IE 670: Special Topics in Dynamic Data Visualization and Optimization

Course Syllabus – Spring 2024

Instructor: Chase Murray, Ph.D.
Email: cmurray3@buffalo.edu Please include "IE 670:" in the subject
Office: 309 Bell Hall
Office hours: to be determined

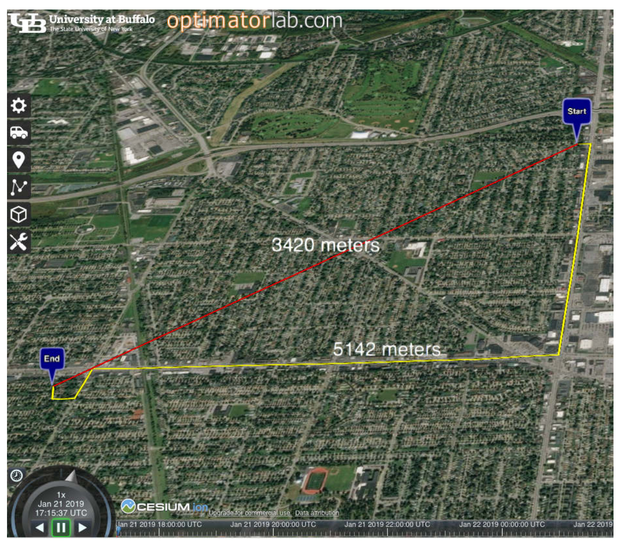
Teaching Assistant: none

Course Meeting Days, Times, and Locations
Lecture Tuesday/Thursday, 12:30-1:50pm, Capen 109.

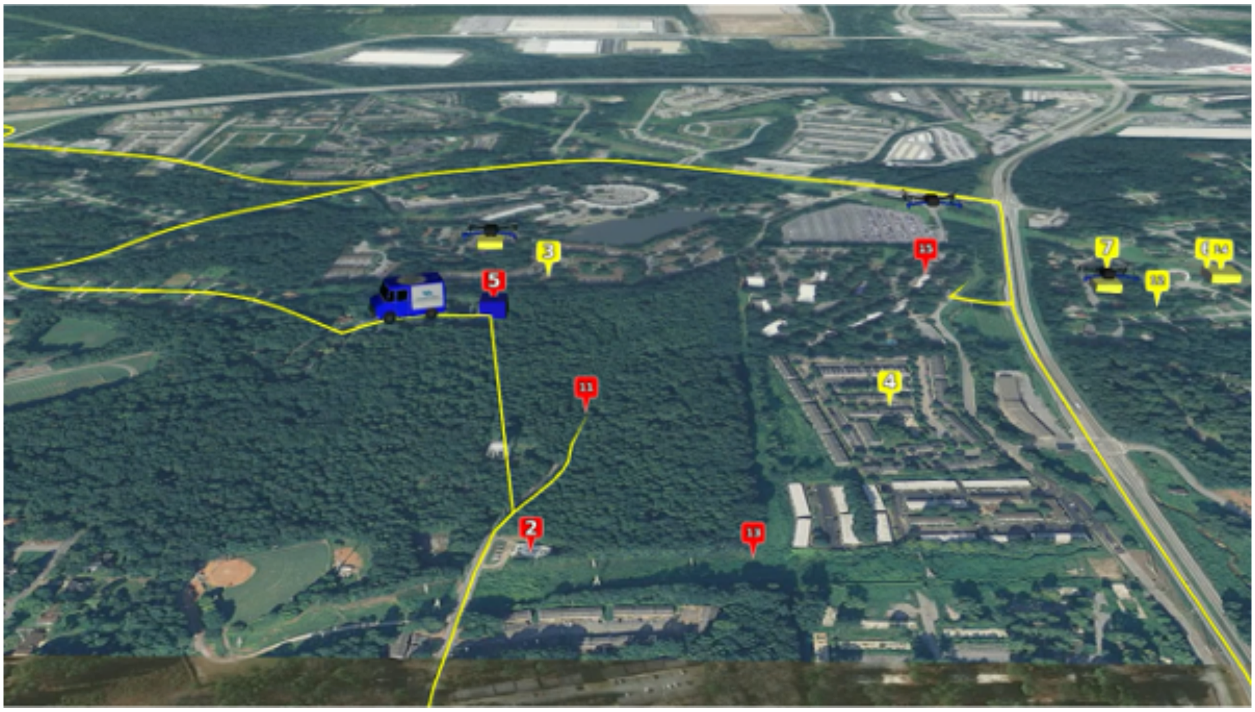
Prerequisites:
- IE 555 (or demonstrated proficiency with Python and/or JavaScript). This course will be programming intensive.
- IE 572 and IE 574. We will be using and building optimization models, some of which may be deterministic, some may be stochastic.

