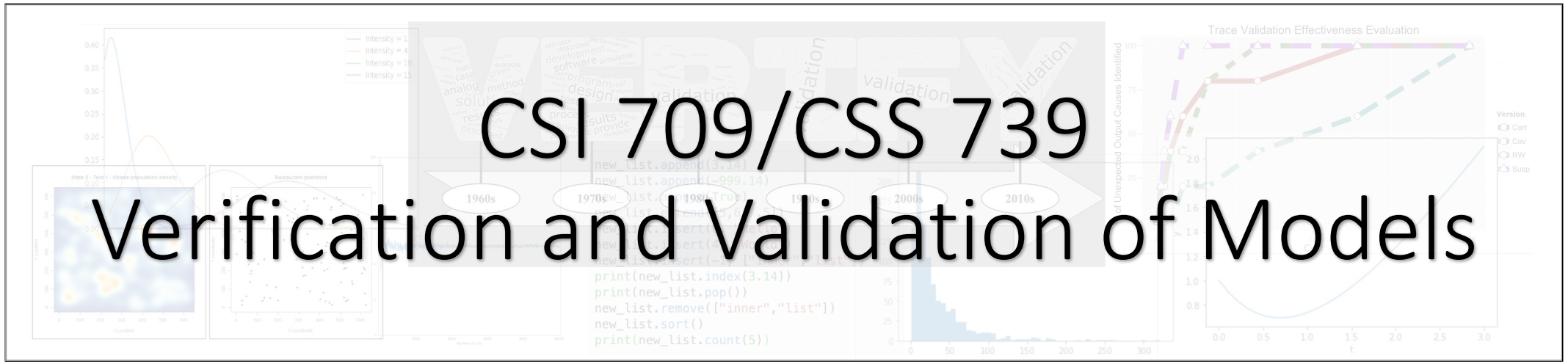

CSI 709/CSS 739
Verification and Validation of Models

Course Introduction

Dr. Hamdi Kavak
Computational and Data Sciences Department

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GEORGE MASON UNIVERSITY

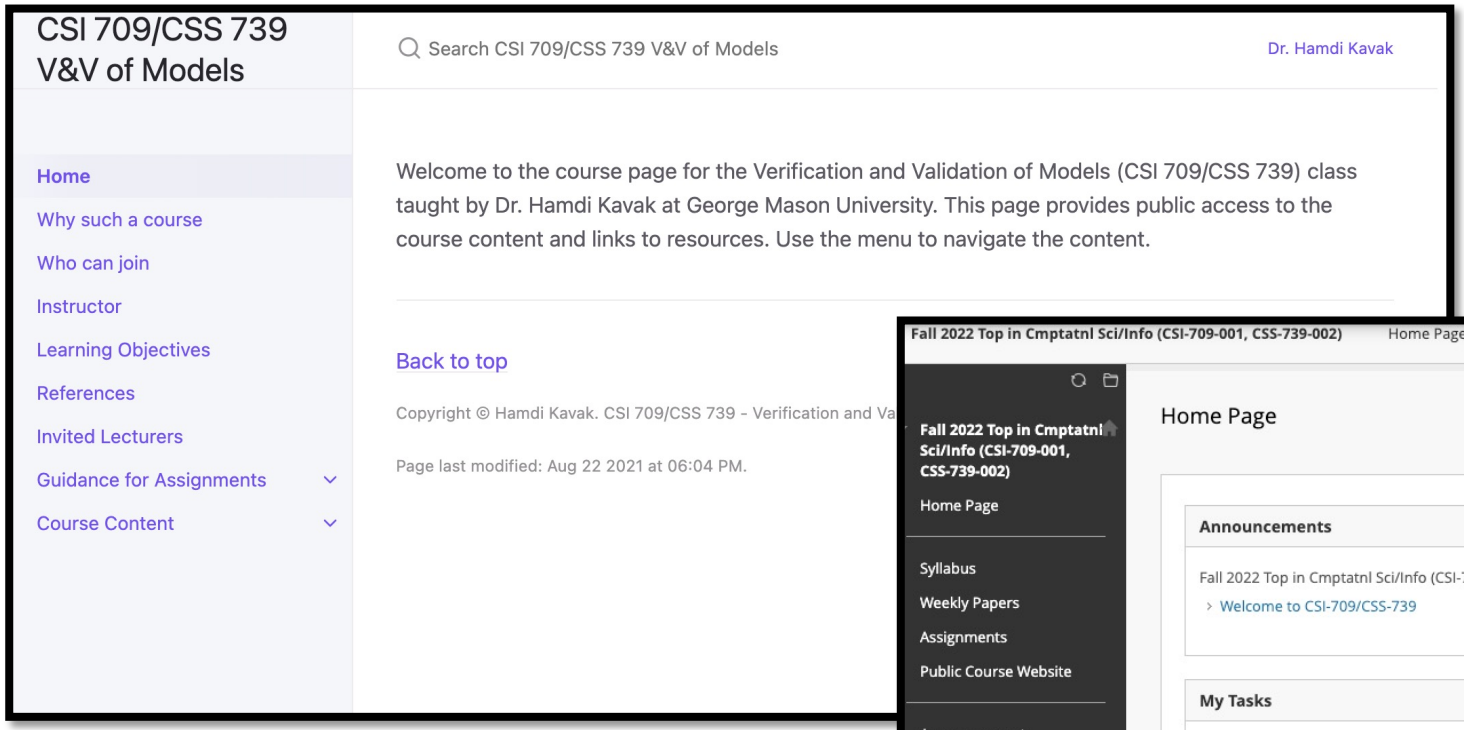
Center for Social Complexity

Welcome to CSI 709/CSS 739

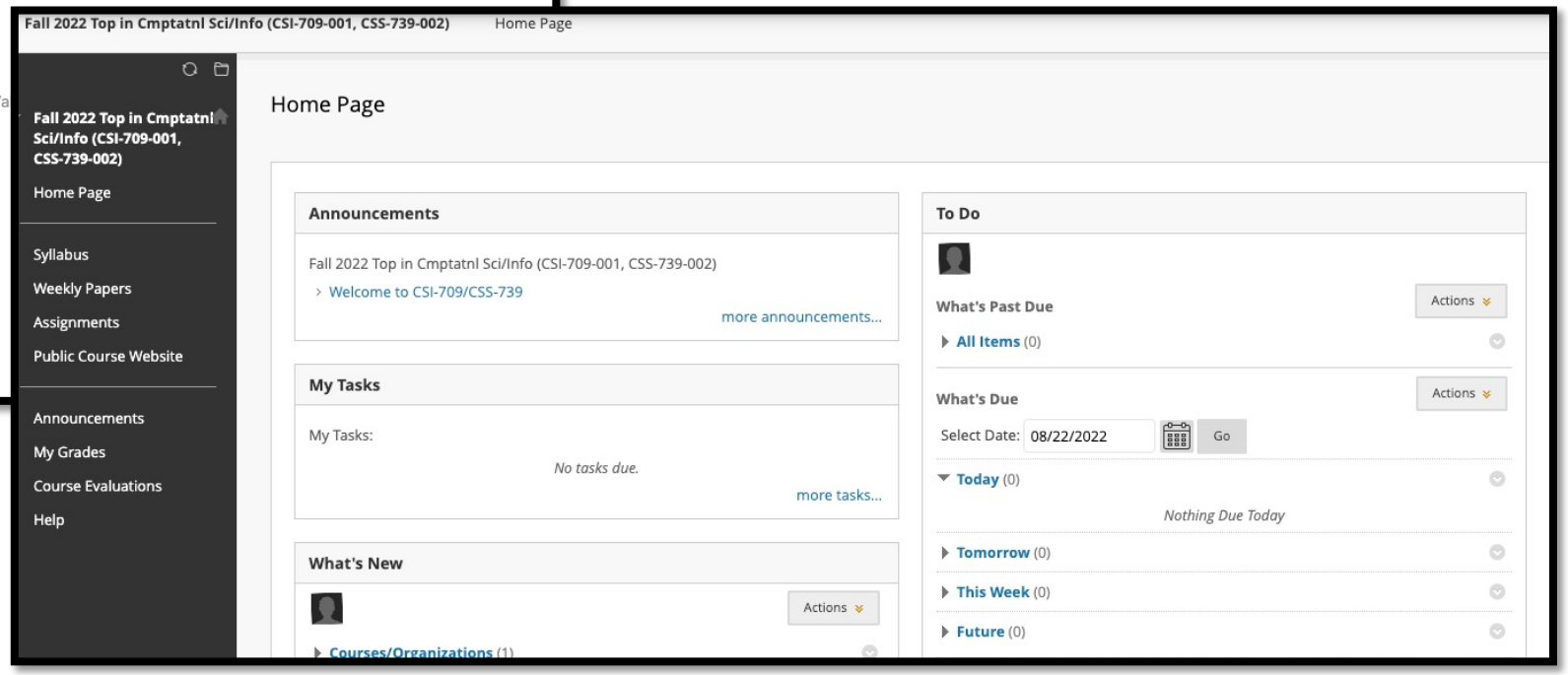
- Instructor: Dr. Hamdi Kavak
  - http://hamdikavak.com/
- Course website
  - http://hamdikavak.com/course-v-and-v
  - Course content
    - Summary
    - Slides
    - Assigned material references
  - Invited lecturers
- Blackboard:
  - Syllabus, PDFs of assigned material, assignment submissions, and announcements.

