

Indian Institute of Technology, Kanpur

Proposal for a New Course

1. Course No: SPA6XX
2. Course Title: Introduction to Space Informatics
3. Lectures per week: 2 (L), Tutorial: 0 (T), Laboratory: 3 (P), Additional hours: (0-2): 0 (A), Credits ($3*L+2*T+P+A$): 9, Duration of Course: Full-Semester
4. Proposing Department: SPASE
5. Proposing Instructor: Rohit Sharma
6. Course Description

(A) Objectives: The course will introduce data and machine learning applications in space sciences. The course will introduce the various sources of space data e.g. satellite- & ground-based observatories, telemetry, data-pipelines, etc.. and their respective formats. The course will delve into data exploration including application of supervised, unsupervised and deep learning, and conclude with an introduction to the Large Language Models (LLMs) and agentic AI usage for the space applications.

(B) Contents (26-28 lectures, 14 lab sessions):

1. **Introduction to Space Informatics** (3 lectures, 1 lab)
 - Space Informatics: scope, applications and scientific challenges
 - Space data: images, spectra, time series, telemetry and catalogues
 - Data-intensive space missions and observatories
 - Examples: satellites, space weather missions, planetary missions, radio telescopes and astronomical surveys
2. **Space Data and Computational Methods** (3 lectures, 1 lab)
 - Scientific data formats, metadata and coordinate systems
 - FITS, HDF5, NetCDF and telemetry data
 - Data calibration, cleaning and preprocessing
 - Astronomical and planetary databases
 - Exploratory data analysis and data visualisation
3. **Statistical Methods for Space Science** (3 lectures, 1 lab)
 - Probability distributions and statistical inference
 - Correlation, covariance and hypothesis testing
 - Regression and model fitting
 - Bayesian inference and likelihood
 - Markov Chain Monte Carlo (MCMC)
4. **Data Visualisation and Exploratory Data Analysis** (2 lectures, 1 lab)
 - Visualisation of astronomical images, spectra and time series
 - Correlations, distributions, dimensionality reduction and uncertainty
5. **Supervised Learning** (3 lectures, 2 lab)
 - Classification and regression
 - Support Vector Machines (SVM), Decision Trees, and Random Forest
 - Probabilistic Random Forest, Artificial Neural Networks
 - Model evaluation and hyperparameter optimisation
6. **Unsupervised Learning and Scientific Discovery** (4-5 lectures, 2 labs)
 - Principal Component Analysis (PCA)
 - K-means clustering, Hierarchical clustering
 - t-SNE and UMAP
 - Self-Organizing Maps

- Anomaly detection
- 7. **Deep Learning for Space Applications** (3 lectures, 2 labs)
 - Neural networks, backpropagation and optimisation
 - Convolutional Neural Networks for space and astronomical images
 - Autoencoders and representation learning
 - Deep learning for time-series and satellite telemetry
- 8. **Large Language Models for Space Science** (3 lectures, 2 labs)
 - Foundational Models, Transformer architecture and Large Language Models
 - Prompting, embeddings and Retrieval-Augmented Generation
 - LLM-assisted scientific programming and data analysis
 - LLMs for scientific literature and mission documentation
 - LLM-based interfaces for space-data archives
- 9. **Agentic AI for Space Science** (2-3 lectures, 2 labs)
 - AI agents, tools and agent architectures
 - Automated data-analysis pipelines, Automated model selection and hyperparameter optimisation
 - AI-assisted programming
 - Scientific discovery: generating, testing and refining hypotheses
 - Autonomous analysis of astronomical, satellite and planetary data

(C) Pre-requisites, if any: Mathematical Techniques in Space Sciences & Engineering (SPA622M), Numerical Techniques in Space Sciences & Engineering (SPA623M) or equivalent courses/topics.

(D) Short summary for including in the Courses of Study Booklet:

7. Recommended Books:

1. **Ivezić, Ž., Connolly, A. J., VanderPlas, J. T., & Gray, A.**, *Statistics, Data Mining, and Machine Learning in Astronomy*, Princeton University Press.
2. **Helbert, J., D'Amore, M., Aye, M., & Kerner, H. (eds.)**, *Machine Learning for Planetary Science*, Elsevier, 2022.
3. **Fortescue, P., Swinerd, G., & Stark, J. (eds.)**, *Spacecraft Systems Engineering*, 4th Edition, Wiley.
4. **Hassanien, A. E., Darwish, A., & El-Askary, H. (eds.)**, *Machine Learning and Data Mining in Aerospace Technology*, Springer, 2020.
5. **Hargitai, H. (ed.)**, *Planetary Cartography and GIS*, Springer, 2019.

8. Any other remarks:

Dated: Proposer:

Dated: DUGC/DPGC Convener:

The course is approved/not approved

Chairman, SUGC/SPGC

Dated: