Link Analysis, Social Network Analysis, Web Mining Applications - Data integration for e-commerce and Web personalization and recommender systems, Web data warehousing, Review of tools, applications, and systems

Reference Material: The following is the recommended list of books (or their latest editions):

1. Zdravko Markov and Daniel T. Larose, Data Mining the Web: Uncovering Patterns in Web Content, Structure, and Usage, Wiley-Interscience, 2007.
2. Bing Liu, Web Data Mining: Exploring Hyperlinks, Contents, and Usage Data, Data-Centric Systems and Applications Series, Springer, 2009.
3. Gordon S. Linoff and Michael J. A. Berry, Mining the Web: Transforming Customer Data into Customer Value, Wily Publishers, 2002.

4. Mark Levene, An Introduction to Search Engines and Web Navigation, Pearson Education, 2005.
5. Soumen Chakrabarti, Mining the Web: Discovering Knowledge from Hypertext Data, Morgan-Kaufmann Publishers, 2002.
6. Pierre Baldi,Paolo Frasconi, Padhraic Smyth, Modeling the Internet and the Web: Probabilistic Methods and Algorithms, John Wiley and Sons Ltd, 2003.

Course Name:	**Ontology Engineering**
Course Code:	CS717
Credit Hours:	3
Pre-requisites:	None

Course Introduction: The general objective is to provide students with a sound grounding of scientific, methodological and technological fundamentals in Ontological Engineering and the Semantic Web areas. This knowledge will be later used to build applications that can integrate, combine and infer heterogeneous and distributed information.

Course Objectives: By the end of the course, as a minimum, the student will be able to:

- Build and implement a small ontology that is semantically descriptive of their chosen problem domain
- Write JAVA code that can access, use and manipulate the ontology
- Represent data from a chosen problem in XML with appropriate semantic tags obtained or derived from the ontology
- Depict the semantic relationships among these data elements using Resource Description Framework (RDF)
- Write a web services application that “discovers” the data and/or other web services via the semantic web (which includes the RDF, data elements in properly tagged XML, and the ontology)

Course Outline: Ontology: Introduction, Components, Types, Design Principles, Outstanding Ontologies, Knowledge Representation Ontologies: OKBC, RDFS, DAML+OIL, OWL, Top-Level Ontologies Cyc, SUMO, Linguistic Ontologies: WordNet etc., Domain Ontologies: PIM, eCommerce, Knowledge Representation, etc, Ontology Engineering Methodologies, Axioms, Rules and Inference, Ontology Merging, Ontology Evolution, Languages for Building Ontologies, Ontology Tools and Tool Suits

Reference Material: The following is the recommended list of books (or their latest editions):

1. Asuncion Gomez-Perez, Oscar Corcho, and Mariano Fernandez-Lopez , Ontology Engineering: with examples from the areas of Knowledge Management, e-Commerce and the Semantic Web, Advanced Information and Knowledge Processing Series, Springer 2004.
2. Jan LG Dietz , Enterprise Ontology: Theory and Methodology, Springer, 2006.
3. Raj Sharman, Rajiv Kishore and Ram Ramesh, Ontologies: A Handbook of Principles, Concepts and Applications in Information Systems, Integrated Series in Information Systems, Springer 2007.

4. Asuncion Gomez-Perez, Oscar Corcho, and Mariano Fernandez-Lopez , Ontology Engineering: with examples from the areas of Knowledge Management, e-Commerce and the Semantic Web, Advanced Information and Knowledge Processing Series, Springer 2004.
5. Jan LG Dietz , Enterprise Ontology: Theory and Methodology, Springer, 2006.
6. Raj Sharman, Rajiv Kishore and Ram Ramesh, Ontologies: A Handbook of Principles, Concepts and Applications in Information Systems, Integrated Series in Information Systems, Springer 2007.

Course Name:	**Business Intelligence**
Course Code:	CS718
Credit Hours:	3
Pre-requisites:	None

Course Introduction: Business Intelligence is a new field. This course discusses current issues highlighting business databases. The course will provide an insight into the business intelligence and techniques of improvement in business intelligence.

Course Objectives: The objectives of this course is as follows:

- To introduce information systems and business intelligence.
- To study advance techniques in ETL process.

Course Outline: Introduction to Information Systems and Business Intelligence, Design of Relational Databases, Querying, Securing and Administrating databases, Data Transformation, Advance Techniques in ETL Process, Introduction to the Unified Dimensional Model (UDM), Dimensions, Cubes and their features, The MDX Language and KPIs, Excel Pivot Table with Analysis Server, Reporting and Visualization, Analysis with Data Mining and Excel 2007/SSAS/SAS

Reference Material: The following is the recommended list of books (or their latest editions):

1. Elizabeth Vitt, Michael Luckevich, Stacia Misner “Business Intelligence: Making Better Decisions Faster” Publisher: Microsoft Press, Publication Date: May 17, 2002, ISBN 0-7356-1627-2
2. Cindi Howson “Successful Business Intelligence: Secrets to Making BI a Killer App” Publisher: The McGraw Hill Companies, Publication Date: November 26, 2007 Edition: 1, ISBN: 978-0-07-149851-7
3. Thomas H. Davenport, Jeanne G. Harris, Robert Morison “Analytics at Work: Smarter Decisions, Better Results” Publisher: Harvard Business School Publishing Corporation Publication Date: February 8, 2010, ISBN 978-1-4221-7769-3
4. Swain Scheps “Business Intelligence for Dummies” Publisher: Wiley Publishing, Inc. Publication Date: January 10, 2008, ISBN 978-0-470-12723-0
5. Current research publications and literature

Course Name:	**Advanced Wireless Network Security**

Course Code:	CS719
Credit Hours:	3
Pre-requisites:	None

Course Introduction: This course looks at misbehavior of nodes, trust and its characteristics, reputation system goals and properties, classification of trust and reputation based systems, information gathering techniques, information dissemination, detection, response, Examples: watchdog and path raters, context aware mechanism, trust aggregation scheme, trusted routing schemes, collaborative reputation based systems, cooperation based models, observation based mechanism, distributed reputation based, beacon based system.

Course Objectives: The objectives of this course is as follows:

- To study the security issues related to wireless network.
- To study the techniques used to solve classic security issues in wireless network.

Course Outline: Secure device association techniques, Reputation and trust based security mechanisms, Mobile Ad hoc Networks, Wireless Sensor Networks, Wirelesses mesh Networks, Countermeasure to selfish misbehavior, countermeasure to greedy misbehavior, countermeasure to MAC layer DoS attacks, Cryptography based solutions, reputation based solutions, add-ons to existing solutions, countermeasure to specific attacks., Pre authentication and authentication models, Identity based key management schemes, Passive attacks, Active and Denial of service attacks, physical layer attacks, MAC layer security issues, Wireless Local Area Networks (WLANs): cross domain mobility adaptive authentication, AAA architecture and authentication.

Reference Material:

The following is the recommended list of books (or their latest editions):

1. William Stallings Network. Security Essentials: Applications and Standards. 6th Edition, 2016.
2. Y. Xiao, X. Shen, D. Z. Du. Wireless Networks security. signal and communication technology series, Springer series, 2007.

Course Name:	Wireless Sensor Networks
Course Code:	CS720
Credit Hours:	3
Pre-requisites:	None

Course Introduction: Wireless Sensor Networks have received tremendous attention over past few years. These networks seek to extend the long-arm of the internet by connecting it to the rich tapestry of the physical world using sensors. Recent technology advancements (low-power radios, MEMS sensors) have opened up the potential for dense and potentially large-scale deployments, where many sensors co-ordinate to accomplish a sensing task. The vast potential for this research area has been demonstrated by numerous scientific and commercial applications that have emerged in recent years, as well as by the number of industrial and research institutions working in this area. Recent research directions include environmental sensing and prediction (CENS, CASA), seismic and structural monitoring (CENS). Commercial interests include

factory automation, power monitoring and energy conservation through distributed climate control, and others. Many exciting applications will be emerging soon.
This course is intended to provide students with an in-depth understanding of systems and algorithmic issues in wireless sensor networks and networked embedded systems. Reading research papers, writing critiques, and class presentations will also be included.

Course Objectives: Students successfully completing this course should be able to:

- Learn the fundamental concepts of sensor network design,
- Learn sensor network protocols, mechanisms, and algorithms to implement sensing systems, design, program, simulate, and experiment with sensor network software and hardware, investigate different research issues.

Course Outline: Introduction to WSN, WSN Platforms, Mac Layer, Link Layer, Topology Control, Clustering, Time Synchronization, Localization, Routing, Tracking, In-Network Querying, Security in WSN, Network support and management, Industrial WSN protocols, WSN network design and implementation, Application development in WSN

Reference Material:
The following is the recommended list of books (or their latest editions):

1. Poellabauer, Christian, and Waltenegus Dargie. Fundamentals of Wireless Sensor Networks. 1st ed., Wiley, 2013. Print. ISBN 978-1-118-35424-7.

