Solved with AI

4.s23
Solved with AI
Mondays 10a– 11:30a
Office hours: Thursdays 10a -12p
Credit Hours: 3-3-0 G/U
Location: 1-132

Instructors
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Pre-requisites
6.001A
OR Knowledge in Python

Course Description

The rise of Artificial Intelligence (AI) dates back over 80 years when digital computers were developed during World War II. Using binary code to represent various phenomena made it possible to solve previously unsolvable numerical problems. AI has rapidly become a transformative technology in various fields, including the built environment. In addition, AI is increasingly being recognized as a crucial tool in the fight against climate change, particularly in cities. As urban areas are major sources of greenhouse gas emissions and also highly vulnerable to the impacts of climate change, it is crucial that innovative solutions are found to address these challenges. One area where AI can make a significant impact is in the optimization of energy use in cities. AI algorithms can be integrated into building management systems to monitor energy consumption, identify inefficiencies, and suggest ways to reduce energy use. AI has the potential to streamline processes, increase efficiency, and improve overall outcomes. For example, drones equipped with AI algorithms can survey construction sites, provide real-time data, and assist with project management. AI can also be used to monitor construction sites and predict potential safety hazards, helping to ensure that construction sites are safer and more secure.

AI has the potential to revolutionize the built environment, making it more efficient, sustainable, and cost-effective. As technology continues to evolve and advance, it is likely that we will see even more innovative applications of AI in the built environment in the years to come. This course offers a thorough understanding of AI's role in the built environment, including hands-on examples of utilizing AI to tackle various urban challenges. Through data-driven case studies, this course will explore how emerging data and AI models are changing the assessment of the built environment. The structure of this course focuses on four key computational areas: *Data Analysis with Satellite Imagery*, Fundamental of Graph Theory and its applications in cities, Overview of Computer vision with a special focus on Object Detection in image data, and Theories of Artificial Neural Networks and image data classification. In this project-based course, students will work in teams to develop a computational approach that addresses the use of these four methods to solve an urban problem.

Course Objectives

- *Provide an overview of the principles of artificial intelligence, including machine learning and computer vision, and their applications in the built environment.*
- *Understand the capabilities and limitations of satellite imagery for data analysis and remote sensing, including image processing techniques, interpretation of spectral information, and geospatial data analysis in Python.*
- *Explore the use of graph theory for modeling and analyzing the built environment, including urban spatial structures and climate change adaptation.*
- *Understand how to utilize graph algorithms for solving problems such as route optimization, urban amenities location, and climate resilience.*
- *Understand computer vision concepts, including image processing, feature extraction, and object recognition.*
- *Examine the foundations of Artificial Neural Networks (ANNs), including convolutional neural networks, Convolution Filters, and pre-trained Networks.*

Pre-requisites/Co-requisites

6.001A or proficiency in Python.

What to expect in this course

The main objective of this course is to provide an overview of AI applications in the built environment and how we can utilize different computational approaches to solve urban challenges. In this project-based course, students will develop the theoretical foundation of AI theories and applications and how to utilize different types of image data to develop solutions for various urban problems.

The course will investigate these core objectives throughout the following sessions.

A. Data Analysis with Satellite Imagery

In this session, we will examine how satellite imagery can be a powerful tool for monitoring and understanding the impact of climate change on cities. Using satellite imagery, urban planners, researchers, and policymakers can collect vast amounts of data on cities' physical and environmental changes over time. This data can inform decisions and actions aimed at mitigating and adapting to the effects of climate change. We will cover topics related to the use of satellite imagery to monitor changes in land use, vegetation, and climate change risks, among other things. These data can then be analyzed to assess the impact of climate change on the built environment and to identify potential mitigation and adaptation strategies.

In the data processing session will cover how to set up a data processing workflow using Python. We will go through .nc files, Python libraries like GeoPandas, NumPy library, which allows for fast and efficient manipulation of large datasets, and Matplotlib library that can provide an extensive suite of visualization tools that can be used to create clear and informative graphs and charts from satellite imagery data.

B. Fundamentals of Graph Theory

In this session, we will cover the key fundamentals of Graph Theory that is used to model relationships between objects. In the built environment, graph theory is applied to analyze and model the relationships between buildings, roads, and other elements in a city. Through data and case studies, we will examine how Graph theory can model complex relationships systematically to provide valuable insights for urban areas and climate change challenges. We also cover the differences between Breadth of First Search (BFS), and Depth of First Search (DFS) models and how we can use them in modeling and analyzing the built *environment. In the data session, we will examine how to set up BFS and DFS algorithms in Python using image data, route optimization, and network analysis.*

C. Fundamentals of Computer Vision

This session will examine the fundamentals of computer vision, visual information interpretation, and other topics such as image processing techniques, object recognition, and image analysis. In the data session, we will focus on understanding how to work OpenCV in Python, models, and segmentation in image data.

D. Introduction to Artificial Neural Networks

This session will cover the theoretical fundamentals of Artificial Neural Networks (ANNs), a type of machine learning designed to mimic the structure and function of the human brain. ANNs have been widely used in various applications, particularly in cities, where they are applied to various problems, such as traffic control, energy management, and disaster response. These networks have proven to be effective in handling large amounts of data and making predictions based on patterns in that data, making them a popular tool for improving the efficiency and safety of urban environments. In the data session, we will focus on setting up ANN in Python and concepts like Convolution filters, Activation Functions, and Gradient Descent.

