# GeoSpatial Artificial Intelligence (GeoAI)

# Course Curriculum

## Course Overview

**Course Title:** GeoSpatial Artificial Intelligence (GeoAI)
**Duration:** One Semester (15 weeks)
**Faculty:** Prof. Dr. Prafulla Parlewar
**Total Marks:** 100

**Course Introduction**

**GeoAI** (Geospatial Artificial Intelligence) is an emerging interdisciplinary field combining geographic information systems (GIS) with artificial intelligence (AI) techniques like machine learning (ML), deep learning, and computer vision to solve complex geospatial problems.

Students will learn applications of Artificial Intelligence (AI) techniques for spatial modeling and analysis, including predictive modeling. The course has a technical focus, with special emphasis on “evolutionary optimization” and “machine learning (including deep learning)” techniques. Different applications of AI in GIS and RS will be explored in the context of exercises, seminars, and the final project. Ethical aspects of AI will also be touched in a lecture.

The course includes lectures and exercises to provide students with both theoretical knowledge and applied skills. It also includes seminars and self-learning activities, as well as quizzes to assess learning of students. As a final project students have to solve a spatial problem using one of the AI techniques that they have studied in the course. All exercises are designed based on ArchGIS/QGIS/Python/Knime.

**An outline for a GeoAI course:**

**Module 1: Introduction to GeoAI - Data Types and Sources (Week 1–2)**

Overview of Geospatial Data and Artificial Intelligence (AI), Introduction to Geographic Information Systems (GIS), AI fundamentals: Machine Learning and Deep Learning, Methods of Machine Learning, AI application in geospatial sciences, Geospatial Raster and Vector data models, Earth Observation Data: Satellites, Drones, etc., Open Geospatial Data Sources (NASA, ESA, OpenStreetMap, etc.), Data Cleaning and Preprocessing for GeoAI, Introduction to geospatial libraries in Python (Geopandas, Shapely, Pyproj), Spatial data manipulation: Handling spatial and temporal data, Use of QGIS for visualization, Use of KNIME for Data Analysis.

Lecture ***Topics:***

- *Introduction to GeoAI: Definition, Need, Scope*
- *Evolution of AI in Geography (1980s–Present)*
- *Role of spatial data in machine learning*
- *GIScience fundamentals:*
- *Spatial relationships*
- *Topology*
- *Spatial autocorrelation (Moran's I, G-statistic)*
- *Spatial heterogeneity*
- *Raster vs Vector Data Models*
- *Coordinate systems, projections, and transformations*
- *Concepts of spectral signatures, reflectance, and remote sensing basics*

*Practical* ***Activities:***

- *QGIS interface & basic operations*
- *Importing, cleaning, and visualizing layers*
- *CRS transformation exercise*
- *Intro to Python notebook environment*

**Module 2: AI in Spatial Analysis (Week 3-5)**

Supervised vs. Unsupervised Learning for Geospatial Data, Regression and Classification Convolutional Neural Networks (CNNs) and Artificial Neural Networks (ANN(ANNs):els for GIS Applications Spatial Interpolation using AI techniques, Clustering Algorithms in Geospatial Context (K-Means, DBSCAN), Dimensionality Reduction (PCA, t-SNE) for spatial data visualization. Python-

based projects using scikit-learn for spatial analysis, Keras learning models and other machine learning models

***Lecture Topics:***

- *ML pipeline for geospatial datasets*
- *Handling spatial autocorrelation in ML models*
- *Types of ML:*
- *Classification (RF, SVM, XGBoost)*
- *Regression (Linear, Random Forest, Gradient boosting)*
- *Clustering:*
- *K-means*
- *DBSCAN*
- *Hierarchical clustering*
- *Feature extraction from spatial datasets*
- *Accuracy Assessment Metrics:*
- *Confusion matrix*
- *Kappa coefficient*
- *ROC-AUC*

***Practical:***

- *Using scikit-learn for geospatial classification*
- *K-means clustering for land parcel segmentation*
- *DBSCAN for identifying urban density patterns*
- *Dimensionality reduction using PCA & t-SNE*

**Module 3: Deep Learning for Remote Sensing (Week 6–8)**

Introduction to Remote Sensing: Image Classification & Object Detection, Fundamentals of Convolutional Neural Networks (CNNs) for image analysis, Popular remote sensing data types: RGB, Multispectral, Hyperspectral, Image Classification in Remote Sensing: Building a classifier for land use/land cover, using pretrained CNN models (ResNet, VGG) for geospatial image classification, Working with Google Earth Engine for large-scale geospatial analysis.

