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| **Course Title** | **INFORMATION THEORY** | | | | | | | | | | | | | | **ISCED Code** | | | | 0541-111 | | | |
| **Course Code** | | | | MTH 5115 | | | |
| **Course Type** | Core | | | | | | | | | | | | | | **Course Status** | | | | Theory | | | |
| **Course Hour** | 3.0 Hr./Week | | | | | | | | | | | | | | **Credit Value** | | | | 3.0 | | | |
| **Prerequisite** | Basic mathematics, probability, and statistics | | | | | | | | | | | | | | **Total Marks** | | | | 100 | | | |
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| ***Course Description*** | Information theory is a branch of applied mathematics. It deals with the quantification, transmission, and analysis of digital information. This course covers the topics such as Shannon entropy, mutual information, Kullback–Leibler divergence, and transfer entropy including their properties and implications. Students will gather both theoretical and computational knowledge about how information flows among variables in a system and how dependencies between random variables can be quantified. Students will be prepared to apply information-theoretical techniques in the advanced research of real-world systems like neural network, biological systems, epidemiology, transportation and more. | | | | | | | | | | | | | | | | | | | | | |
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| ***Rationale*** | In today’s data-driven world, understanding and interpretation of information flow is important in the fields from communication technology to neuroscience and biological systems. Information theory offers mathematical tools to analyze uncertainty, detect network structure, and understand relationships between individuals. This course is designed to introduce students to the key concepts and tools of information theory, enabling them to analyze information flow and dependencies in various real-world systems. | | | | | | | | | | | | | | | | | | | | | |
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| ***Course***  ***Objectives*** | 1. To provide the basic concepts of ‘Information’. 2. To quantify the information of an event. 3. To determine the dependency of two events. 4. To understand the process of information flow. 5. To learn the shortcomings of information measure schemes. 6. To know the real-life applications of information measure. | | | | | | | | | | | | | | | | | | | | | |
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| ***Course***  ***Learning Outcomes (CLOs)*** | On satisfying the requirements and successful completion of this course, students will have the knowledge and skills to- | | | | | | | | | | | | | | | | | | | | | |
| CLO1 | | | Describe the concepts of ‘information’. | | | | | | | | | | | | | | | | | | |
| CLO2 | | | Explain the elementary information-theoretic quantities both analytically and graphically. | | | | | | | | | | | | | | | | | | |
| CLO3 | | | Determine the dependency of two events. | | | | | | | | | | | | | | | | | | |
| CLO4 | | | Elucidate the direction of information flow. | | | | | | | | | | | | | | | | | | |
| CLO5 | | | Clarify the causality between two processes. | | | | | | | | | | | | | | | | | | |
| CLO6 | | | Assess limitations of different information-theoretical schemes. | | | | | | | | | | | | | | | | | | |
| CLO7 | | | Apply information theory concepts to practical problems (e.g., neural network, complex systems). | | | | | | | | | | | | | | | | | | |
| CLO8 | | |  | | | | | | | | | | | | | | | | | | |
| CLO9 | | |  | | | | | | | | | | | | | | | | | | |
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| ***Course Contents*** | **Course Contents** | | | | | | | | | | | | | | | | **Hours** | | | | **CLOs** | |
| **1.** | **Statistical Preliminaries:** Set theory. Discrete probabilities. Conditional, Independent, and Joint Probabilities. Statistical Expectations, Moments, and Correlations. Probability Distributions: Binomial Distribution, Poisson Distribution, Continuous Probabilities, Gaussian Distribution, Multivariate Gaussian Distribution. | | | | | | | | | | | | | | |  | | | |  | |
| **2.** | **Concepts of Information**: Basic Ideas. Uncertainty, Definition of information. Properties of information. | | | | | | | | | | | | | | |  | | | |  | |
| **3.** | **Fundamental information-theoretical quantities:** Entropy and its properties. Joint entropy and its properties. Conditional entropy. Applications of the above-mentioned schemes. | | | | | | | | | | | | | | |  | | | |  | |