Co-requisites:
- IE 573 and IE 575. Again, this is an applied operations research course, so students will need to draw upon their knowledge of deterministic and stochastic optimization.

Course Description
This course explores tools for capturing, generating, visualizing, and utilizing geospatial data for OR applications.



When developing OR models, we make lots of assumptions. Sometimes this is done for the sake of model tractability, sometimes it's done because we do not have access to data. For example, in vehicle routing, it used to be commonplace to assume Euclidean (or Manhattan) travel metrics. One reason was that it was difficult to obtain actual turn-by-turn directions on real road networks. Now, this data is easy to obtain (although many researchers have yet to incorporate such data in their work). When dealing with coordinated vehicle routing problems (such as launching drones from delivery trucks), the precise location and timing of vehicle movements is of critical importance.



This course examines the dangers of making some of these assumptions.
More importantly, we will re-examine problems with these simplifying assumptions removed.

The aim is to identify ways in which existing (and emerging) problems can be handled with more realism by using (and developing) state-of-the-art tools for data collection and visualization. These tools allow us to examine new problems, or to re-examine "old" problems from a different perspective. We may discover that some problems change dramatically with the simplifying assumptions removed; or perhaps we'll determine that those simplifying assumptions were actually quite reasonable.

Textbook and/or Other Required Materials

- No textbook, but we will make extensive use of these applications:
  - VeRoViz – Vehicle Routing Visualization Toolkit (https://veroviz.org)
  - CesiumJS (https://cesium.com)
- Each student must have a laptop that meets UB's requirements: https://www.buffalo.edu/ubit/service-guides/hardware/getting-started-with-hardware/purchasing-or-using-an-existing-computer.html

Course Websites

- Brightspace will be used for all course grades;
- GitHub will be used for disseminating course materials (e.g., code, homework, and academic papers)
  https://github.com/IE-670/spring2024

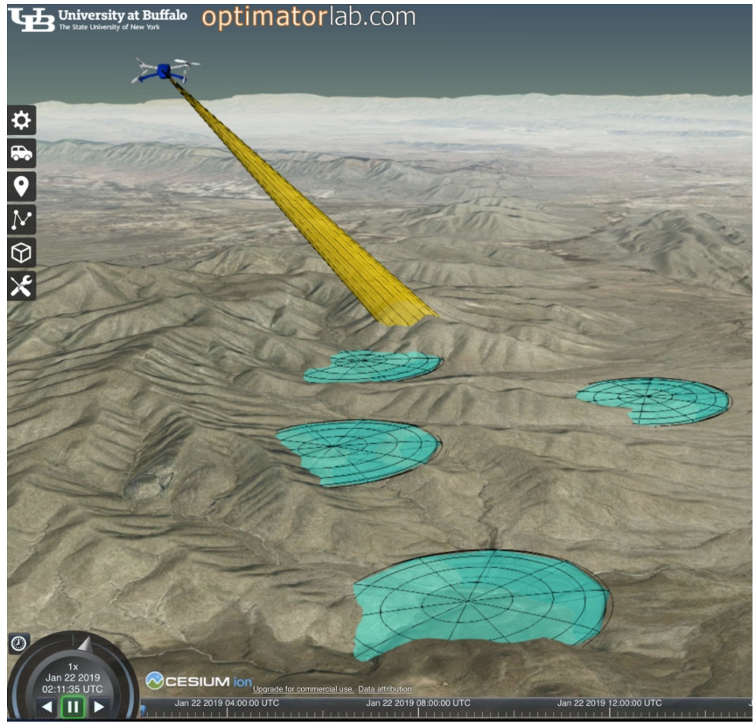
Course Learning Outcomes
The following table lists learning outcomes for this course. The statements generally complete the sentence, "Upon completing this course, students will be able to..."