Course Name:	**Empirical Methods in Software Engineering Research**
Course Code:	CS721
Credit Hours:	3
Pre-requisites:	None

Course Introduction: Empirical software engineering is a hot topic among researchers in the field of software engineering. This course explores different research methods and techniques applied in software engineering research.

Course Objectives: The objectives of this course is as follows:

- To make students understand the concepts of software engineering research and the different qualitative and quantitative research methods, their role, importance, and impact in the research.
- To introduce different methods to conduct research in software engineering so that the students can effectively and select an appropriate method for their work.

Course Outline: Introduction and overview of scientific studies, Empirical framework. Overview of empirical strategies. Empirical comparison. Empiricism in a software engineering context, Basic concepts relevant to measurement. Measurement scales. Objective and subjective measures. Direct or indirect measures. Measurements in software engineering and practice, Empirical research processes. Case Study, Grounded Theory, Systematic Literature review.

Experimental research process in detail. Detailed description of validity threats., Ethnographies, Ethical issues in empirical studies of software engineering.

Reference Material: The following is the recommended list of books (or their latest editions):

1. C. Wohlin, P. Runeson, M. Höst, M. C. Ohlsson, B. Regnell and A. Wesslén, "Experimentation in Software Engineering", Springer, ISBN 978-3-642-29043-5, 2012
2. Guide to Advanced Empirical Software Engineering, Forrest Shull, Janice Singer, Springer | ISBN: 184800043X, 2006
3. Per Runeson and Martin Höst, "Guidelines for conducting and reporting case study research in software engineering," Empirical Software Engineering, 14(2):131-164, April 2009.
4. Steve Easterbrook, Janice Singer, Margaret-Anne Storey, and Daniela Damian, "Selecting Empirical Methods for Software Engineering Research," Guide to advanced empirical software engineering, 2008.
5. A selection from classical research papers of renowned researchers in the field of software engineering will also be used as reference to the course.

Course Name:	**Emerging Technologies in Software Engineering**
Course Code:	CS722
Credit Hours:	3
Pre-requisites:	None

Course Introduction: Software engineering is a dynamic and rapidly evolving field. As new technologies emerge and development practices change, it's critical for software engineers to stay up-to-date on the latest trends and trajectory of the industry. Understanding where software engineering is heading allows engineers to future-proof their skills, ensure they are learning relevant and in-demand programming languages and frameworks, and identify new career opportunities.

Course Objectives: The objectives of this course is as follows:

- To keep the students up to date with the latest advancements in the field of software engineering.
- To be able to discuss current issues in software engineering research.

Course Outline: Following are some of the proposed topics, the instructor may add any other topic(s) of interest from the latest technologies and may cover two or more of the following topics in detail:
Agile methodology, DevOps, DevSecOps, Software sustainability aspects, Emerging software architectures, AI driven software development, Low-code/No-code culture. Cloud computing. Literature review and support tools (if apply)

Reference Material: The following is the recommended list of books (or their latest editions):

1. Fujita, H., and G. A. Papadopoulos. New Trends in Software Methodologies, Tools and Techniques. IOS Press, 2016
2. Arabnia, Hamid R., et al. Advances in Software Engineering, Education, and e-Learning.

Springer Nature, 2021

3. Latest research publications and books.

Course Name:	**Agile Software Development**
Course Code:	CS723
Credit Hours:	3
Pre-requisites:	None

Course Introduction: This course describes agile software methodologies and discusses how to select the appropriate methodology for a project. The course covers Extreme Programming methodology in detail. The students will work in teams to implement and understand the process of agile software development and to simulate the real work environment.

Course Objectives: To understand the principals behind agile methodologies
To gain knowledge of new vocabulary for describing methodologies,
To understand the concept of adjusting a methodology for a project.

Course Outline: Concept of agility, Agile Manifesto, The 12 Agile Principles, Agile Practices, Agile Software development, Agile Technologies, distributed agile teams and development: issues and solutions, Agile enterprise architecture, Team dynamics, Business intelligence, Enterprise agility, Agile project management, Agile leadership, adoption, Agile transformation, Concept of DevOps, Case studies and experience reports on latest agile trends. CASE tools for Agile development. Strategizing agile for user interface design.

Reference Material:
The following is the recommended list of books (or their latest editions):

1. Malakar, Sudipta. AGILE in Practice. BPB Publications, 2021
2. Agile Methodologies In-Depth. BPB Publications, 2021
3. Current research publications and literature.

Course Name:	**Real-Time Systems**
Course Code:	CS724
Credit Hours:	3
Pre-requisites:	None

Course Introduction: Real-time systems play a crucial role in many applications, such as avionic control systems, automotive electronics, telecommunications, industrial automation, and robotics. Such safety-critical applications require high reliability in timing assurance to prevent from serious damage to the environment and significant human loss.

Course Objectives: The objective of this course is to bring students into the position to understand the broad concept of real-time systems. The course aims to provide a practical understanding for industry and tries to stimulate research interest. At the end of the course the students should be able to:

- Understand and apply the fundamental concepts of real-time systems
- Explain and address the fundamental problems of real-time systems
- Analyze and partially design real-time systems

Course Outline: Introduction to Real Time Systems: basics, task scheduling, periodic task management, Schedulability Analysis, Aperiodic server mechanisms accessing shared resources, predictable communication mechanisms, limits of hard real time systems, flexible real time systems, programming real time applications.

Reference Material:

The following is the recommended list of books (or their latest editions):

1. Burns, Alan, and Andy Wellings. Real-Time Systems and Programming Languages: ADA 95, Real-Time Java, and Real-Time POSIX. 4th ed., Addison-Wesley Longman Publishing Co., Inc., 2009. Print. ISBN 978-0-321-41745-9.
2. Buttazzo, Giorgio. Hard Real-Time Computing Systems: Predictable Scheduling Algorithms and Applications. Springer, 2011. Print. ISBN 978-1-4419-8238-0.

Course Name:	**High Performance Computing**
Course Code:	CS725
Credit Hours:	3
Pre-requisites:	None

Course Introduction: The course will study high performance computer architectures, including modern parallel processors, and will describe how an algorithm interacts with these architectures. It will also look at practical methods of estimating and measuring algorithm/architecture performance.

Course Objectives: Students successfully completing this course should be able to:

- Transform algorithms in the computational area to efficient programming code for modern computer architectures;
- Write, organize and handle programs for scientific computations;
- Use tools for performance optimization and debugging;
- Analyze code with respect to performance and suggest and implement performance improvements;
- Report on performance analysis in clear and correct writing.

Course Outline: Algorithmic models (the view from Berkeley); Computational models (Flynn's taxonomy); Communication models (interconnects, message passing); Memory models (NUMA etc); Single-computer technologies (vector/SIMD computing via AVX/SSE, multi-core computing via OpenMP, many-core computing via OpenCL); Multi-computer technologies (cluster computing via MPI); Other approaches (cloud, distributed and redundant file systems, load balancing, check-pointing); Design and implementation of parallel algorithms and libraries.

Reference Material: The following is the recommended list of books (or their latest editions):

1. Eijkhout, Victor, et al. Introduction to High Performance Scientific Computing. Lulu, 2015. Print. ISBN 978-1-312-91767-5.

2. Hager, Georg, and Gerhard Wellein. Introduction to High Performance Computing for Scientists and Engineers. CRC Press, 2010. Print. ISBN 978-1-4200-7315-3.

Course Name:	**Concurrency and Parallelism**
Course Code:	CS726
Credit Hours:	3
Pre-requisites:	None

Course Introduction: In the past, software controlling these systems have used sequential frameworks. The result has been systems which are inflexible, difficult to design and costly to maintain. Having concurrency supported explicitly by a programming language makes an enormous difference to the expressive power of that language. The Java programming language is one of the few standard concurrent object-oriented programming languages.
Course Objectives: This course provides an in-depth study on both the concurrency and the real-time facilities of Java (including the Real-Time Specification for Java). After the course students should be able to:

- Analyze requirements for programming concurrent systems.
- Evaluate strengths and weaknesses of the Java concurrency model and how it can be used to facilitate the programming of concurrent systems.
- Compare the concurrency support among the most popular programming platforms

Course Outline: Introduction to Parallel Computing and its Importance, Concurrent Processes Basic Concepts of Concurrency, Concurrency in Operating Systems, Problems in Concurrent Programming, Basic Models of Parallel Computation, Shared Memory Model and Examples, Threads and multithreading, data race conditions, synchronization, read-write locks, reentrant locks, Executors, Virtual threads, atomic operations.