CSI 709/CSS 739 Websites

http://hamdikavak.com/course-v-and-v



BlackBoard

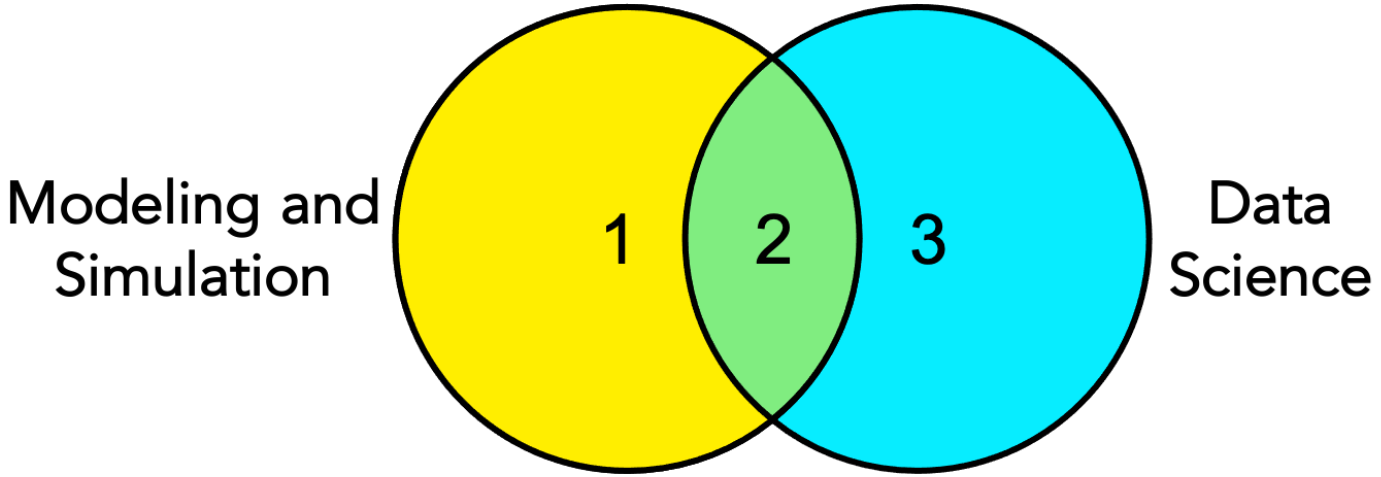


About Me

- Education
  - Ph.D. and M.E. in Modeling and Simulation from Old Dominion University
    - Dissertation title: A Data-Driven Approach for Modeling Agents
  - B.S. in Computer Engineering from Karadeniz Tech. Univ. (Turkey)
- Currently
  - *Assistant Professor* at Computational and Data Sciences Dept. (2019-…)
  - *Co-Director* of the Center for Social Complexity (2021-…)
- Past
  - *Research Associate* at Geography and Geoinformation Science Dept. at GMU
  - *Research Assistant* at Virginia Modeling Analysis and Simulation Center