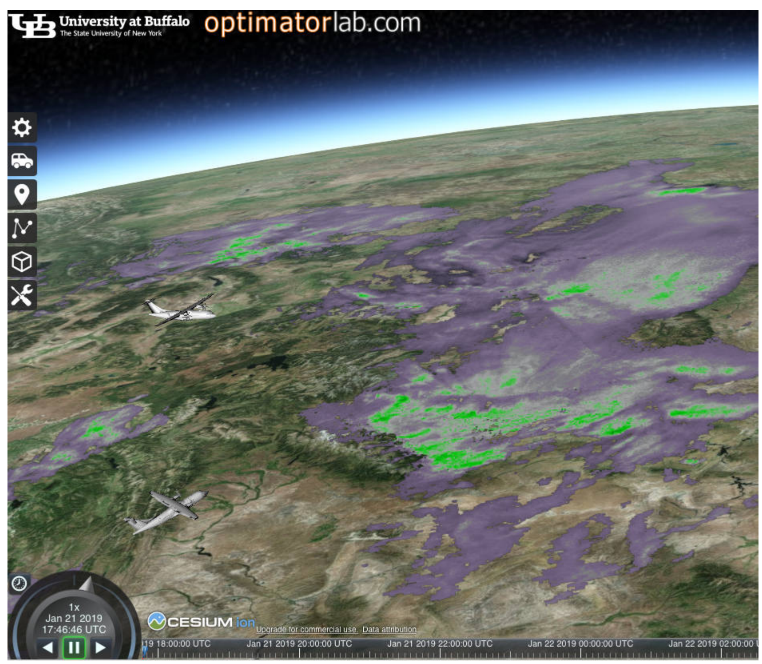
	Course Learning Outcome	**Assessment Method(s)**
1	Understand the capabilities (and current limitations) of VeRoViz and Cesium as visualization tools.	Homework
2	Utilize VeRoViz functionality to visualize vehicle routing problems.	Homework
3	Create Cesium applications (i.e., incorporating entities, adjusting camera angles, using callbacks and promises, capturing user interactions).	Homework
4	Import and utilize external data sources within VeRoViz and Cesium (e.g., traffic, weather, airspace, and population density).	Homework
5	Critically evaluate published literature related to the intersection of geospatial data and operations research.	In-class participation
6	Identify new OR problems that have either not been addressed at all in the literature, or whose treatment has been insufficient in the existing literature.	In-class participation, course project
7	Develop proof-of-concept optimization models for newly-identified geospatial problems.	Course project

Tentative Course Schedule
The course will consist of three parts:

1. **[Weeks 1-9] Applications**
   We will examine several papers from the literature, with a focus on those that are related to geospatial data. Some of these papers will be assigned to students, other papers will need to be identified through student-led searching. We will examine not only the optimization models described in these papers, but will also identify relevant data sources (e.g., traffic and weather data, terrain profiles, sensor attributes, etc.). We will then discuss the reasonableness of assumptions made in these papers. Some of the sample applications include:
   - Monitoring movements of "CitiBike" bicycles in NYC.
   - "Green" vehicle routing problems.
   - Dynamic VRPs, impacted by traffic and/or weather.
   - Search/track for targets in a region characterized by terrain and/or buildings.
   - Vehicle routing with population density considerations.

2. **[Weeks 2-12] Using VeRoViz and Cesium to Visualize Geospatial Data**
Note that Parts I and II overlap; we'll use VeRoViz and Cesium to visualize the problems under study in Part I. VeRoViz has been developed by the instructor's lab, and is a Python toolkit for easily visualizing vehicle routing problems. Cesium is a web-based tool for visualizing geospatial data. We will write JavaScript functions to interact with Cesium, allowing us to create visualizations of key problem features. In particular, we will use Cesium to:
    - Find the min/max altitudes along a path or across a region. This information is crucial for UAV flight planning, and may also have an impact on fuel consumption for ground-based vehicles.
    - Model the coverage of optical sensors (cameras). UAVs have been extensively used for airborne surveillance. However, buildings and terrain can block visibility. Ground sensors are similarly affected by obstacles. We'll use Cesium to determine realistic sensor coverage areas.
    - Incorporate weather maps, which may impact routing decisions.
    - Incorporate cloud cover, which can limit the visibility of targets from the air.
    - Incorporate population density data. For UAV routing, it may be desirable to avoid heavily-populated areas.
    - Model FAA airspace restrictions.





3. **[Weeks 8-15] Student Projects**
   Note that Parts II and III overlap; students will work on their projects while we continue to explore VeRoViz/Cesium functionality in class. Each student will choose one research topic that possesses a geospatial component. The tasks of the project are to
   - Conduct a thorough review of the relevant literature, identify gaps/shortcomings of the existing literature;
   - Define a new problem that addresses one or more of these gaps;
   - Create a visualization of the newly-defined problem;
   - Develop a preliminary optimization model for this problem;
   - Represent a solution to this problem in VeRoViz and/or Cesium.

Grading Policy
Students will be evaluated on:

- **Class participation [30%]**: This is a research class. Students will be expected to actively engage in course discussions, and to bring in ideas sparked by reading news articles. This also means that students will be expected to attend class (on time). Students will be expected to read journal articles suggested by classmates. Students will be expected to present recent relevant journal articles, and will lead in-class discussions. There will also be a "peer evaluation" component" related to the quality of presentations.