Reference Material:
The following is the recommended list of books (or their latest editions):

1. Czech, Zbigniew J. Introduction to Parallel Computing. Latest ed., Cambridge University Press, 2017. Print. ISBN 978-1-107-15588-6.
2. Wellings, Andy. Concurrent and Real-Time Programming in Java. John Wiley & Sons, 2004. Print. ISBN 978-0-470-84471-9.

Course Name:	**Advanced Data Analytics**
Course Code:	CS727
Credit Hours:	3
Pre-requisites:	None

Course Introduction: This course provides an in-depth exploration of data analytics techniques, focusing on advanced methods for analyzing, interpreting, and visualizing large and complex datasets. The course covers various statistical, machine learning, and computational techniques that enable data-driven decision-making. Students will engage with real-world data

sets, applying theoretical knowledge to uncover insights, make predictions, and guide strategic decisions in various domains.

Course Objectives: The objectives of this course are as follows:

- Apply advanced statistical and machine learning techniques to analyze and interpret large-scale datasets.
- Use of Transformer models for various machine learning tasks.
- Evaluate the performance of Transformers in comparison to other deep learning models.

Course Outline: Introduction to Advanced Data Analytics, Data Preprocessing and Cleaning Techniques, Exploratory Data Analysis (EDA), Feature Engineering and Selection, Supervised Learning Techniques (e.g., Regression, Decision Trees, SVM), Unsupervised Learning Techniques (e.g., Clustering, Dimensionality Reduction), Time Series Analysis and Forecasting, Advanced Machine Learning Algorithms (e.g., Ensemble Methods, Neural Networks), Model Evaluation and Validation Techniques (e.g., Cross-Validation, A/B Testing), Big Data Analytics Tools and Techniques, Data Visualization with Advanced Tools (e.g., Tableau, Power BI, D3.js), Case Studies and Applications in Various Domains (e.g., Finance, Healthcare, Marketing), Ethical Considerations in Data Analytics.

Reference Material: The following is the recommended list of books (or their latest editions):

1. Hastie, Trevor, Robert Tibshirani, and Jerome Friedman. The Elements of Statistical Learning: Data Mining, Inference, and Prediction. 2nd ed., Springer, 2009.
2. James, Gareth, et al. An Introduction to Statistical Learning: With Applications in R. 2nd ed., Springer, 2021.
3. Murphy, Kevin P. Machine Learning: A Probabilistic Perspective. 1st ed., MIT Press, 2012.

Course Name:	Software Engineering in Society
Course Code:	CS728
Credit Hours:	3
Pre-requisites:	None

Course Introduction: The course is designed to highlight how software engineering can address the opportunities and challenges posed by the rapidly accelerating pace of technological advances that are impacting the economic, political, environmental, social, and technical aspects of society. The course discusses emerging trends in the development of software that is part of larger systems and whose development is tackled within the specific areas listed below.

Course Objectives: The objectives of the course is follows:

- To understand use of software applications in different paradigms and scenarios
- Implications of software use and maintenance under different circumstances challenges and issues which are faced in those applications but are not there in normal software development and application scenario.

Course Outline: (The instructor may select topics from the following important areas)
Diversity and Inclusion in software engineering: Organizational Culture; Designing,

Engineering, and Testing Software for Diverse Users; Communication and collaboration: conflict and resolution, successful and unsuccessful communication or collaboration patterns, The impact of COVID-19 on software development, including underrepresented groups within software engineering, Software Engineering for Diverse areas: Environmental Sciences (e.g., Sustainability, Urban Planning), Social Sciences (e.g.,Software Fairness), Management (e.g. socio-technical ecosystems, technical debt, social debt); Economics (e.g., Electronic payments, Blockchain technologies); Law (e.g., combating and investigating crime, impact on the legal system); Manufacturing (e.g., Industry 4.0, smart factory); Arts (e.g. Digital Art), Interdisciplinary research (e.g. Cognitive Science, Digital Social Innovation); Society and societal challenges: Security and Privacy (e.g., security and privacy preserving software development); Ethics (e.g., Responsible AI)

Reference Material:
The following is the recommended list of books (or their latest editions):

1. Botto-Tobar, Miguel, et al. Artificial Intelligence, Computer and Software Engineering Advances. Springer Nature, 2021
2. Finkelstein, Clive. "Enterprise integration using enterprise architecture." Constructing the Infrastructure for the Knowledge Economy: Methods and Tools, Theory and Structure. Boston, MA: Springer US, 2004. 43-82.
3. Latest research from online sources.
4. Proceedings of ICSE2X-SEIS track

Course Name:	Software Evolution and Reengineering
Course Code:	CS729
Credit Hours:	3
Pre-requisites:	None

Course Introduction: Change is an inherent property of all software systems and software development life-cycles. Systems that have long passed the life expectancy envisioned by their initial developers have accumulated many changes because of the maintenance of defects, advancements in technology, and new business needs.

Course Objectives: The course aims to:

- Introduce the challenges presented by existing systems and examine various reverse engineering and forward engineering techniques for evolving systems.
- Explores the concepts of software evolution and reengineering and introduces approaches and support tools used to extract the information from existing software systems.
- Introduce various principles of software reuse and reverse engineering techniques are presented and researched through research papers.

Course Outline: Principles and techniques of software maintenance. Impact of software development process on software justifiability, maintainability, evolvability, and planning of release cycles. Use of very high-level languages (VHLL) and dependencies for forward engineering and reverse engineering. Achievements, pitfalls, and trends in software reuse, reverse engineering, and re-engineering. Review of tools and techniques, working on a real-world software problem.

Reference Material: The following is the recommended list of books (or their latest editions):

1. Tripathy, Priyadarshi, and Kshirasagar Naik. Software Evolution and Maintenance. John Wiley and Sons, 2014
2. AntiPatterns: Refactoring Software Architectures, and Projects in Crisis, Brown, Malveau, Mowbray & McCormick, Wiley, ISBN 0471197130, 1998 Press. Reifer, D. 2012.
3. Brown, William H., et al. AntiPatterns: refactoring software, architectures, and projects in crisis. John Wiley & Sons, Inc., 2012.
4. Reifer, Donald J. Software Maintenance Success Recipes. CRC Press, 2016.

Course Name:	Engineering Privacy in Software
Course Code:	CS730
Credit Hours:	3
Pre-requisites:	None

Course Introduction: This graduate-level course covers the methods and tools needed to design systems for privacy with a specific focus on the requirements, design and testing stages of the software development lifecycle.

Course Objectives: The students will understand how to:

- Integrate privacy into the software engineering lifecycle phases
- Collect, analyse and reconcile system requirements in a privacy-sensitive ecosystem
- Evaluate software designs based on privacy principles and privacy requirements
- Interface with software developers on critical privacy issues

Course Outline: Engineering privacy in SDLC, Requirements: express and analyze system and privacy requirements, privacy principles, privacy patterns and privacy controls as a source of requirements knowledge, Goal-based analysis to refine privacy goals into functional, privacy-enhancing system specifications. Privacy threat and risk analysis to apply different risk models to explore privacy threats, vulnerabilities and mitigations, Design: students identify and evaluate alternative design strategies to implement requirements, Architecture vs. Policy, Data Lifecycle, Evolution & Adaptability: effects of privacy, including deployment, maintenance and upgrades that risk violating privacy requirements.

Reference Material:

The following is the recommended list of books (or their latest editions):

1. Adkins, Heather, et al. Building Secure and Reliable Systems. O'Reilly Media, 2020
2. Lamsweerde, A. van. Requirements engineering: from system goals to UML models to software specifications. John Wiley & Sons, Ltd, 2009.
3. Latest research from online sources.

Course Name:	**Real-time Stream Processing**
Course Code:	CS731

Credit Hours: 3
Pre-requisites: None

Course Introduction: This course provides the fundamentals of real-time stream processing paradigm. It introduces the key components of this paradigm, including the distributed system infrastructure, the programming model, the design patterns, and the real-time streaming analytics.

Course Objectives: Students successfully completing this course should be able to:

- Capturing real-time data
- Processing real-time data
- Aggregating data
- Monitor streaming in real-time

Course Outline: Introduction to stream processing, application development, large-scale development, visualization and debugging, architecture of a stream processing, design principles and patterns for stream processing applications, stream analytics.

Reference Material: The following is the recommended list of books (or their latest editions):

1. Andrade, Henrique C., Bugra Gedik, and Deepak S. Turaga. Fundamentals of Stream Processing: Application Design, Systems, and Analytics. Cambridge University Press, 2014. Print. ISBN 978-1-107-06124-4.
2. Ellis, Brian. Real-Time Analytics: Techniques to Analyze and Visualize Streaming Data. John Wiley & Sons, 2014. Print. ISBN 978-1-118-86663-1.