My research interests

More at http://hamdikavak.com/



Data-Driven Modeling of Agents

Verification and Validation

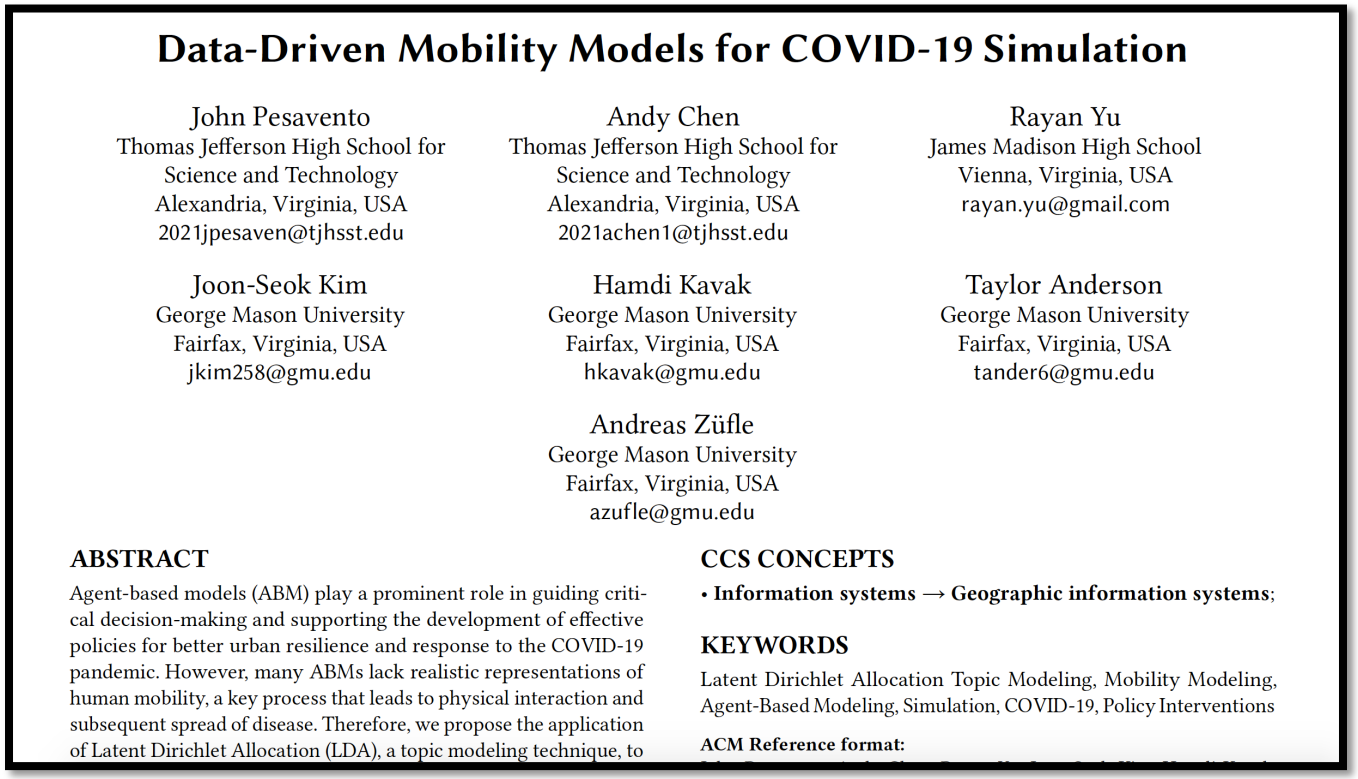
Social Media Analytics

Simulation of Cybersecurity

Simulation Data Analytics

This research is supported by National Science Foundation under Grant No. DEB-203068, “RAPID: An Ensemble Approach to Combine Predictions from COVID-19 Simulations."

Some recent work



Data-Driven Mobility Models for COVID-19 Simulation

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ABSTRACT

Agent-based models (ABM) play a prominent role in guiding critical decision-making and supporting the development of effective policies for better urban resilience and response to the COVID-19 pandemic. However, many ABMs lack realistic representations of human mobility, a key process that leads to physical interaction and subsequent spread of disease. Therefore, we propose the application of Latent Dirichlet Allocation (LDA), a topic modeling technique, to

CCS CONCEPTS

• **Information systems** → **Geographic information systems**;