- **Homework [20%]**: There will be approximately 3 homework assignments, primarily during the first 1/3 of the semester. These will be designed to ensure that students have gained sufficient familiarity with the tools that we will leverage in the last 2/3 of the course.

- **Course Projects [50%]**: The majority of the course grade will be based on performance on the course project. There will be multiple milestones along the way.
  - **Project proposal [~15%]**. This will be in the form of a 1-page written document, due at the beginning of Week 8 (unless otherwise directed). Each student will give a brief (~20-minute) oral presentation outlining the proposed project scope.
  - **Project status reports [~10%]**. In Weeks 11 and 13, each student will submit a written document outlining the status of the project. This document should clearly list all milestones, and should identify those activities that have been completed, those that are in progress, and those that are in danger of being missed. In the latter case, a plan to address these potential misses should be provided. Each student will present their status reports orally in class.
  - **Final presentation [~25%]**. During Week 14, each student will give a final presentation in class.
  - **Final report [~50%]**. The final report, including all source code and instructions, will be due at end of Finals Week (Week 15).

Final course grades will be determined based on the following scale:

Final Avg ≥ 94.0%	A
Final Avg ≥ 90.0%	A-
Final Avg ≥ 87.0%	B+
Final Avg ≥ 83.0%	B
Final Avg ≥ 80.0%	B-
Final Avg ≥ 77.0%	C+
Final Avg ≥ 73.0%	C
Final Avg ≥ 70.0%	C-
Final Avg ≥ 67.0%	D+
Final Avg ≥ 60.0%	D
Final Avg < 60.0%	F

Do not expect your grade to be "rounded up."

Incomplete Grades

A grade of incomplete ("I") indicates that additional course work is required to fulfill the requirements of a given course. Students may only be given an "I" grade if they have a passing average in coursework that has been completed and have well-defined parameters to complete the course requirements that could result in a grade better than the default grade. An "I" grade may not be assigned to a student who did not attend the course.

Prior to the end of the semester, students must initiate the request for an "I" grade and receive the instructor's approval. Assignment of an "I" grade is at the discretion of the instructor.

Grade Disputes

If you disagree with the manner in which an assignment was graded, you may request a re-evaluation of your assignment within two (2) weeks of the due date of that assignment. A re-evaluation request should consist of two (2) components:

- Page 1: A photocopy of the graded assignment.
- Page 2: A detailed explanation, not exceeding one-half page in length, describing why you believe your answer was correct.

The instructor will consider each case at the end of the term, but only if it appears that it may change your final grade. Obvious arithmetic errors will be corrected immediately.

Professionalism

UB SEAS aims to enhance the education of the students in various aspects of professionalism, and to elevate the standards of behavior that are expected from students. The goals are two-fold: (1) to improve the working and learning environment within SEAS, and (2) to best equip students for employment after graduation.

- Students are expected to use professional style in all communications, including email, with course faculty and teaching assistants. This includes the use of salutations and closings (including clear identification of the author) and correct grammar.
- Students are expected to arrive prior to the start of class, and to remain for the duration of the class.

- Students are expected to refrain from the use of cell phones or other electronic devices unless they are clearly linked to class purposes (e.g., note-taking). Cell phones must remain off or muted.

Accessibility Resources

If you have a disability and may require some type of instructional and/or examination accommodation, please inform me early in the semester so that we can coordinate the accommodations you may need. If you have not already done so, please contact the Office of Accessibility Resources; 60 Capen Hall; email: stu-accessibility@buffalo.edu Phone: 716-645-2608 (voice); 716-645-2616 (TTY); and on the web at https://www.buffalo.edu/studentlife/who-we-are/departments/accessibility.html. All information and documentation is confidential.

Academic Integrity

This course will operate with a zero-tolerance policy regarding cheating and other forms of academic dishonesty. Any act of academic dishonesty will subject the student to penalty, including the high probability of failure of the course (i.e., assignment of a grade of 'F'). It is expected that you will behave in an honorable and respectful way as you learn and share ideas. Therefore, *recycled papers, work submitted to other courses, and major assistance in preparation of assignments without identifying and acknowledging such assistance* are not acceptable. All work for this course must be original for this course. Please be familiar with the University at Buffalo Academic Integrity Policy and Procedure outlined at https://catalog.buffalo.edu/policies/integrity.html .

Syllabus prepared by C. Murray

Revision History:

1/25/2024 – Unofficial (pre-release) version of syllabus posted on instructor's Website.