Course Name:	**Linked Open Data**
Course Code:	CS732
Credit Hours:	3
Pre-requisites:	None

Course Introduction: We are surrounded by data everywhere. By helping us to make better decisions, data plays a central role in our daily lives. An ever-increasing number of data sources, driven by individuals and organizations, contribute to this data deluge by sharing their data with others. However, data is locked up behind proprietary, unreliable, and even unstable programming interfaces that prevent us from optimally making use of it. Linked Data has the potential to revolutionize the way we discover, access, integrate, and use data; just in the way the World Wide Web has revolutionized the way we consume and connect documents. This course will introduce students with the basic principles, standards, and technologies of Linked Open Data to enable data sharing and reuse on a massive scale across multiple platforms and enterprises. This course will introduce students with the tools and methods for querying linked data and for representing rich ontologies that help define data-rich domains. Held together by ontologies, i.e. knowledge representations based on Semantic Web technologies, Linked Data serves as the central building block of the emerging Web of Data.

Course Objectives: By the end of the course, as a minimum, the student will be able to:

- Understand advance web technologies and applications of these technologies for the designing and implementation of web applications.
- Understand and use the basics of the XML based technologies, and Web Services and the implementation of Web Services for Service Oriented Architecture (SOA).
- Use XML and XML based technologies.
- Design and implement user interfaces based on the AJAX and web mashup technologies.

Course Outline: Linked Data and the Web of Data, Moving from Open Data to Linked Data, Power and Role of Linked Open Data, Origins of Linked Open Data, Linked Data Paradigms, Dereferencing, Ontology as a Shared Model of Objects, Properties and Relationships in a Domain, OWL (Web Ontology Language), Description Logic, Meta-Models, Re-use, Relationship to Vocabulary, Taxonomies, Linked Data Vocabularies and Ontologies, Metadata, URIs and URLs as the Foundation of the Semantic Web, RDF & RDFs Data Model, Dataset Based on Domain Ontology, RDF Serialization Formats (RDF/XML, Turtle),Triple stores, Named Graphs, Querying RDF with SPARQL, SPARQL Query Language, SPARQL Endpoints, Publishing Linked Data, Publishing Models on the Web, Open Linked Data, Enterprise Linked Data, Linked Data Mashups and Applications, Consuming and Visualizing Linked Data, Web-Based JavaScript Clients, JSON-LD, D3 Visualization, Applications of Linked Open Data in Specific Domains, Linked Data Tools.

Reference Material: The following is the recommended list of books (or their latest editions):

1. Bauer, Florian, and Martin Kaltenböck. Linked Open Data: The Essentials. Ed mono/monochrom, 2011.
2. Ordóñez de Pablos, Patricia, ed. Cases on Open-Linked Data and Semantic Web Applications. IGI Global, 2013.
3. Bryl, Volha, and Sebastian Tramp. Linked Open Data-Creating Knowledge Out of Interlinked Data: Results of the LOD2 Project. Springer, 2014.
4. Heath, Tom, and Christian Bizer. Linked Data: Evolving the Web into a Global Data Space. Morgan & Claypool, 2011.

Course Name:	**Advanced Web Technologies**
Course Code:	CS733
Credit Hours:	3
Pre-requisites:	None

Course Introduction:

Course Objectives: Students successfully completing this course should be able to:

- Understand the Semantics representation, Resource Description Framework (RDF).
- Understand the Ontology, Web Ontology Language (OWL); metadata; vocabularies.
- How to publish and consume the Linked Data.
- Applications of linked open data.

Course Outline: Basic XML technologies, XML Parser, XML Namespace, XML Document Type Definition (DTD), XML Schema, XML Validator, Simple API for XML, XML Path Language (XPath), Extensible Stylesheet Language Transformation (XSLT), Extensible Stylesheet Language Formatting Objects (XLink, XPointer, XInclude, and XBase), Web Sevices with Simple Object Access Protocol (SOAP) and Web Service Desciption Language (WSDL), Universal Description Discovery and Integration (UDDI),AJAX technology with JavaScript Programming and Document Object Model (DOM), AJAX integration with XML, Creating Web Application using Web Mashups, Web 2.0 Technologies, JQUERY, JSON, Bootstrap, Basics of Search Engine Optimization (SEO).

Reference Material:
The following is the recommended list of books (or their latest editions):

1. Right, Christopher. XML Programming: The Ultimate Guide to Fast, Easy, and Efficient Learning of XML Programming. CreateSpace Independent Publishing Platform, 2015.
2. Benz, Bill, and John R. Durant. XML Programming Bible. John Wiley & Sons, 2004.
3. Sikos, Leslie F. Web Standards: Mastering HTML5, CSS3, and XML. Apress, 2014.
4. Newcomer, Eric. Understanding Web Services: XML, WSDL, SOAP, and UDDI. Addison-Wesley Professional, 2002.

Rosen, M., Lublinsky, B., Smith, K. T., & Balcer, M. J. (2012). Applied SOA: service-oriented architecture and design strategies. John Wiley & Sons.

Course Name:	**Digital Libraries**
Course Code:	CS734
Credit Hours:	3
Pre-requisites:	None

Course Introduction: This course examines both theoretical and practical aspects of digital library activities, focusing largely on technological and socioeconomic issues. It aims to develop a broad understanding of digital libraries, including basic concepts, types and formats of digital content, the creation and organization of digital libraries, underlying technologies, the preservation of digital content, access management of digital library resources, and social and economic factors. It will demonstrate and exemplify current activities in the digital library field, and will give students up-to-date, hands-on experience in a rapidly developing field. Students will plan and create fully operational models for real-life digital library activities.

Course Objectives: When students complete this course, they will be able to:

- Get an overview of current digital library programs and activities, both in North America and internationally.
- Get familiarized with the major techniques and software used in the creation and maintenance of digital libraries.

- Evaluate the major components of digital libraries by considering their supporting technologies and social-economic factors.
- Examine the social, economic, cultural, and political issues related to digital libraries and their services.
- Get professional track, plan and create a small-scale, but useful and functional, digital library.
- Do research track, review a practical (or research) problems associated with digital libraries and develop a valid approach to solve it.

Course Outline: Introduction and Overview to Digital Libraries, Digital Content: Image Digital Content: Text, Metadata and Markup, Metadata for Representing and Organizing Digital Objects, Basic Elements of Dublin Core for Digital Objects, Functionalities of the Major Components of XML, Creating Simple XML Documents for Describing Digital Objects), Digital Content, Time-Based Formats (Audio and Video), Digital Objects and System Architecture Digital Objects and DOI, Major Components of Digital Libraries, Digital Library Architecture, SOA and Digital Libraries, Digital Library Software, Knowledge Organization Schemes and Content Organization, User Interface, Usability and Evaluation, Access in Digital Libraries, Digital Preservation, Repositories and Archives, Social and Economic Factors, Social Life of Documents, Social Impacts of DL, Social Issues in Designing and Developing DL, Access Management, Human Factors of Digital Libraries, Digital Librarians.

Reference Material:
The following is the recommended list of books (or their latest editions):

1. Lesk, Michael. Understanding Digital Libraries. 2nd ed., Elsevier, 2005.
2. Reese, Terry, and Kyle Banerjee. Building Digital Libraries: A How-To-Do-It Manual. Neal-Schuman Publishers, 2008.
3. Calhoun, Karen. Exploring Digital Libraries: Foundations, Practice, Prospects. Facet Publishing, 2014.
4. Ashraf, Thabit, ed. Design, Development, and Management of Resources for Digital Library Services. IGI Global, 2012.

Course Name:	**Wireless Ad hoc Networks**
Course Code:	CS735
Credit Hours:	3
Pre-requisites:	None

Course Introduction: This course covers advanced topics in mobile ad hoc networking, one of the most challenging fore-fronts of wireless communications. Overview and descriptions of Mobile Ad-Hoc Networks, Classification, Guided and Un Guided Media, Wireless Fixed/ Wireless Ad Hoc Networks, Ad Hoc Wireless Networks , IEEE 802.11 standard/ Architecture, Ad Hoc Wireless Media Access Protocols, Channelization, Bluetooth Technology, Routing Protocols, Multicast routing in ad-hoc wireless networks, Communication Performance of Ad Hoc Networks, Power Issues, Internet and Ad Hoc Service Discovery, WAP, QoS in wireless ad-hoc networks, Security Issues in MANETS. At the end of semester each student will submit a survey report related to the course.