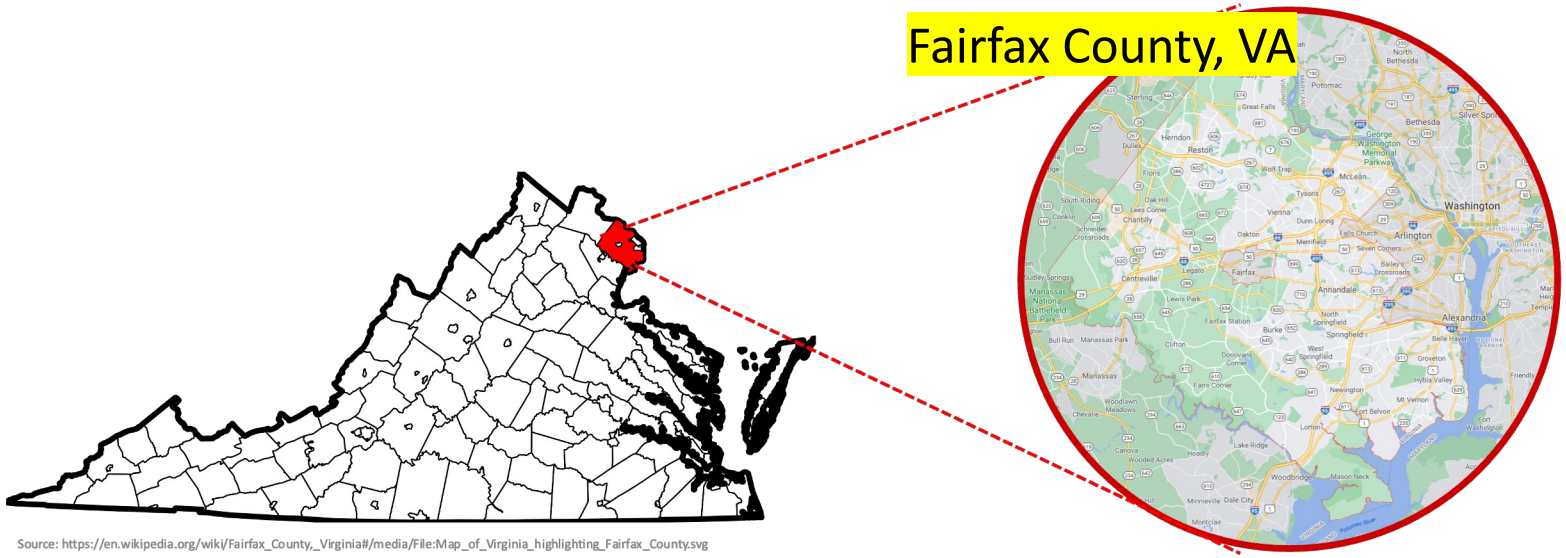
KEYWORDS

Latent Dirichlet Allocation Topic Modeling, Mobility Modeling, Agent-Based Modeling, Simulation, COVID-19, Policy Interventions

ACM Reference format:

Pesavento, J., Chen, A., Yu, R., Kim, J. S., Kavak, H., Anderson, T., & Züfle, A. (2020). Data-driven mobility models for COVID-19 simulation. In *Proceedings of the 3rd ACM SIGSPATIAL International Workshop on Advances in Resilient and Intelligent Cities* (pp. 29-38).

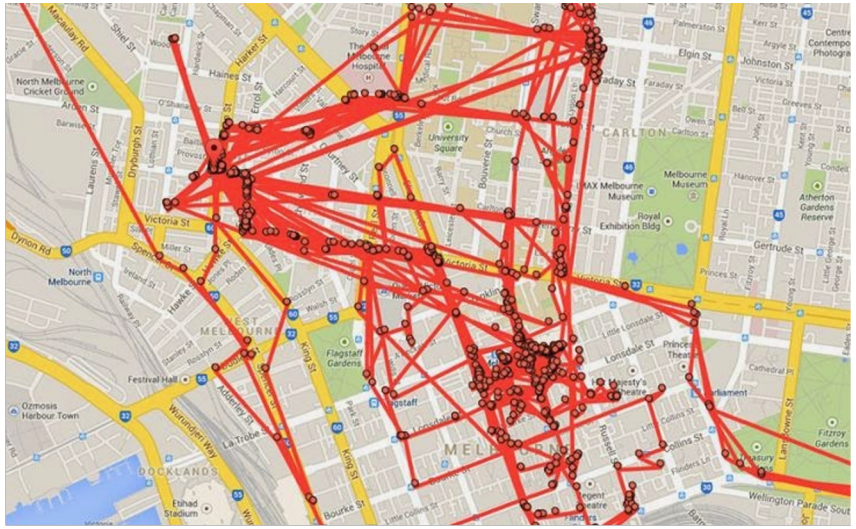
Fairfax County, VA



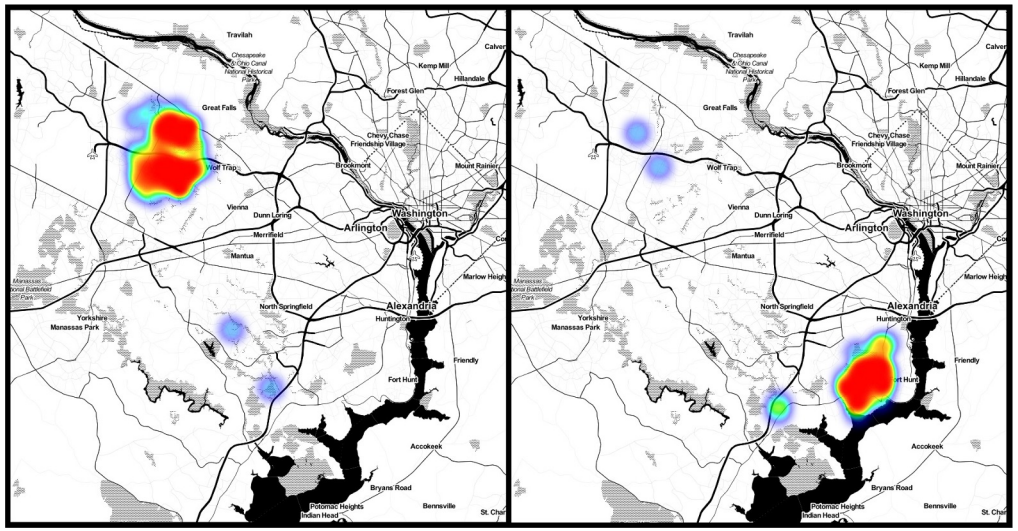
Source: https://en.wikipedia.org/wiki/Fairfax_County,_Virginia#/media/File:Map_of_Virginia_highlighting_Fairfax_County.svg

Source: https://www.google.com/maps/place/Fairfax+County,+VA/@38.8556079,-77.2203788,11z/data=!4m5!3m4!1s0x89b660b1fe460cd3:0x7d0bfa4ee1381699!8m2!3d38.9085472!4d-77.2405153

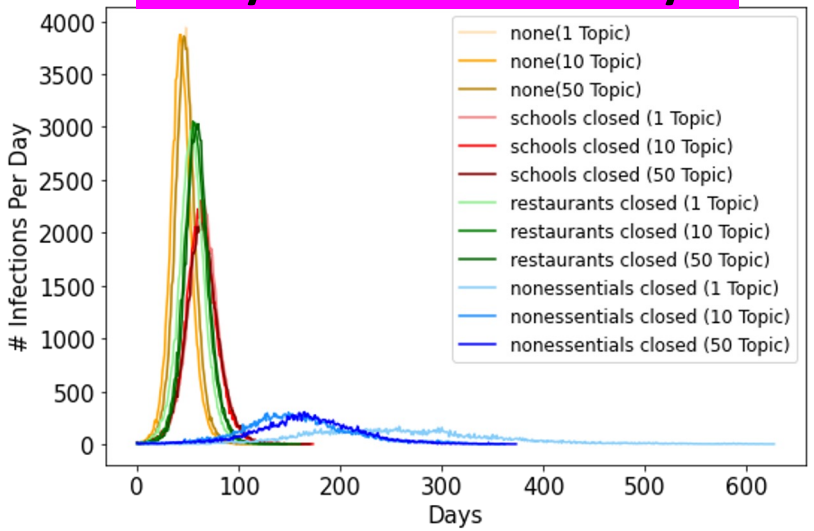
SafeGraph Mobility Data



Latent Dirichlet Allocation based mobility modeling



Policy intervention analysis



Human mobility

PLOS ONE

RESEARCH ARTICLE

Change of human mobility during COVID-19: A United States case study

Justin Elarde[1], Joon-Seok Kim[1], Hamdi Kavak[2], Andreas Züfle[1], Taylor Anderson[1]*