Date	**Topic**
Monday, February 6th (5-6 pm)	**First Meeting (Info session)** *Course introduction, structure, outline*
Monday, February 13th	**Satellite Imagery as a powerful tool for cities**
Thursday, February 16th	***Satellite Data Processing Session (1)*** *Intro to .nc files, NumPy, GeoPandas, Matplotlib*
Tuesday, February 21st	**Guest Speaker** *Sensing Lights: Transforming Street lights into a Networked Urban Knowledge Platform.* **| Assignment 1 Brief |**
Thursday, February 23rd	***Satellite Data Processing Session (2)*** *Shapefiles integration, setting up processing pipeline, serial data*
Monday, February 27th	**Fundamentals of Graph Theory and its applications**
Assignment 1 Submission	***Working with serial data and integration with Satellite Imagery***
Thursday, March 2nd	**Data Processing – BFS Setup**
Monday, March 6th	**Using Graph Theory for Climate Risk Adaptation** **|Assignment 2 Brief|**
Thursday, March 9th	**Applying BFS in other applications**
Assignment 2 Submission	***Calculation of Proximity to the point of interest using BFS***
Monday, March 13th	***Introduction to Computer Vision and Image Analysis*** *Guest Lecture: Computer Vision for Climate Risk Assessment*
Thursday, March 16th	***CV Pipeline in Python*** *Intro to Numpy, opencv, and Color Segmentation*
Monday, March 20th	***Using CV with Aerial Data for Building Performance Evaluation*** ***|Assignment 3 Brief |***
Thursday, March 23rd	***Data session*** *HSV color analysis*

Monday, March 27th	**Spring Break**
Monday, April 3rd	**Guest Lecture: Theories of Artificial Neural Networks (ANN)** **|Assignment 4 Brief|**
Assignment 3 Submission	***Color Segmentation in Image Data using CV*** ***Final Project Synopsis***
Thursday, April 6th	***Setting up ANN in Python, Pretrained Networks, Convolution filters***
Monday, April 10th	**Final Project Concept Presentation**
Thursday, April 13th	***Intro to Activation Function and Gradient Descent*** *Object detection with YOLO*
Assignment 4 Submission	***Detection and classification of multiple objects in image data***
Monday, April 17th	**Application of ANN in the Built Environment**
Thursday, April 20th	**Debugging and work session for Final Project**
Monday, April 24th	**Final Project Feedback Session (1)**
Monday, May 1st	**Final Project Feedback Session (2)**
Monday, May 8th	**Final Project Presentation**

Assessments

Attendance in the class will be essential to the success of this course as it will help you develop the proper skill set needed for the final class project. Therefore, your grade is weighted accordingly, with 10% of your grade dependent on weekly participation in class sessions and attending the weekly data sessions. The other portion of your grade will be based on the class assignments and final project, as described below.

A. **Weekly Assignments (40%)**
   - *Assignment (1): Working with serial data and integration with Satellite Imagery.*
   - *Assignment (2): Calculating Proximity to the point of interest using BFS.*
   - *Assignment (3): Color Segmentation in Image Data using CV.*
   - *Assignment (4): Detection and classification of multiple objects in image data.*
B. **Final Project (50%)**
   - *Final Project Synopsis (10%)*
   - *Final Project Presentation (40%)*
C. **Class Participation and Attendance (10%)**

Course Expectations and Policies

Attendance: Regular class attendance and active engagement in class are essential and will help you better develop your final project. The four weekly assignments will further determine your engagement level in class and the data sessions. More than two missed class sessions will be considered excessive, resulting in an NC grade. Your participation in the data sessions is essential to the course's success as it will help you develop the technical skill set needed in this course. We welcome your thoughts throughout the course on improving class processes that will encourage effective communication and dialogue.

Late Assignments: Late assignments will not be accepted; however, we understand that the semester can get hectic. Therefore, you will have two 48-hours extension periods to use for any late submission during the semester. Please let the teaching team know at the time the assignment is due that you will be using the extension period. If you use all your extension periods (two extensions periods allowed) and you have an emergency and need another, come talk with the teaching team and we will find an alternative for your situation. This policy does not apply to the final project presentation.

Inclusivity Statement

MIT values an inclusive environment. Our intent for this class is that students from all backgrounds and perspectives to be equally served by this course. We hope in this course to develop a supportive learning community that will foster rich discussions that are respectful for diversity, gender, identity, sexuality, religion, and culture. Any student who has difficulty in the class environment and believes this may affect their performance in the course is urged to contact us directly.

Special Accommodations and Disability Support Services

If you need disability-related accommodations, we encourage you to meet with me early in the semester. If you have not yet been approved for accommodations, please contact Student Disability Services at sds-all@mit.edu.

We look forward to working with you to assist you with your approved accommodations.

Mental Health

As a student, you may experience a range of challenges that can interfere with learning, such as strained relationships, increased anxiety, substance use, feeling down, difficulty concentrating and/or lack of motivation. These mental health concerns or stressful events may impact your ability to attend class, concentrate, complete work, take an exam, or participate in daily activities.

Undergraduates: Please discuss this with Student Support Services (S3). You may consult with Student Support Services in 5-104 or at 617-253-4861.

Graduate Students: Please reach out to the deans for personal support in the Office of Graduate Education.