Course Objectives: Students successfully completing this course should be able to:

- Understand the fundamentals of IP and multi-hop wireless networking
- Understand the current topics in wireless ad hoc networks both in industry and research point of view.
- Principles of wireless Adhoc networks and what makes it different from infrastructure networks.
- Conduct survey report

Course Outline: WSN introduction, applications and challenges. WSN architecture (node architecture and network architecture), Programming basic WSN node, operating environments (TinyOS, nesC, Mica mote etc). Network architecture, typical scenarios, distributed WSN, design principles, energy efficiency issues. Protocols for WSN (Layer 2 and Layer 3 protocols and addressing structures, data centric approach etc), QoS issues in WSN, QoS parameters and network performance, throughput and network convergence. QoS metrics dependency on maximizing performance. Security aspects of WSN (Symmetric vs Asymmetric cryptography concepts, Trust, Security and Privacy). Key management in WSN. WSN deployment with Symmetric encryption, data aggregation, data gathering and reporting. Secure routing in WSN.

Reference Material:
The following is the recommended list of books (or their latest editions):

1. Oh, Chai-Keong. Ad Hoc Mobile Wireless Networks: Protocols and Systems. Pearson Education Inc., 2007. Print. ISBN 0-470-09510-5.
2. Relevant research papers

Course Name:	**Introduction to Computer Vision**
Course Code:	CS736
Credit Hours:	3
Pre-requisites:	None

Course Introduction: This course gives students an introductory insight into theory of computer vision. It focuses on some basic vision issues such as shape and region representation/description as examples of the vision problem. Some advanced topics are introduced.

Course Objectives: After completing the courses students should be able to:

- To explain the computer vision problem and identify its various forms and types.
- Gain acquaintance with tools, methods, and algorithms to handle computer vision tasks.
- Implement vision algorithms in MATLAB and other tools.

Course Outline: Image processing: edge detection, segmentation, local features, shape and region description in 2D and 3D. Insight from human vision studies. Representation for vision: object models, synthetic images, matching, gaps, algorithms. interference, production system, synthetic networks. Planning spatial reasoning for robot vision.

Reference Material: The following is the recommended list of books (or their latest editions):

1. Prince, Simon J. D. Computer Vision: Models, Learning, and Inference. 1st ed., Cambridge University Press, 2012. ISBN 978-1107011793.
2. Szeliski, Richard. Computer Vision: Algorithms and Applications. Springer, 2011. ISBN 978-1848829343.
3. Kaehler, Adrian, and Gary Bradski. Computer Vision with OpenCV Library. 1st ed., O'Reilly Media, 2008. ISBN 978-0596516130.
4. Solem, Jan Erik. Programming Computer Vision with Python. 1st ed., O'Reilly Media, 2012. ISBN 978-1449316549.

Course Name:	**Advanced Digital Image Processing**
Course Code:	CS737
Credit Hours:	3
Pre-requisites:	None

Course Introduction: Advanced Digital Image Processing investigates algorithms and techniques for a variety of imaging applications. The techniques build on the background that is established in the course, Introduction to Digital Image Processing, which focuses on basic image processing methods.

Course Objectives: After completing this course, students:
Through this course, students will be able to gain a deeper understanding of the vision tasks such as enhancement, segmentation, and object recognition. Familiarity with advanced techniques will be gained and theoretical understanding will be enhanced.

Course Outline: Image Enhancement in Spatial Domain, Image Enhancement in Frequency Domain, Image Restoration, Color Image Processing, Morphological Image Processing, Image Segmentation, Object Recognition, Wavelet and Multi-resolution Processing, Feature Detection and Classification.

Reference Material:
The following is the recommended list of books (or their latest editions):

1. Gonzalez, Rafael C., and Richard E. Woods. Digital Image Processing. 3rd ed., Prentice Hall, 2008.
2. Gonzalez, Rafael C., and Richard E. Woods. Digital Image Processing Using MATLAB. Prentice Hall, 2008.

Course Name:	**Pattern Recognition**
Course Code:	CS738
Credit Hours:	3
Pre-requisites:	None

Course Introduction: This course provides an in-depth study of techniques and methods used to identify patterns in data and learn from them. The course covers both classical pattern recognition approaches and contemporary machine learning techniques, equipping students with

the skills to analyze and classify complex datasets. Emphasis is placed on practical applications, model evaluation, and emerging trends in pattern recognition.

Course Objectives: The objectives of this course are as follows:

- Understand various pattern recognition techniques and algorithms for analyzing data.
- Design and implement machine learning models that integrate pattern recognition methods.
- Evaluate and optimize models using appropriate performance metrics and validation techniques.

Course Outline: Introduction to Pattern Recognition, Statistical Pattern Recognition, Feature Extraction and Selection, Classification Algorithms (e.g., k-Nearest Neighbors, Decision Trees, SVM), Clustering Techniques (e.g., k-Means, Hierarchical Clustering), Bayesian Methods and Gaussian Mixture Models, Neural Networks and Deep Learning for Pattern Recognition, Dimensionality Reduction Techniques (e.g., PCA, LDA), Model Evaluation and Performance Metrics, Applications in Image and Speech Recognition, Ensemble Methods and Hybrid Approaches, Handling Noisy and Incomplete Data, Advanced Topics in Pattern Recognition (e.g., Transfer Learning, Anomaly Detection), Case Studies and Practical Applications.

Reference Material:

1. Duda, Richard O., Peter E. Hart, and David G. Stork. Pattern Classification. 2nd ed., Wiley, 2000.
2. Bishop, Christopher M. Pattern Recognition and Machine Learning. 1st ed., Springer, 2006.
3. Haykin, Simon. Neural Networks and Learning Machines. 3rd ed., Pearson, 2009.
4. Hastie, Trevor, Robert Tibshirani, and Jerome Friedman. The Elements of Statistical Learning: Data Mining, Inference, and Prediction. 2nd ed., Springer, 2009.

Course Name:	**Technology Enhanced Learning**
Course Code:	CS739
Credit Hours:	3
Pre-requisites:	None

Course Introduction: Information and Communication technologies have revolutionized the learning activities. Technology Enhanced Learning is a broader term that represents use of technologies to facilitate, improve or scale educational activities. This course will introduce students to a range of areas and applications of Technology Enhanced Learning. The main objective of this course is to expose students to the applications of technology in learning for enhanced learning experiences.

Course Objectives: After completing the courses students should be able to

• Have knowledge of a range of range of learning technologies
• Understand many of the theoretical and pedagogical issues which define digital education
• Explore different themes in the field of technology enhanced learning
• Identify various ways of improving students' learning experience and engagement with learning systems

• To design learning systems with appropriate tools to enhance learning experiences.

Course Outline: Introduction to Technology Enhanced Learning, Application areas of Technology Enhanced learning, Intelligent Tutoring System, Adaptive Learning systems, Personalisation in Learning System, Learner Model, Concepts Maps, Learning Objects, Learning Object Models. Open Educational Resources, Ontologies for learning systems. Blended Learning, Virtual Learning Environment (VLE), Educational Games, Ubiquitous Learning, Mobile Learning, Gamification in Learning Applications, Learning Analytics, MOOCs, Issues in Online Learning, Learners engagement, Collaborative Learning and Case studies of different learning tools. Smart Learning Spaces, Review of existing popular E-learning applications, Authoring tools for learning materials. Ethical implications of technology in education, AI and Machine Learning in TEL, Learning Analytics.

Reference Material:
The following is the recommended list of books (or their latest editions):

1. Nick, Rushby. The Wiley Handbook of Learning Technology. 1st ed., Wiley & Sons, 2016.
2. Duval, Erik. Technology Enhanced Learning: Research Themes. 1st ed., Springer, 2017.
3. Beetham, Helen, and Rhona Sharpe, eds. Rethinking Pedagogy for a Digital Age: Principles and Practices of Design. 3rd ed., Routledge, 2019.
4. Other readings will be assigned in class.

Course Name:	**Persuasive Technologies**
Course Code:	CS740
Credit Hours:	3
Pre-requisites:	None

Course Introduction: This course is designed to provide the student with opportunity to understand the emerging field of Persuasive Technologies and how to design and develop persuasive applications in any field of interest.

Course Objectives: After completing the course students should be able to

- Understand how human behavior works.
- Under potential strategies for developing applications for behaviour change
- Identify areas of applications of mobile interventions through persuasive applications
- Design and develop strategies for building persuasive mobile and web applications.

Course Outline: Persuasive Technologies, Introduction to Captology, Behavior change support systems, How the Mind Decides What to Do Next, A Simple Model of When, and Why, We Act, The Create Action Funnel, Strategies for Behavior Change, Figuring Out What You Want to Accomplish, Selecting the Right Target Action, Structuring the Action, Moving from Conceptual Designs to Interface Designs, Reviewing and Fleshing Out the Interface Designs, Measuring Impact, Identifying Obstacles to Behavior Change, Persuasive Interfaces, Persuasion and Social Media, Persuasive Games, Implementation Technologies: Mobile Applications, Web Systems,

Cloud Technologies. Sensors, Applications of Persuasive Technologies in Education, Health, Behavioural Change, Workplace, E-Commerce.