| **4.** | **Relative Entropy and Mutual Information:** Kullback–Leibler Divergence. Relative Entropy. Mutual information. Relationship Between Entropy and Mutual Information. Chain Rules for Entropy, Relative Entropy, and Mutual Information. Mutual Information and Phase Transitions. Time-delayed mutual information and its application. | | | | | | | | | | | | | | |  | | | |  | |
| **5.** | **Inequalities and their Consequences:** Jensen’s Inequality and Its Consequences. Log Sum Inequality and Its Applications. Data-Processing Inequality. Sufficient Statistics. Fano’s Inequality. | | | | | | | | | | | | | | |  | | | |  | |
| **6.** | **Rate Distortion Theory:** Quantization,definition and calculation of rate distortion function, converse to the rate distortion theorem, Achievability of the rate distortion function, strongly typical sequences and rate distortion, Characterization of the rate distortion function. | | | | | | | | | | | | | | |  | | | |  | |
| **7.** | **Transfer Entropy:** Definition of Transfer Entropy. Determination of History Lengths. Computational Interpretation as Information Transfer. Conditional Transfer Entropy. Source–Target Lag. | | | | | | | | | | | | | | |  | | | |  | |
| **8.** | **Miscellaneous Applications of Transfer Entropy:** Applications in Neuroscience, social media, biology, transportation, financial market, etc. | | | | | | | | | | | | | | |  | | | |  | |
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| ***Alignment of CLOs VS PLOs*** | **Mapping of Course Learning Outcomes (CLOs) to Program Learning Outcomes (PLOs)** | | | | | | | | | | | | | | | | | | | | | |
| **PLOs/ CLOs** | | | | | **PLO1** | **PL02** | **PLO3** | **PLO4** | **PLO5** | **PLO6** | **PLO7** | | **PLO8** | | **PLO9** | | **PLO10** | | **PLO11** | | **PLO12** |
| CLO1 | | | | | *♦* |  |  |  |  |  |  | |  | |  | |  | | *−* | | *−* |
| CLO2 | | | | | *♦* |  |  |  |  |  |  | |  | |  | |  | | *−* | | *−* |
| CLO3 | | | | | *♦* |  |  |  |  |  |  | |  | |  | |  | | *−* | | *−* |
| CLO4 | | | | |  |  |  |  |  |  |  | |  | |  | |  | | *−* | | *−* |
| CLO5 | | | | |  |  |  |  |  |  |  | |  | |  | |  | | *−* | | *−* |
| CLO6 | | | | |  |  |  |  |  |  |  | |  | |  | |  | | *−* | | *−* |
| CLO7 | | | | |  |  |  |  |  |  |  | |  | |  | |  | | *−* | | *−* |
| CLO8 | | | | |  |  |  |  |  |  |  | |  | |  | |  | | *−* | | *−* |
| CLO9 | | | | | *−* | *−* | *−* | *−* | *−* | *−* | *−* | | *−* | | *−* | | *−* | | *−* | | *−* |
| *♦ Aligned − Not-aligned* | | | | | | | | | | | | | | | | | | | | | |
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| ***Teaching-Learning* and *Assessment Strategy*** | **Mapping of Course Learning Outcomes (CLOs) with the Teaching-Learning & Assessment Strategy** | | | | | | | | | | | | | | | | | | | | | |
| CLOs | | | | **Teaching-Learning Strategy** | | | | | | | | **Assessment Strategy** | | | | | | | | | |
| CLO1 | | | | Please fill out the required information | | | | | | | | Please fill out the required information | | | | | | | | | |
| CLO2 | | | |  | | | | | | | |  | | | | | | | | | |
| CLO3 | | | |  | | | | | | | |  | | | | | | | | | |
| CLO4 | | | |  | | | | | | | |  | | | | | | | | | |
| CLO5 | | | |  | | | | | | | |  | | | | | | | | | |
| CLO6 | | | |  | | | | | | | |  | | | | | | | | | |
| CLO7 | | | |  | | | | | | | |  | | | | | | | | | |
| CLO8 | | | |  | | | | | | | |  | | | | | | | | | |
| CLO9 | | | |  | | | | | | | |  | | | | | | | | | |
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| ***Learning Materials*** | **Recommended Readings** | | | | | | | | | | | | | | | | | | | | | |
| **i.** | | Bossomaier, T., Barnett, L., Harré, M., & Lizier, J. T. *An Introduction to Transfer Entropy*. | | | | | | | | | | | | | | | | | | | |
| **ii.** | | Cover, T. M., & Thomas, J. A. *Elements of Information Theory*. | | | | | | | | | | | | | | | | | | | |
| **Supplementary Readings** | | | | | | | | | | | | | | | | | | | | | |
| **v.** | | Mc. Eliece, R. J. *The Theory of Information and Coding*. | | | | | | | | | | | | | | | | | | | |
| **vi.** | | Bose, R. *Information Theory, Coding and Cryptography*. | | | | | | | | | | | | | | | | | | | |
| **vii.** | | Togneri, R., & DeSilva, C. J. S. *Fundamentals of Information Theory and Coding Design*. | | | | | | | | | | | | | | | | | | | |