1 Department of Geography and Geoinformation Science, George Mason University, Fairfax, VA, United States of America, **2** Department of Computational and Data Sciences, George Mason University, Fairfax, VA, United States of America

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OPEN ACCESS

Citation: Elarde J, Kim J-S, Kavak H, Züfle A, Anderson T (2021) Change of human mobility during COVID-19: A United States case study. PLoS ONE 16(11): e0259031. https://doi.org/10.1371/journal.pone.0259031

Editor: Itzhak Benenson, Tel Aviv University, ISRAEL

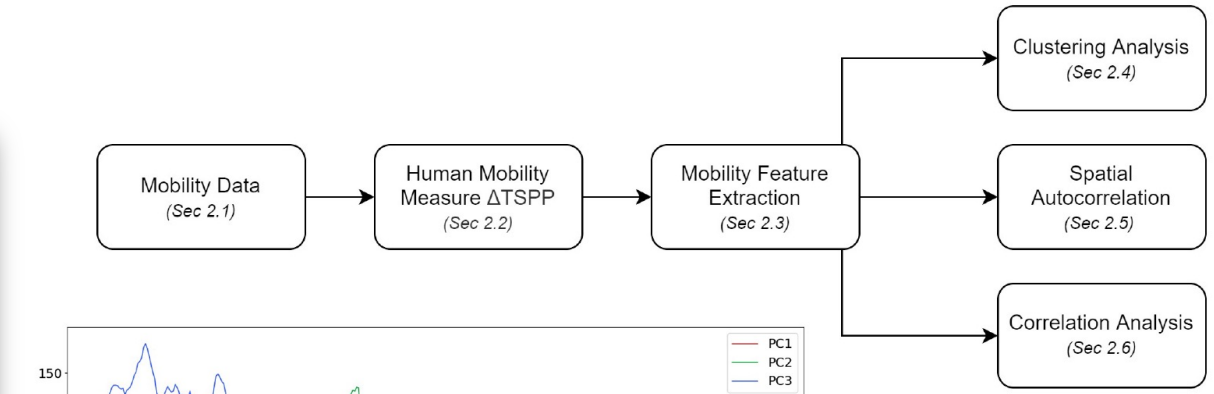
Received: March 26, 2021

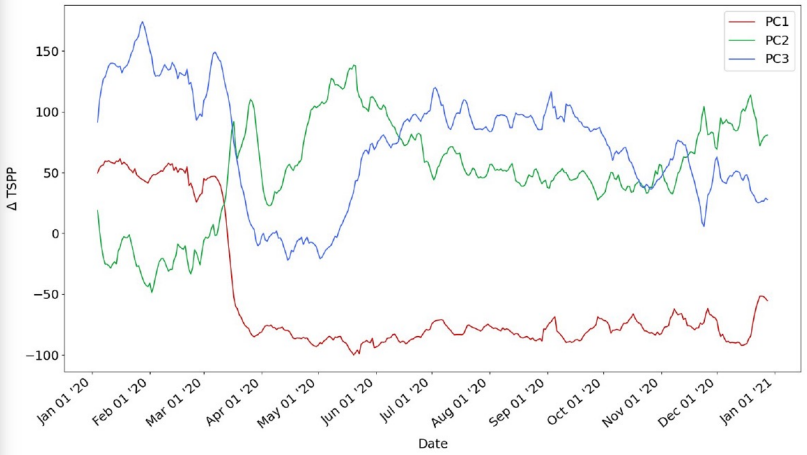
Accepted: October 12, 2021

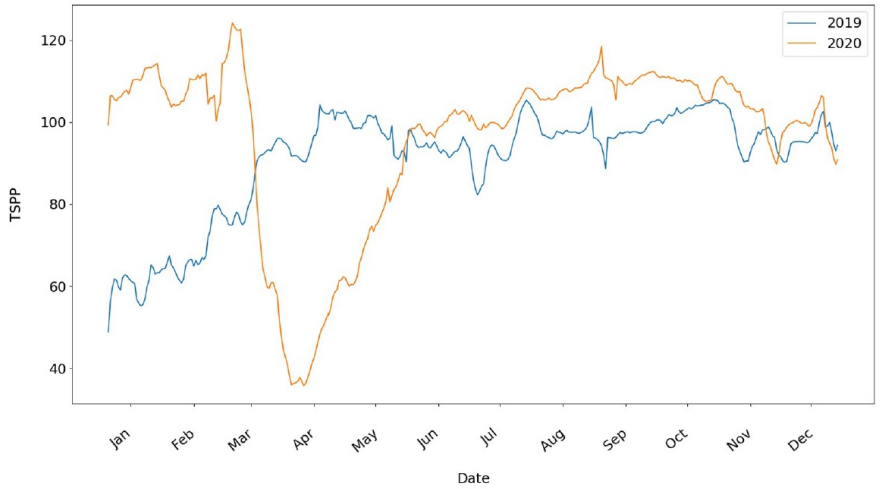
Published: November 2, 2021

Abstract

With the onset of COVID-19 and the resulting shelter in place guidelines combined with remote working practices, human mobility in 2020 has been dramatically impacted. Existing studies typically examine whether mobility in specific localities increases or decreases at specific points in time and relate these changes to certain pandemic and policy events. However, a more comprehensive analysis of mobility change over time is needed. In this paper, we study mobility change in the US through a five-step process using mobility footprint data. (Step 1) Propose the *Delta Time Spent in Public Places* (Δ*TSPP*) as a measure to quantify daily changes in mobility for each US county from 2019-2020. (Step 2) Conduct Principal Component Analysis (PCA) to reduce the ΔTSPP time series of each county to lower-dimensional latent components of change in mobility. (Step 3) Conduct clustering analysis to find counties that exhibit similar latent components. (Step 4) Investigate local and global spatial autocorrelation for each component. (Step 5) Conduct correlation analysis to investigate how various population characteristics and behavior correlate with mobility patterns. Results show that by describing each county as a linear combination of the three latent components, we can explain 59% of the variation in mobility trends across all US counties. Spe-