Reference Material: The following is the recommended list of books (or their latest editions):

1. Wendel, Stephen. Designing for Behavior Change: Applying Psychology and Behavioral Economics. 2nd ed., O'Reilly Media, 2020.
2. Fogg, B. J. Persuasive Technology: Using Computers to Change What We Think and Do. Interactive Technologies, Morgan Kaufmann, 2002. (Or latest edition.)
3. Fogg, B. J. Mobile Persuasion: 20 Perspectives on the Future of Behavior Change. Stanford Captology Media, 2007.

Course Name:	**Interaction Design**
Course Code:	CS741
Credit Hours:	3
Pre-requisites:	None

Course Introduction: This course aims to give students an understanding of the area of Interaction Design and provide students with knowledge and skills to design usable interfaces. This course discusses different factors that affect the design of interactive hardware and software systems and exposes students to contemporary Human Computer Interaction issues in different application areas. This course also introduces students to various evaluation techniques for evaluating interactive systems.

Course Objectives: After completing the courses students should be able to

- Demonstrate knowledge and understanding of the main concepts (conceptual model, metaphors and paradigms) that influence human-computer interaction
- Understand how to design, prototype and evaluate a user interface for an interactive system.
- Design solutions for interacting computer systems.
- Design usable interfaces
- Use practical skills selecting an appropriate evaluation technique for evaluating interactive system.

Course Outline: What Is Interaction Design? The User Experience, The Process of Interaction Design. Conceptualizing Interaction, Conceptual Models, Interaction Types, Paradigms, Visions, Theories, Models, and Frameworks, Cognitive Aspects, Social Interaction, Emotional Interaction, Interfaces, Interface Types, Participatory Design, Data Gathering, Interviews, Questionnaires, Observation, Data Analysis, Interpretation, And Presentation, Qualitative and Quantitative Analysis, Prototyping, Types of Evaluation, Evaluation Case Studies, Usability Testing, Conducting Experiments, Field Studies, Inspections: Heuristic Evaluation and Cognitive Walkthroughs.

Reference Material: The following is the recommended list of books (or their latest editions):

1. Rogers, Yvonne, Helen Sharp, and Jenny Preece. Interaction Design: Beyond Human-Computer Interaction. 6th ed., Wiley & Sons, 2023.

2. Shneiderman, Ben. Designing the User Interface. 6th ed., Addison Wesley, 2016.
3. Dix, Alan, and Russell Beale. Human-Computer Interaction. Prentice Hall, 2003. (Or latest edition.)
4. Jacko, Julie A., ed. Human-Computer Interaction Handbook: Fundamentals, Evolving Technologies, and Emerging Applications. 3rd ed., CRC Press, 2012.

Course Name:	**User Centered Research and Evaluation**
Course Code:	CS742
Credit Hours:	3
Pre-requisites:	None

Course Introduction: This course aims to give students an understanding of the area of Interaction Design and provide students with knowledge and skills to design usable interfaces. This course discusses different factors that affect the design of interactive hardware and software systems and exposes students to contemporary Human Computer Interaction issues in different application areas. This course also introduces students to various evaluation techniques for evaluating interactive systems.

Course Objectives: After completing the courses students should be able to

- Design, prototype and evaluate usability of interactive system
- Have advanced knowledge and skills in the area of evaluating interactive systems
- Have necessary practical skill to design and conduct experimental research studies in the area of HCI
- Select appropriate HCI Design Methodologies and apply them in the solution of real world design problems
- Select appropriate methodologies for the evaluation of HCI systems and implement these methodologies on real systems and analyse and discuss the results produced
- Have understanding and knowledge of designing quantitative and qualitative studies for evaluating interaction designs

Course Outline: Introduction to Interfaces and Design, Humans and Computers, The basics of Designing, Design and Usability, Evaluation Basics, Establishing Requirements, Design, Prototyping, Mock-ups and Wireframing, Using Scenarios, Data Analysis And Interpretation, Quantitative Evaluation and Qualitative Evaluation, Designing Evaluation Studies, Types of Evaluation, Conducting Experiments, Questionnaires, Interviews, Observation, Evaluation Case Studies, Focus Groups, Usability Testing, Field Studies, Inspections: Heuristic Evaluation and Walkthroughs, Introduction to Statistical Tests, Result Gathering and Interpreting, Tools to Support Data Analysis, Analysing Quantitative data with SPSS, Analysing Qualitative data with NVivo, Ethical Issues in Experiment design.

Reference Material: The following is the recommended list of books (or their latest editions):

1. Lazar, Jonathan. Research Methods in Human-Computer Interaction. 2nd ed., Wiley, 2017.
2. Rogers, Yvonne, Helen Sharp, and Jenny Preece. Interaction Design. 6th ed., Wiley & Sons, 2023.
3. LUMA Institute. Innovating for People: Handbook of Human-Centered Design Methods.

2012.
4. Goodman, Elizabeth. Observing the User Experience: A Practitioner's Guide to User Research. Morgan Kaufmann, 2012.

Course Name:	**Advanced Machine Learning**
Course Code:	CS743
Credit Hours:	3
Pre-requisites:	None

Course Introduction: This course provides an in-depth exploration of sophisticated machine learning techniques and their applications. Building on foundational machine learning concepts, this course delves into advanced algorithms, model optimization strategies, and cutting-edge research areas. Students will develop expertise in designing, implementing, and evaluating complex machine learning models for real-world data-driven problems.

Course Objectives: The objectives of this course are as follows:

- Design advanced machine learning models for complex data sets and applications.
- Analyze the performance of machine learning models using appropriate validation techniques and performance metrics.
- Apply advanced optimization algorithms to improve model accuracy and efficiency.

Course Outline: Introduction to Advanced Machine Learning Concepts, Mathematical Foundations for Machine Learning, Optimization Techniques (e.g., Gradient Descent, Stochastic Optimization), Ensemble Methods (e.g., Bagging, Boosting, Random Forests), Support Vector Machines (SVM) and Kernel Methods, Dimensionality Reduction Techniques (e.g., PCA, LDA, t-SNE), Bayesian Methods and Probabilistic Graphical Models, Deep Learning Architectures (e.g., CNNs, RNNs, GANs), Reinforcement Learning Algorithms, Transfer Learning and Domain Adaptation, Handling Imbalanced and High-Dimensional Data, Model Evaluation and Hyperparameter Tuning, Interpretability and Explainability in Machine Learning, Applications and Case Studies in Various Domains, Ethical Considerations and Bias in Machine Learning.

Reference Material: The following is the recommended list of books (or their latest editions):

1. Murphy, Kevin P. Machine Learning: A Probabilistic Perspective. 1st ed., MIT Press, 2012.
2. Bishop, Christopher M. Pattern Recognition and Machine Learning. 1st ed., Springer, 2006.
3. Hastie, Trevor, Robert Tibshirani, and Jerome Friedman. The Elements of Statistical Learning: Data Mining, Inference, and Prediction. 2nd ed., Springer, 2009.
4. Goodfellow, Ian, Yoshua Bengio, and Aaron Courville. Deep Learning. 1st ed., MIT Press, 2016.

Course Name:	**Privacy Enhancing Technologies (PETs)**
Course Code:	CS744

Credit Hours: 3
Pre-requisites: None

Course Introduction: This course provides a comprehensive overview of Privacy Enhancing Technologies (PETs), focusing on methods and tools to protect user privacy in various computing environments. Students will explore fundamental concepts, advanced techniques, and practical applications of PETs. The course covers a wide range of topics including data anonymization, differential privacy, secure multi-party computation, homomorphic encryption, anonymous communication networks, privacy-preserving data mining, and more. Through lectures, case studies, hands-on projects, and research discussions, students will gain the skills and knowledge necessary to design and implement privacy-preserving systems.

Course Objectives:

- Understand the principles and importance of privacy in the digital age.
- Apply data anonymization and pseudonymization techniques to protect sensitive information.
- Implement differential privacy mechanisms to ensure privacy in data analysis.