***Lecture Topics:***

- *CNN architecture:*
- *Convolution*
- *Pooling*

- *Batch normalization*
- *Activation functions*
- *Hybrid models for geospatial datasets*
- *Transfer learning using ImageNet models*
- *Segmentation architectures: UNet, SegNet, DeepLabV3+*
- *Hyperspectral image analysis*
- *LULC classification using DL models*

·***Practical:***

- *Build CNN model in Python-Keras for satellite image classification*
- *Implement UNet for segmentation*
- *Use patch extraction and tiling strategies for large images*

**Module 4: Object Detection & Change Detection in Remote Sensing (Week 9–10)**

Object Detection Techniques (YOLO, Faster R-CNN) in satellite imagery, Case Studies: Detecting buildings, roads, forests using satellite data, Change Detection Algorithms (Pixel-based and Feature-based), Applications: Urban growth, deforestation, disaster impact assessment, Using machine learning models to predict and detect changes over time

***Lecture Topics:***

- *Introduction to object detection architectures: YOLO, RetinaNet, Faster R-CNN*
- *Common use cases:*
- *Building extraction*
- *Road extraction*
- *Vehicle detection*
- *Damage assessment*
- *Change detection:*
- *Pixel-based (image differencing, NDVI differencing)*
- *Feature-based (Siamese networks)*
- *Time-series satellite analysis workflows*

***Practical:***

- *Train a YOLO model for building/vehicle detection*
- *Perform NDVI-based change detection*
- *Use GEE for flood/drought monitoring*

**MODULE 5: GeoAI Applications, Case Studies & Industry Use (Week 11–12)**

***Case Studies:***

- *Urban regeneration & gentrification pattern detection*
- *Smart mobility, traffic prediction, micro-mobility*
- *Precision agriculture using NDVI + ML*
- *Public health GIS + GeoAI*
- *Climate risk mapping, flood prediction*
- *Disaster impact analysis using object detection*
- *Cultural heritage detection (archaeological)*
- *Topographic mapping automation (USGS examples)*

***Practical:***

- *Student case study presentations*
- *Real-world dataset exploration*
- *Project design workshops*

**Module 6: Advanced GeoAI, Big Data & Spatio-Temporal Analytics (Week 13 -14)**

AI for Environmental Monitoring (wildfire detection, flood prediction), AI in Urban Planning (Smart Cities, Traffic Management, Pollution Control), Precision Agriculture using AI and Geospatial Analysis, AI for Climate Change and Sustainability, AI in Urban Design, AI in Heritage Rehabilitation, AI in Infrastructure Planning and Management, AI for Built Environment etc.

***Lecture Topics:***

- *Handling massive geospatial datasets*
- *Spatial Hadoop, GeoSpark, RasterFrames*
- *Spatio-temporal patterns in mobility, environment, weather data*
- *Real-time AI: GPS streams, IoT sensors*

***Practical:***

- *GEE time-series data analysis*
- *Heatmap generation & hotspot analysis*
- *Air quality forecasting using ML*

**Week 15: Final Project Submission & Viva**

Each student demonstrates a complete GeoAI pipeline:

**Dataset → Preprocessing → Model → Evaluation → Maps → Final Paper.**

**Course Assessment:**

- Weekly assignments: Data analysis, spatial modelling, and Python programming exercises,
- Mid-term project: A small GeoAI project (e.g., satellite image classification),
- Final project: End-to-end GeoAI project solving a real-world problem

**Tools and Technologies Covered:**

- Python Libraries: Geopandas, scikit-learn, TensorFlow, Keras, PyTorch, GIS Software: QGIS, ArcGIS, Google Earth Engine,
- Remote Sensing Platforms: SentinelHub, Landsat data sources, MODIS
- KNIME: Analytics Platform to visual interface and build analyses in machine learning

**Detailed Assessment & Marking Distribution (100 Marks)**

**1. Weekly Practical Assignments – 30 Marks**

| Component | Details | Marks |
|---|---|---|
| **Data preprocessing** | **raster/vector cleaning** | **1** |
| **Python/QGIS execution** | **correct code & output** | **1** |
| **Interpretation** | **maps & explanation** | **1** |
| **Total per assignment** | | **3** |

- 10 Assignments × 3 marks = **30 Marks**

**2. Mid-Term Exam – 20 Marks**

- **Section A (5 marks):** Theory concepts
- **Section B (10 marks):** Practical coding/QGIS operations
- **Section C (5 marks):** Short case analysis