Synthetic populations

Jiang *et al. Computational Urban Science* (2022) 2:7
https://doi.org/10.1007/s43762-022-00034-1

Computational Urban Science

ORIGINAL PAPER Open Access

A method to create a synthetic population with social networks for geographically-explicit agent-based models

Na Jiang[1*], Andrew T. Crooks[2], Hamdi Kavak[1], Annetta Burger[3] and William G. Kennedy[1]

Abstract

Geographically-explicit simulations have become crucial in understanding cities and are playing an important role in Urban Science. One such approach is that of agent-based modeling which allows us to explore how agents interact with the environment and each other (e.g., social networks), and how through such interactions aggregate patterns emerge (e.g., disease outbreaks, traffic jams). While the use of agent-based modeling has grown, one challenge remains, that of creating realistic, geographically-explicit, synthetic populations which incorporate social networks. To address this challenge, this paper presents a novel method to create a synthetic population which incorporates social networks using the New York Metro Area as a test area. To demonstrate the generalizability of our synthetic population method and data to initialize models, three different types of agent-based models are introduced to explore a variety of urban problems: traffic, disaster response, and the spread of disease. These use cases not only demonstrate how our geographically-explicit synthetic population can be easily utilized for initializing agent populations which can explore a variety of urban problems, but also show how social networks can be integrated into such populations and large-scale simulations.

Keywords: Synthetic population generation, Agent-based modeling, New York, Traffic dynamics, Disease, Disaster

USING GENERATIVE ADVERSARIAL NETWORKS TO ASSIST SYNTHETIC POPULATION CREATION FOR SIMULATIONS

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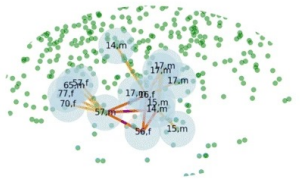
ABSTRACT

Synthetic populations are heavily used in agent-based simulations and microsimulations to create realistic representations of real-world populations. Many existing techniques rely on duplicating or selecting a sample of disaggregated records captured via surveys to generate the entire synthetic population. The challenge here is the potential bias present in the sample of disaggregated records. This paper posits that such disaggregated records can be improved or replaced by training a generative adversarial network (GAN). We present a case study of a 1.1 million population using iterative proportional fitting (IPF). We illustrate that IPF makes a better fit using GAN-based disaggregated records rather than original census-based disaggregated records. Our results show a promising use of GANs for synthetic population generation.

Keywords: generative adversarial networks, synthetic populations, iterative proportional fitting, agent-based simulation, microsimulation.



Step 1

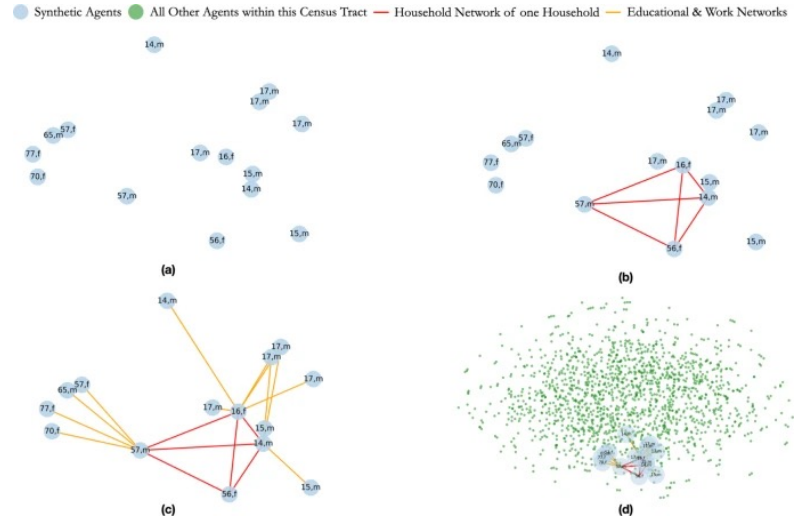
Step 2

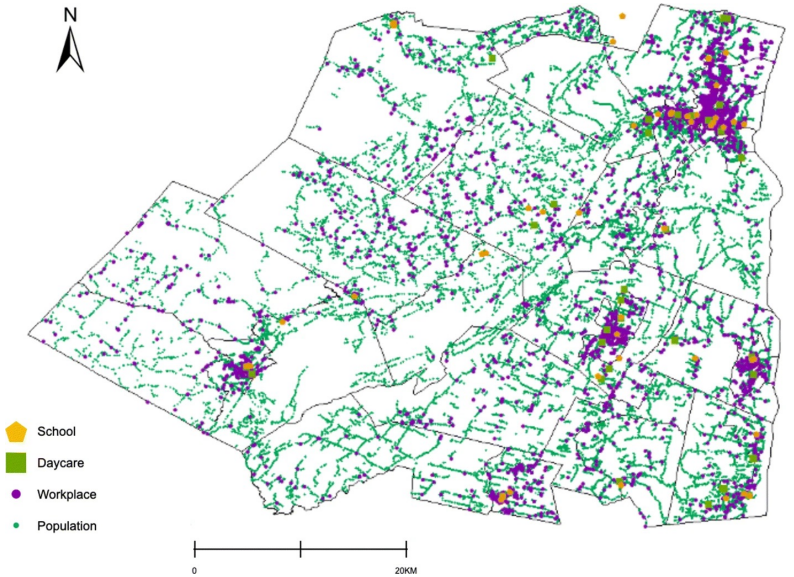
Step 3

Create Individuals and Space		
Tasks	Data	Python Package
• Create Living Space for Home, Work Locations on Road Networks	Road Network	Geopandas, Pandas, Numpy
• Create Individuals	Census Data 2010	Pandas, Random
• Group Individuals into Household	Census Data 2010	Pandas, Itertools, Numpy, Random