Course Outline: Introduction to Privacy, Definitions, importance, and challenges, Types of privacy threats in the digital age., GDPR, CCPA, and other privacy regulations, K-anonymity, l-diversity, t-closeness, Use cases and effectiveness, Case studies and mitigation strategies, Differential Privacy, Fundamentals of Differential Privacy: Definitions and principles, Mechanisms for Differential Privacy: Laplace mechanism, exponential mechanism, Applications of Differential Privacy: Use cases in industry and research, Multi-Party Computation (SMPC), Introduction to SMPC: Concepts and protocols, Cryptographic Techniques for SMPC: Secret sharing, homomorphic encryption, Applications and Case Studies: Real-world applications of SMPC, Homomorphic Encryption Basics of Homomorphic Encryption: Types (partially, fully), Homomorphic Encryption Schemes: RSA, Paillier, Gentry's scheme, Applications: Secure data processing in the cloud, Anonymous Communication Networks, Introduction to Anonymous Communication: Principles and motivations, Tor Network: Architecture, usage, and vulnerabilities, Mix Networks and DC-Nets: Concepts and differences, Privacy-Preserving Data Mining, Overview of Privacy-Preserving Data Mining (PPDM): Goals and techniques, Techniques in PPDM: Data perturbation, secure computation, Case Studies: Real-world applications of PPDM, Location Privacy, Location-Based Services and Privacy: Threats and challenges, Techniques for Protecting Location Privacy: Location obfuscation, cloaking, Case Studies: Implementations and evaluations of location privacy techniques, Identity Management and Authentication, Digital Identity Management: Concepts and architectures, Privacy-Preserving Authentication: Techniques and protocols, Anonymous Credentials: Use cases and technologies, Blockchain and Privacy Introduction to Blockchain Technology: Basics and applications, Privacy Concerns in Blockchain: Anonymity vs. traceability, Privacy-Preserving Blockchain Techniques: Zero-knowledge proofs, confidential transactions, Privacy in Machine Learning, Challenges and Open Problems: Future research directions.

Reference Material: The following is the recommended list of books (or their latest editions):

1. Aumasson, Jean-Philippe. Serious cryptography: a practical introduction to modern encryption. No Starch Press, 2017.

2. Banoth, Rajkumar, and Rekha Regar. "An Introduction to Classical and Modern Cryptography." Classical and Modern Cryptography for Beginners. Cham: Springer Nature Switzerland, 2023. 1-46.

Course Name:	**Intelligent Wireless Networks**
Course Code:	CS745
Credit Hours:	3
Pre-requisites:	None

Course Introduction: This course provides the fundamentals of machine learning within the context of communication systems, allowing students to comprehend and design intelligent communication networks. Students will gain a thorough understanding of the intersection of machine learning and communication systems, preparing them for future research and innovative applications in the field.

Course Objectives: The objectives of this course are as follows:

- To gain a solid foundation of the use of machine learning principles, algorithms, and techniques in the context of communication systems
- To explore how machine learning can be applied to enhance communication systems, including signal processing, modulation, and error correction.
- To encourage students to explore advanced topics and emerging trends in the intersection of machine learning and communication, fostering research and innovation.

Course Outline: This course explores the intersection of machine learning and communication systems, giving students the knowledge and tools they need to build intelligent communication networks. The course starts with an overview of machine learning, including supervised, unsupervised, and reinforcement learning. It then investigates how machine learning can enhance signal detection, filtering, and error correction in communication systems, optimize data transmission through adaptive modulation and coding, and optimize network resources such as spectrum and power control. Machine learning techniques, including reinforcement learning, are used to optimize network performance, particularly in 5G and beyond. This course will also discuss 5G-V2X (cellular-V2X) features and use cases The course also covers improving the security and privacy of communication systems using machine learning, and how machine learning is advancing IoT, cognitive radio networks, and intelligent antennas. Additionally, the course provides an introduction to the foundation of machine learning and deep neural networks in the context of IoT systems, such as for wearable devices and sensors for health monitoring and medical informatics, and explores machine learning for IoT systems and distributed resource-constrained platforms. Standardization activities on AI-enabled wireless networks, 3GPP and 5GAA, ETSI Zero touch networks.

Reference Material: The following is the recommended list of books (or their latest editions):

1. Yonina C. Eldar, Andrea Goldsmith, Deniz Gündüz, H. Vincent Poor. Machine Learning and Wireless Communication, New Edition. Cambridge University Press. 2022
2. Hoang, Dinh Thai, Nguyen Van Huynh, et al. Deep Reinforcement Learning for Wireless Communications and Networking: Theory, Applications and Implementation. Willy, 2023.

3. Gopi, E. S., and P. Maheswaran, editors. Proceedings of the International Conference on Machine Learning, Deep Learning and Computational Intelligence for Wireless Communication: MDCWC 2023. Springer, 2024. Signals and Communication Technology.
4. Agrawal, S. K. 5G Wireless Communication System Using Machine Learning (ML). LAP LAMBERT Academic Publishing, 2020.
5. Luo, Fa-Long. Machine Learning for Future Wireless Communications. IEEE Press, 2019.

Course Name:	**Improving Deep Neural Networks**
Course Code:	CS746
Credit Hours:	3
Pre-requisites:	None

Course Introduction:
This course covers topics related to optimization, regularization, and architectural improvements, with an emphasis on practical strategies to address common challenges such as overfitting, convergence issues, and computational constraints. Students will gain hands-on experience in refining and optimizing deep learning models for better accuracy and generalization.

Course Objectives: The objectives of this course are as follows:
- Advanced techniques for improving the performance of deep neural networks.
- ML Algorithms' hyperparameter tuning and advanced training methods, to enhance model accuracy and convergence.
- Conduct research on emerging trends and advancements in neural network improvements, demonstrating expertise in experimentation and analysis.

Course Outline:
Introduction to Deep Neural Networks, Optimization Algorithms (e.g., Adam, RMSprop, SGD), Hyperparameter Tuning and Search Methods, Regularization Techniques (e.g., Dropout, L2 Regularization, Batch Normalization), Advanced Architectures (e.g., Residual Networks, DenseNets, Attention Mechanisms), Transfer Learning and Fine-Tuning Strategies, Data Augmentation and Synthetic Data Generation, Handling Imbalanced Data and Class Weights, Techniques for Improving Convergence (e.g., Learning Rate Schedulers, Gradient Clipping), Model Evaluation and Performance Metrics, Efficiency and Scalability in Training Deep Networks, Case Studies of Successful Deep Learning Models, Future Directions and Emerging Trends in Deep Neural Networks.

Reference Material:

1. Goodfellow, Ian, Yoshua Bengio, and Aaron Courville. *Deep Learning*. 1st ed., MIT Press, 2016.
2. Bengio, Yoshua. *Learning Deep Architectures for AI*. Foundations and Trends in Machine Learning, 2009.
3. Ruder, Sebastian. *An Overview of Gradient Descent Optimization Algorithms*. 1st ed., arXiv, 2016.

4. Hinton, Geoffrey, et al. *Improving Neural Networks by Preventing Co-Adaptation of Feature Detectors*. 1st ed., arXiv, 2012.

Course Name:	**Large Language Models**
Course Code:	CS747
Credit Hours:	3
Pre-requisites:	None

Course Introduction: This course explores the principles, techniques, and applications of state-of-the-art language models. The course covers foundational concepts, training methodologies, and practical uses of large-scale language models like GPT-3, BERT, and their successors. Students will gain hands-on experience with these models, learning how to fine-tune them for various natural language processing tasks and evaluate their performance in real-world scenarios.

Course Objectives: The objectives of this course are as follows:

- Understand the underlying principles and architectures of large language models for natural language processing tasks.
- Develop and fine-tune large-scale language models to improve their performance on specific applications such as text generation, classification, and translation.
- Evaluate the effectiveness of language models, considering metrics like accuracy, fluency, and computational efficiency.

Course Outline: Introduction to Language Models, Transformer Architecture and Variants, Pre-training Methods (e.g., Masked Language Modeling, Causal Language Modeling), Fine-Tuning Techniques and Strategies, Evaluation Metrics for Language Models, Large-Scale Training and Resource Management, Transfer Learning and Domain Adaptation, Applications in Text Generation, Summarization, and Translation, Few-Shot and Zero-Shot Learning, Handling and Mitigating Bias in Language Models, Ethical Considerations in Large Language Modeling, Future Trends and Emerging Techniques in NLP, Case Studies of Leading Language Models (e.g., GPT-3, BERT, T5).

Reference Material: The following is the recommended list of books (or their latest editions):

1. Vaswani, Ashish, et al. Attention Is All You Need. 1st ed., NeurIPS, 2017.
2. Devlin, Jacob, et al. BERT: Pre-training of Deep Bidirectional Transformers for Language Understanding. 1st ed., NAACL, 2019.
3. Brown, Tom B., et al. Language Models are Few-Shot Learners. 1st ed., NeurIPS, 2020.
4. Radford, Alec, et al. Learning Transferable Visual Models From Natural Language Supervision. 1st ed., CVPR, 2021.

Course Name:	**Transformers in Machine Learning**
Course Code:	CS748
Credit Hours:	3
Pre-requisites:	None

Course Introduction: This course delves into the foundational and advanced concepts of Transformer models, a revolutionary architecture in the field of machine learning. The course covers the mechanics of Transformers, their role in various machine learning tasks, and their applications across domains such as natural language processing, computer vision, and beyond. Students will gain hands-on experience in implementing and fine-tuning Transformer models, understanding their scalability, and exploring their use in cutting-edge research.