**3. Seminar Presentation – 10 Marks**

| Criterion | Marks |
|---|---|
| **Research quality** | **4** |
| **Presentation clarity** | **3** |
| **Visualization/maps** | **2** |
| **Question handling** | **1** |

**4. Final Project – 35 Marks**

| Component | Description | Marks |
|---|---|---|
| **Problem formulation** | **clarity, relevance** | **5** |
| **Dataset & preprocessing** | **justification, methodology** | **5** |
| **Model architecture** | **choice of ML/DL model** | **10** |
| **Results & maps** | **accuracy, interpretation** | **10** |
| **Report & viva** | **structure, visualization, defense** | **5** |
| **Total** | | **35** |

**5. Attendance & Participation – 5 Marks**

- 75–80% = 1 mark
- 81–90% = 3 marks
- 91–100% = 5 marks

**Project Topics**

**1. Urban Land Use–Land Cover (LULC) Classification using Deep Learning**

- Use CNN/UNet for classifying satellite imagery.
- Application: Smart cities, urban sprawl analytics.

**2. Automated Building Footprint Extraction using YOLOv8**

- Detect buildings from high-resolution imagery.
- Application: Disaster damage assessment, cadastral mapping.

**3. Urban Heat Island (UHI) Detection & Prediction using Spatio-Temporal ML**

- Combine thermal imagery + ML regression.
- Application: Climate resilience, heat mitigation strategies.

**4. Road Network Extraction using Deep Learning (UNet/DeepLab)**

- · Automatic road segmentation for mobility planning.
- · Application: Autonomous navigation, traffic modeling.

**5. Flood Susceptibility Mapping using ML (RF, SVM, XGBoost)**

- Use DEM, rainfall, soil, LULC, drainage data.
- Application: Climate adaptation, risk zoning.

**6. Deforestation Monitoring using Change Detection Algorithms**

- Use NDVI differencing + feature-based DL change detection.
- Application: Forest governance, environmental monitoring.

**7. Precision Agriculture Monitoring using NDVI & ML**

- Crop health, yield prediction, pest/disease detection.
- Application: Sustainable farming.

**8. Landslide Susceptibility Prediction using SVM & Random Forest**

- Use topographic, rainfall, soil, land use features.

- Application: Hazard mapping in hilly regions.

**9. Traffic Congestion Prediction using GeoAI & GPS Data**

- Use LSTM/spatio-temporal analysis of mobility datasets.
- Application: Intelligent transportation systems.

**10. Air Quality Prediction using Spatio-Temporal Machine Learning**

- Combine satellite + ground sensor + meteorology data.
- Application: Public health and policy analytics.

**11. Urban Expansion & Gentrification Analysis using Satellite Time-Series**

- Use temporal classification and clustering.
- Application: Urban regeneration, land market analysis.

**12. Smart City Waste Collection Route Optimization using GeoAI**

- Use clustering + path optimization.
- Application: Urban sanitation planning.

**13. Automated Water Body Detection & Seasonal Change Analysis**

- Use segmentation networks on multispectral imagery.
- Application: Water resource planning, drought monitoring.

**14. Archaeological Site Detection using Deep Learning & Geospatial Data**

- ·dentify ancient patterns, mounds, ruins using imagery.
- Application: Heritage conservation.

**15. Solar Potential Mapping using GIS + ML**

- Predict rooftop solar suitability using DEM, orientation, shading.
- Application: Renewable energy planning.

**16. Green Cover Detection & Urban Tree Inventory using Object Detection**

- Use YOLO for tree canopy detection.
- Application: Urban forestry & carbon assessment.

**17. Railway or Road Accident Hotspot Prediction using Spatial Analytics**

- Use GIS + ML with accident records.
- Application: Transport safety planning.

**18. Automated Slum Boundary Detection using High-Resolution Imagery**

- ·Use CNN segmentation + texture-based features.
- · Application: Urban poverty mapping & redevelopment planning.

**19. Glacier Retreat & Snow Cover Analysis using Multi-Temporal Imagery**

- Use remote-sensing time-series analysis.
- Application: Climate change research.

**20. Coastal Erosion Detection using Change Detection + ML**

- Satellite-based shoreline extraction & temporal monitoring.
- Application: Coastal infrastructure planning.

**Learning Outcomes:**

Understand the intersection of geospatial data and AI techniques, build machine learning and deep learning models for spatial data, Apply AI to solve real-world geospatial challenges like land cover mapping, object detection, etc., Utilize modern GeoAI tools for sustainable development and environmental management

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