Coding and Information Theory	Code & No:	CS 440
	Credits:	3 (3,0,1)
	Pre-requisite:	IT 341
	Co-requisite:	None
	Level:	9

Course Description:

The aims of this course are to introduce the principles and applications of information theory & Coding. The course will study how information is measured in terms of probability and entropy, and the relationships among conditional and joint entropies; how these are used to calculate the capacity of a communication channel, with and without noise; coding schemes, including error correcting codes; Rate distortion theory which provides the theoretical foundations for lossy data compression and Network information theory considers the information carrying capacity of a network.

Topics to be covered:

1) Source coding, optimal codes
2) Information measures: entropy, relative entropy and mutual information.
3) Asymptotic equipartition property.
4) Entropy rates of stochastic processes.
5) Data compression.
6) Channel capacity.
7) Differential entropy and the Gaussian channel.
8) Rate distortion theory.
9) Network information theory

Course Aims:

1) To learn basic concepts in Information theory
2) To learn how to formulate and tackle Information-theoretical problems in communications and signal processing through the exposition to main results in Information theory
3) To learn the basic mathematical principles of information theory and coding theory, and to introduce them to some of the more elementary applications of these theories.

Student Outcomes (SOs):

☐(a) An ability to apply knowledge of computing and mathematics appropriate to the program's student outcomes and to the discipline

☒(b) An ability to analyze a problem, and identify and define the computing requirements appropriate to its solution

☐(c) An ability to design, implement, and evaluate a computer-based system, process, component, or program to meet desired needs

☐(d) An ability to function effectively on teams to accomplish a common goal

☐(e) An understanding of professional, ethical, legal, security and social issues and responsibilities

☐(f) An ability to communicate effectively with a range of audiences

☐(g) An ability to analyze the local and global impact of computing on individuals, organizations, and society

☐(h) Recognition of the need for and an ability to engage in continuing professional development

☐(i) An ability to use current techniques, skills, and tools necessary for computing practice.

☒(j) An ability to apply mathematical foundations, algorithmic principles, and computer science theory in the modeling and design of computer-based systems in a way that demonstrates comprehension of the tradeoffs involved in design choices. [CS]

☐(k) An ability to apply design and development principles in the construction of software systems of varying complexity. [CS]

☐(j) An ability to use and apply current technical concepts and practices in the core information technologies of human computer interaction, information management, programming, networking, and web systems and technologies. [IT]

☐(k) An ability to identify and analyze user needs and take them into account in the selection, creation, evaluation, and administration of computer-based systems. [IT]

☐(l) An ability to effectively integrate IT-based solutions into the user environment. [IT]

☐(m) An understanding of best practices and standards and their application. [IT]

☐(n) An ability to assist in the creation of an effective project plan. [IT]

Course Learning Outcomes (CLOs):

1. Understand the definitions and basic properties of uniquely decodable, instantaneous, prefix and optimal codes, the entropy function, error-correcting codes; compression;
2. Implement Huffman's algorithm for the construction of optimal codes;
3. State and prove basic theorems, such as the McMillan and Kraft inequalities and Hamming's sphere-packing bound;
4. State and apply deeper results, such as the Sardinas-Patterson Theorem and Shannon's Fundamental Theorem (for the binary symmetric channel);
5. Construct some simple error-correcting codes, such as the binary Hamming codes, calculates the minimum transmission bit-rate R for a required picture quality.

SOs and CLOs Mapping:

CLO/SO	a	b	c	d	e	f	g	h	i	j	k	l	m	n
CLO1		√												
CLO2		√								√				
CLO3		√												
CLO4										√				
CLO5		√												

No.	Topics	Weeks	Teaching hours
1	Source Coding, optimal codes Information measures: entropy, relative entropy and mutual information.	2	6
2	Asymptotic equipartition property.	2	6
3	Entropy rates of stochastic processes.	1	3
4	Information Channel, Channel capacity	2	6
5	Differential entropy and the Gaussian channel.	2	6
6	Error correcting and Linear Codes	2	6
7	Rate distortion theory	1	3
8	Network information theory	2	6
	Total	**14**	**42**

Textbook:

- Information and Coding theory, by Gareth A. Jones & J. Mary Jones, Springer Verlag, 2000.

Essential references:

- Elements of Information Theory (Second Edition) by Thomas M. Cover and Joy A. Thomas (ISBN: 0471241954), Second Edition
- Information Theory, Inference, and Learning Algorithms. By D. J. C. MacKay, NY: Cambridge Univ. Press, 2003
- Introduction to Data Compression, by K Sayood, 4/e, Morgan Kaufmann 2012.