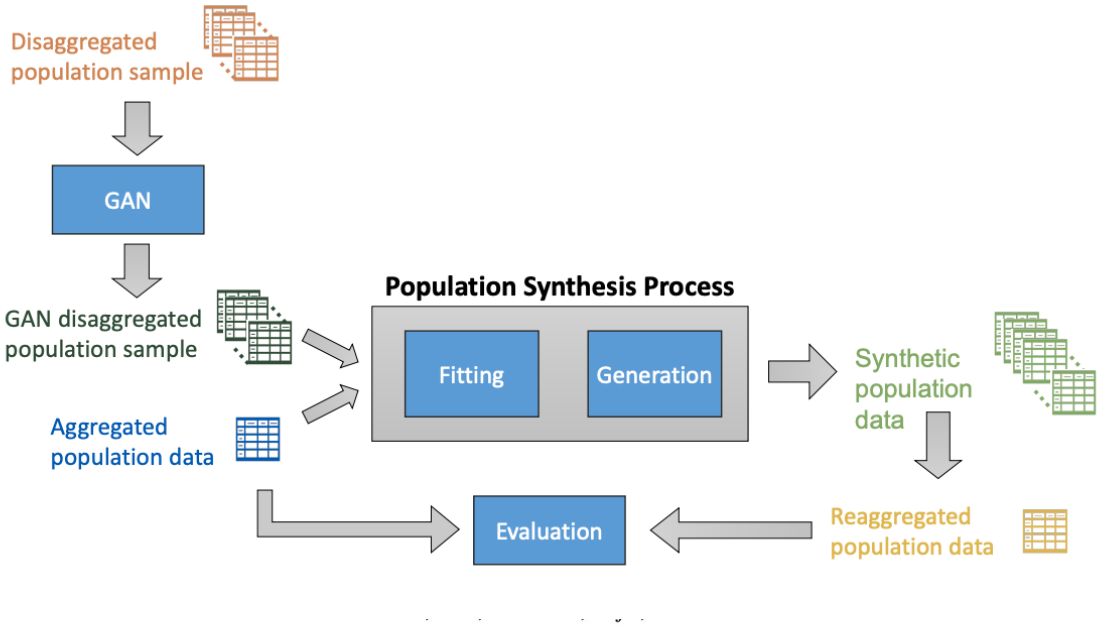
Assign Daytime Locations		
Tasks	Data	Python Package
• Create Workplaces and Assign them to Individuals	Data Generated from Step 1, LEHDs LODES	Pandas, Sklearn, Numpy, Random
• Place Home and Work Places on the Spaces	Road Network	Pandas, Geopandas
• Assign Educational Sites based on age and the closest distance	Data Generated from Step 1, EPA OEI	Pandas, Geopandas

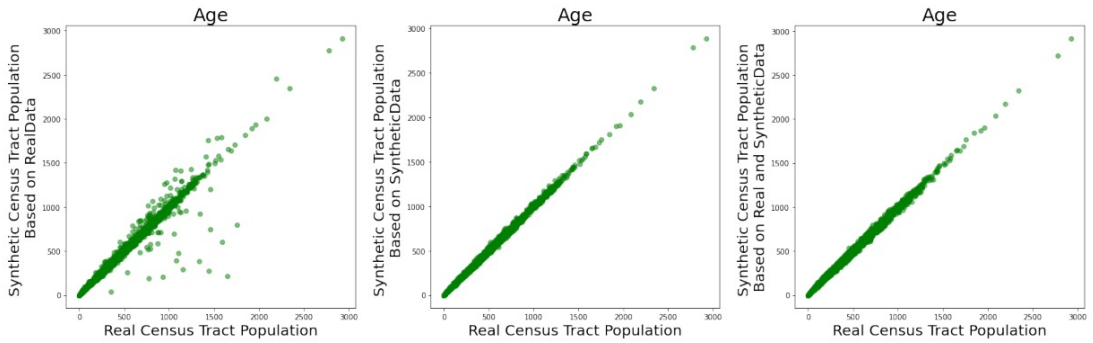
Create Social Networks		
Tasks	Data	Python Package
• Create 3 types of Social Networks (e.g., Household, Work, and Educational)	Data Generated from Step 1 & 2	Pandas, Networkx

