SIAM Graduate Students Research Day 2023

Time: 3-5 PM, April 14, 2023

List of Participants and Schedule for Talk:

- 3:00-3:05 Short introduction by SIAM President
- 3:05-3:20 Das (Statistics)
- 3:20-3:35 James (Pure Math)
- 3:35-3:50 Holtman (Applied Math)
- 3:50-4:05 Rahman (Applied Math)
- 4:05-4:20 Hossain (Statistics)
- 4:20-4:35 Sajal (Applied Math)
- 4:35-4:50 Fahad (Statistics)

List of Judges:

- Dr. Aulisa Eugenio
- Dr. Alex Trindade
- Dr. Travis Thompson

List of Abstracts: Pages 2-5

Dip Das

Statistics

Title

Classification performance of Supervised Machine learning methods on Multivariate Normal Mixture models with application to Stroke dataset.

Abstract

The mixture model represents the presence of subpopulation within a population, and it doesn't require that an observed data set identify the sub-population to which an individual observation belongs. So, population simulated from multivariate normal mixture models can be classified into sub-populations using several existing supervised machine learning models. In this research, multivariate normal mixture datasets were generated with 1000, 2000, 5000, and 10000 observations with four groups. Each dataset had three different mean vectors, which follow the uniform distribution and three different covariance matrices generated from the Identity, Toeplitz and Equi-correlation matrices. A total of nine combinations of mean vector and covariance matrix were used to generate the datasets. After that, classification was performed using supervised machine learning methods on those datasets, and accuracy was assessed using the test dataset after splitting the datasets into training data and test data. Multinomial logistic regression, support vector machine, K nearest neighborhood classifier, decision tree, bagging, and boosting were used to classify the multivariate normal mixture datasets. After that, the classification of the stroke dataset was performed using the seven supervised machine learning methods.

Mohammad Mahabubur Rahman

Applied Mathematics

Title

GLOBAL REGULARITY CRITERION OF THE THREE DIMENSIONAL HALL-MAGNETOHYDRODYNAMICS SYSTEM

Abstract

The global regularity issue of the 3-dimensional Hall-magnetohydrodynamics system remains an outstanding open problem. This talk presents a regularity criterion for the 3- dimensional Hall-magnetohydrodynamics system of only horizontal components of velocity and magnetic fields.

GM Fahad Mostafa

Mathematics and Statistics

Title

Improved Graph-based Clustering by Spectral Learning and Preconditioning

Abstract

Graphs are commonly used to represent connected data in various domains including social systems, ecosystems, and information systems. With the growth of artificial intelligence technologies, there is a growing interest in graph learning or machine learning on graphs, among researchers and practitioners. Graph learning from networks is expensive and sometimes misleading in clustering for high-dimensional datasets. We present a new and scalable approach for graph clustering, named preconditioned inverse power iteration clustering (PIPIC) with preconditioned Laplacian matrices from graph learning. It utilizes truncated power iteration on a normalized pairwise similarity matrix of the data to obtain a low-dimensional embedding of the dataset, which is an effective cluster indicator. PIPIC shows superior performance to commonly used spectral methods like Spectral Clustering (SC) on real datasets and can run efficiently on large datasets with preconditioning. The PIPIC algorithm runs significantly faster than the state-of-the-art SC and PIC implementations based on the eigenvector computation technique, with a speedup of over a thousand times. Modified Laplacian-based clustering shows better clustering than original embeddings. Moreover, in Graph Convolution Network(GCN), the node embeddings are updated by aggregating information from neighboring nodes in a graph. This aggregation can be performed using the graph Laplacian matrix, which captures the structure of the graph. The eigenvectors of the Laplacian matrix are used as a basis for node embeddings, leading to improved performance on tasks such as node classification, link prediction, and graph clustering.

Nathan Holtman

Applied Mathematics

Title

Bio-Economic Optimal Control of Wolf Predation of Livestock.

Abstract

Since their reintroduction into the environment and being placed on the endangered species list, the wolf (Canis lupus) population has steadily increased. In particular, this phenomenon has been occurring in key beef-producing states, such as Montana, Wyoming, Idaho, and Colorado. As wolf territory has expanded, wolf encroachment onto private ranching lands has caused an increase in attacks on livestock. The two decision-makers in this study are ranchers (whose objective is to maximize profit from livestock operation) and conservationists (whose objective is to maximize utility from the wolf population). This study will take into account the objectives of ranchers and conservationists, as well as the biological characteristics of wolves and livestock, to determine an optimal wolf-management solution for both ranchers and conservationists.