Course Objectives: The objectives of the course are as follows:

- Understand the architecture and working principles of Transformer models.
- Use of Transformer models for various machine learning tasks.
- Evaluate the performance of Transformers in comparison to other deep learning models.

Course Outline: Introduction to Transformer Architecture, Self-Attention Mechanism, Multi-Head Attention, Positional Encoding, Encoder-Decoder Structures, Pre-training and Fine-tuning Strategies, Transformers for Natural Language Processing (e.g., BERT, GPT, T5), Transformers in Computer Vision (e.g., Vision Transformers), Advanced Variants of Transformers (e.g., Longformer, Reformer), Scaling Transformers for Large Datasets, Transfer Learning with Transformers, Performance Optimization and Evaluation, Applications in Real-World Scenarios, Future Directions in Transformer Research

Reference Material: The following is the recommended list of books (or their latest editions):

1. Vaswani, Ashish, et al. *Attention Is All You Need*. 1st ed., NeurIPS, 2017.
2. Devlin, Jacob, et al. BERT: Pre-training of Deep Bidirectional Transformers for Language Understanding. 1st ed., NAACL, 2019.
3. Raffel, Colin, et al. Exploring the Limits of Transfer Learning with a Unified Text-to-Text Transformer. 1st ed., JMLR, 2020.

Course Name:	**Convolutional Neural Network**
Course Code:	CS749
Credit Hours:	3
Pre-requisites:	None

Course Introduction: This course explores the principles, architectures, and applications of Convolutional Neural Networks (CNNs), which are a cornerstone of modern deep learning, particularly in computer vision. The course provides a deep dive into the design and implementation of CNNs, examining their ability to perform image classification, object detection, segmentation, and other tasks. Students will gain practical experience in developing and optimizing CNN models for various applications.

Course Objectives: The objectives of this course are as follows:

- Understand the core concepts and architectures of Convolutional Neural Networks..
- Design and implement CNN models for different computer vision tasks, including image classification, object detection, and segmentation.
- Evaluate CNN models using appropriate metrics and validation techniques.

Course Outline: Introduction to Convolutional Neural Networks, Convolutional Layers and Operations, Pooling Layers and Techniques, Activation Functions (e.g., ReLU, Sigmoid, Tanh), CNN Architectures (e.g., LeNet, AlexNet, VGG, ResNet, Inception), Regularization Techniques (e.g., Dropout, Batch Normalization), Advanced CNN Techniques (e.g., Transfer Learning, Fine-Tuning, Data Augmentation), Object Detection and Localization (e.g., R-CNN, YOLO, SSD), Image Segmentation Techniques (e.g., U-Net, FCN), Model Evaluation and Performance Metrics (e.g., Accuracy, Precision, Recall, IoU), Efficient Training and Optimization Strategies, Case Studies and Applications in Various Domains (e.g., Healthcare, Autonomous Vehicles, Robotics), Future Directions and Innovations in CNNs.

Reference Material: The following is the recommended list of books (or their latest editions):

1. Goodfellow, Ian, Yoshua Bengio, and Aaron Courville. Deep Learning. 1st ed., MIT Press, 2016.
2. Krizhevsky, Alex, Ilya Sutskever, and Geoffrey Hinton. ImageNet Classification with Deep Convolutional Neural Networks. 1st ed., NeurIPS, 2012.
3. O'Reilly, Michael. Deep Learning for Computer Vision with Python. 1st ed., O'Reilly Media, 2020.

Course Name:	**Web Security**
Course Code:	CS750
Credit Hours:	3
Pre-requisites:	None

Course Introduction: This course is a comprehensive overview of web security. The goal is to build an understanding of the most common web attacks and their countermeasures. Given the pervasive insecurity of the modern web landscape, there is a pressing need for programmers and system designers to improve their understanding of web security issues. We'll be covering the fundamentals as well as the state-of-the-art in web security.

Course Objectives: By the end of the course, as a minimum, the student will be able to:

- Understand the concepts and terminology used in web security
- Understanding of the most prevalent security challenges and attacks of web applications, and the ability to identify vulnerabilities in applications and their counter measures
- Be aware of best practices and secure design principles for development

Course Outline: Web Security & HTML & JavaScript Review, HTTP, Cookies, Sessions, Session Attacks, Cross-Site Request Forgery, Same Origin Policy and Exceptions to the Same Origin Policy, Cross-Site Scripting (XSS), Cross-Site Scripting Defenses, Fingerprinting and Privacy on the Web, Denial-of-service, Phishing, Side Channels, Code Injection, Transport Layer Security, HTTPS in the Real World, Authentication, WebAuthn - The future of user authentication, Managing security concerns in a large Open Source project, Server security: Safe coding practices, Local HTTP server security, DNS rebinding attacks, Browser architecture, Writing secure code.

Reference Material: The following is the recommended list of books (or their latest editions):

1. Yaworski, Peter. Real-world bug hunting: a field guide to web hacking. No Starch Press, 2019.
2. Stuttard, Dafydd, and Marcus Pinto. The web application hacker's handbook: Finding and exploiting security flaws. John Wiley & Sons, 2011.
3. Zalewski, Michal. The tangled Web: A guide to securing modern web applications. No Starch Press, 2011.

Course Name:	**Internet of Things Architecture, Protocols, and Standards**
Course Code:	CS751
Credit Hours:	3
Pre-requisites:	None

Course Introduction: This is a graduate level course which delves into the concepts of Internet of Things (IOT).

Course Objectives: By the end of the course, students should be able to:

- Design and evaluate IoT architectures and systems.
- Select and implement appropriate IoT protocols and standards.
- Address security and privacy issues in IoT deployments.
- Analyze and optimize IoT applications in real-world scenarios.

Course Outline: Introduction to IoT: Overview of IoT concepts, history, and significance, IoT market trends and future directions.
IoT Architecture: Components and layers of IoT architectue, design principles for scalable IoT systems.
Communication Protocols: Deep dive into IoT-specific protocols (MQTT, CoAP, etc.), comparison of protocol performance and suitability.
Networking for IoT: Role of wireless technologies (Wi-Fi, Bluetooth, Zigbee, etc.) in IoT, low-power and long-range communication technologies.
Standards and Regulations: Key standards and frameworks governing IoT, impact of regulations on IoT deployment and operation.
Security and Privacy in IoT: Threats and vulnerabilities specific to IoT, implementing security best practices and protocols.
IoT Data Management: Techniques for collecting, processing, and analyzing IoT data, Cloud platforms and services for IoT data storage and processing.
IoT Applications and Case Studies: Examination of successful IoT projects across various sectors. Lessons learned and best practices.
Future Trends and Innovations: Emerging technologies and their integration with IoT, the future landscape of IoT development and deployment.

Reference Material: The following is the recommended list of books (or their latest editions):

1. Buyya, Rajkumar, and Amir Vahid Dastjerdi, editors. Internet of Things: Principles and Paradigms. Morgan Kaufmann, 2016.

2. Hersent, Olivier, David Boswarthick, and Omar Elloumi. The Internet of Things: Key Applications and Protocols. Wiley, 2012.

Course Name:	**Blockchain Technologies**
Course Code:	CS752
Credit Hours:	3
Pre-requisites:	None

Course Introduction: This course offers an in-depth exploration of blockchain technology, covering fundamental concepts, technical details, and practical smart contracts development and deployment. Students will gain a solid understanding of how blockchain based network works, its impact on various industries, and hands-on experience with blockchain development.

Course Objectives: The objectives of the course are as follows:

- Gain a solid understanding of blockchain technology and its core components.
- Develop practical skills in using blockchain tools and platforms.
- Analyze real-world use cases and evaluate the potential impact of blockchain solutions.
- Stay informed about the latest developments and future directions in the blockchain space.

Course Outline: Introduction to Blockchain Technologies, Components, Types, Use Cases and Applications, Consensus algorithms, Blockchain Fundamentals (Cryptography & Crypto currency, Ethereum and Hyper Ledger Fabric, Smart Contracts, Blockchain Development Tools e.g. Solidity Remix IDE, Truffle, Hardhat, Solidity Programming Fundamentals, Smart Contract Compilation & Deployment, Ethereum Eco systems, Decentralized Applications(Interaction with smart contracts, Blockchain Future Trends and Emerging Technologies(DeFi, NFTs).

Reference Material: The following is the recommended list of books (or their latest editions):

1. Bashir, Imran. Mastering blockchain. Packt Publishing Ltd, 2017.
2. Morabito, Vincenzo. "Business innovation through blockchain." Cham: Springer International Publishing (2017).
3. Laurence, Tiana. Blockchain for dummies. John Wiley & Sons, 2023.