The increase in wolf population is costly to ranchers who incur costs associated with (i) lost cattle killed by wolves or euthanized due to severe wolf injury, (ii) additional infrastructure to provide more protection to dissuade wolf attacks, and (iii) hunting or removing problematic wolves that persist in attacking their herd. Similarly, (i) a growing livestock population, (ii) increasing conservation efforts, and (iii) counteracting the effects of over-hunting increase the costs of managing a wolf population, which are paid by conservationists. In order to find an optimal solution, ranchers will be choosing the rate to remove wolves (hunting) while conservationists will be choosing a preservation rate of wolves to push the dynamical system into an optimal state. Using wolf predation data to parameterize the model, this study will also compare the results from optimization from and a "natural" steady-state equilibrium to determine how far the optimized system is from a steady-state system. This study will also determine the effects of changes in factors such as the availability of natural prey, wolf prey-preference, and competition among wolves on the optimal and equilibrium solutions.

Sajal Chakroborty

Applied Mathematics

Title

On the use of the Koltchinskii transform for quantile calculations.

Abstract

The goal of our research is to determine outliers in measurements from medical devices such as a Shack Hartmann aberrometer. The measurements take the form of functions that contain information on the quality of vision of a patient. The rejection of outliers in this data is important in the objective determination of the loss of visual acuity. The data from measurements lie in an infinite dimensional space as a sequence of numbers. One uses percentiles to make sense of data that can be ordered such as scores in a test. Percentiles are used for detecting outliers in data and is a very important tool for statisticians. When there is more than one variable involved, it is not clear how to define percentiles because the data cannot be ordered. Koltchinskii proposed a mathematical elegant theory in 1997 to extend the notion of cumulative distribution functions to the multivariate case. This theory has since been extended to infinite dimensional data such as sequences. It is known that Koltchinskii transform is invertible. Some authors have suggested that this property may be used to detect outliers in multivariable data. In our work, we propose a novel algorithm for the computation of the inverse of this transform. Furthermore, we conduct a detailed study to determine its suitability for outlier detection. Our conclusion is that transform has a peculiar property not detected in prior literature that we call the zoom-in effect. Due to this property, we show that it is unsuitable for outlier detection.

Md Sakhawat Hossain

Statistics

Title

Two-input and two-output predictive model for multifunctional materials with hysteresis and thermodynamics compatibility.

Abstract

Multifunctional materials have tremendous potential for engineering applications as they are able to convert mechanical to electromagnetic energy and vice-versa. One of the features of this class of materials is that they show significant hysteresis, which needs to be modeled correctly in order to maximize their application potential. A method of modeling multifunctional materials that exhibit the phenomenon of hysteresis and is compatible with the laws of thermodynamics was developed recently. The model is based on the Preisach hysteresis operator and its storage function and may be interpreted as a two-input, two-output neural net with elementary hysteresis operators as the neurons. The difficulty is that the parameters in the model appear in a non-linear fashion, and there are several constraints that must be satisfied by the parameters for thermodynamic compatibility. In this research, we present a novel methodology that uses the rate-independent memory evolution properties of the Preisach operator to split the parameter estimation problem into three numerically well-conditioned, linear least squares problems with constraints. The alternative direction method of multipliers(ADMM) algorithm and accelerated proximal gradient method are used to compute the Preisach weights. Numerical results are presented over data collected from experiments on a Galfenol and a Terfenol-D sample. We show that the model is able to fit not only experimental data for strain and magnetization over a wide range of magnetic fields and stress but also able to predict the response for stress and magnetic fields not used in the parameter estimation.

James Francese

Pure Mathematics

Title

Exceptional symmetries in the higher geometry of prequantum field theory.

Abstract

The conventional framework of gauge theory is that of principal G-bundles with the connection. But why are we so confident that infinitesimal gauge transformations are Lie algebra-valued? We will present the traditional justification for this assumption within mathematical physics, and point to a more general class of infinitesimal symmetries provided by Leibniz algebras, which also conceal higher-categorical geometric structures in field theory beyond the Standard Model.