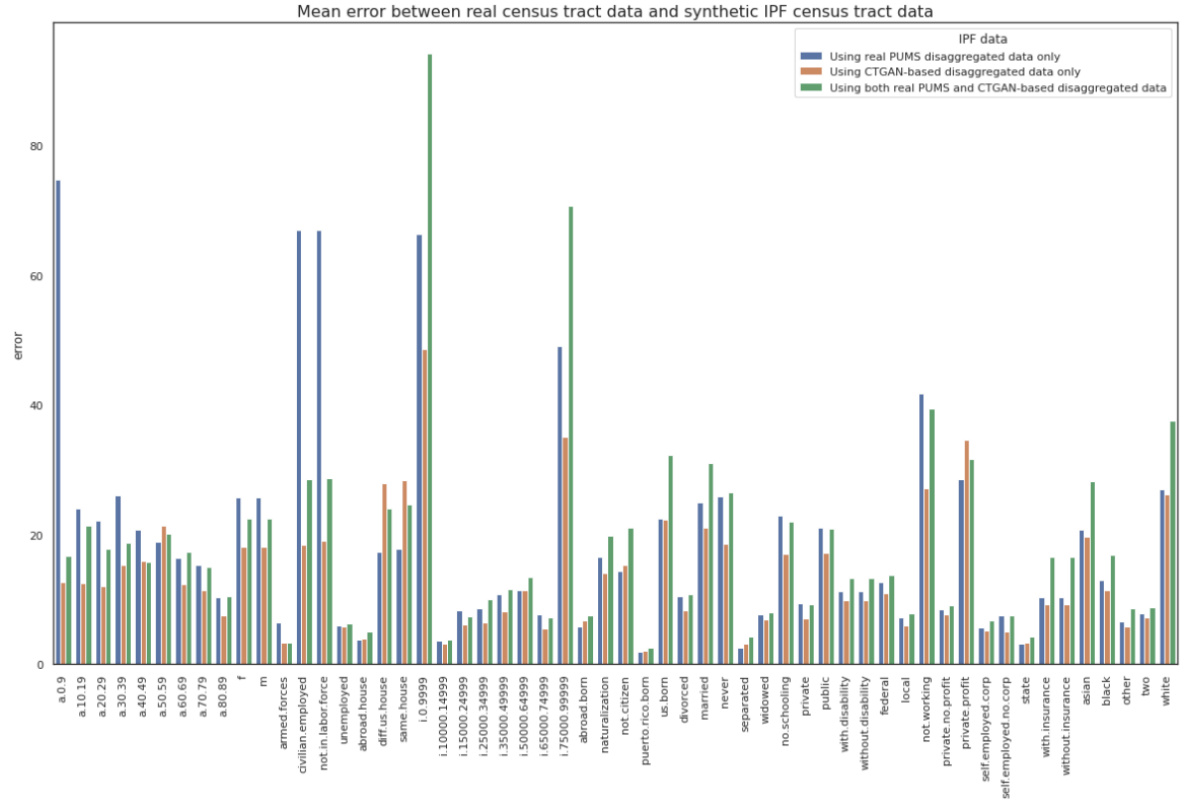




Jiang, N., Crooks, A. T., Kavak, H., Burger, A., & Kennedy, W. G. (2022). A method to create a synthetic population with social networks for geographically-explicit agent-based models. *Computational Urban Science*, *2*(1), 1-18.







Kotnana, S., Han, D., Anderson, T., Züfle, A., & Kavak, H. Using Generative Adversarial Networks to Assist Synthetic Population Creation for Simulations. *Annual Modeling and Simulation Conference 2022*.

Natural language processing

2022 Systems and Information Engineering Design Symposium (SIEDS)

Investigating Disinformation Through the Lens of Mass Media: A System Design

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Gowri Prathap
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***Abstract*—Mass media is a medium of communication with a significant impact on public opinion and perception of issues of global significance. This study is centered around developing a software system to detect and analyze disinformation efforts through mass media outlets and predict shifts in public opinion or reveal active campaigns. The developed system uses a multi-step process to analyze and reveal anti-American sentiment in any country of interest, particularly US allies. We used Turkey as a use case to test our system. Turkey is an important country because it holds a critical role within NATO as a US ally and has recently had significant shifts in anti-American views. We collected mass media articles from various Turkish media outlets.**

that this campaign was one of the many that Russia had been diligently conducting against the U.S., many studies to date have focused on the detection and assessment of the impact of such campaigns [16]. Although similar studies also investigated influence campaigns in the U.S. allies [24], these studies were not clearly attributing Russia's involvement and were not specifically looking into the public opinion about the U.S. in these countries.

Although the last decade has seen an increase in disinformation on social media [4], there has been increasing scrutiny of

2022 Systems and Information Engineering Design Symposium (SIEDS)

A System to Study Anti-American Misinformation and Disinformation Efforts on Social Media

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***Abstract*—Misinformation and disinformation are two significant challenges of our century with societal, political, and economic implications. This study focuses on building a software system to investigate the role of social media in instilling anti-American sentiment among US allies through misinformation and disinformation efforts. Our system has four major components, which are executed stepwise: (1) Data collection, (2) Data handling, (3) Machine learning, and (4) Analysis.**

We designed and implemented this system for Twitter using the Python ecosystem. As a use case, we selected Turkey - a

From 2016 onward, the United States has provided an abject lesson in the impact of disinformation and its utility to foreign and domestic actors. On January 6th, 2017, U.S. intelligence agencies released a report citing that Russia had attempted to influence the 2016 U.S. Presidential Election results in favor of Donald Trump on President Vladimir Putin's orders. Russia's activities included hacking the DNC and relaying their e-mails to WikiLeaks to be released, spreading fake news on social media and using trolls to start arguments on social

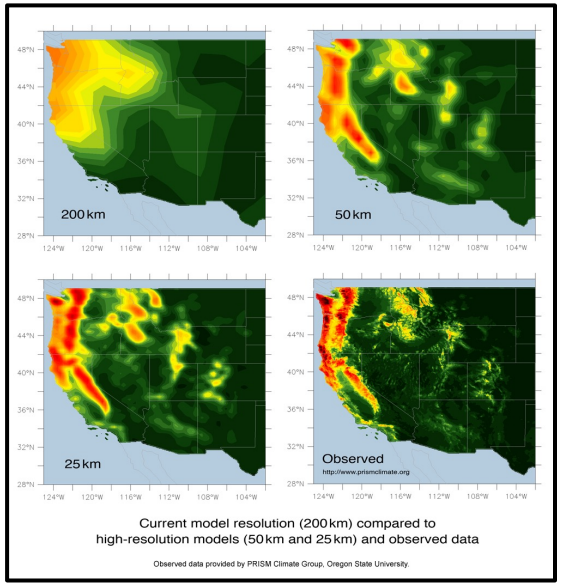
Now your turn

- Your name
- Program name (CSI PhD, CSS PhD, MS…)
- Research interests
- Expectations from this class

just before we start

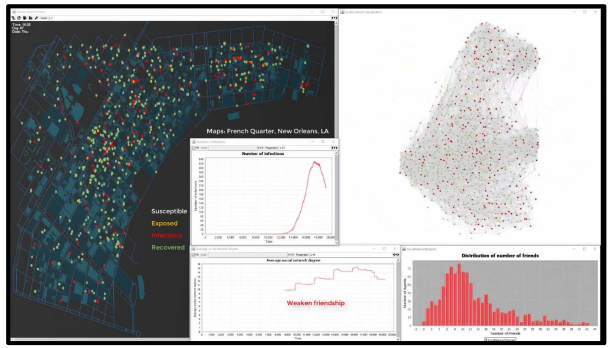
V&V means Verification and Validation

Models are everywhere



Climate Change

Urban Development



Disease Dynamics

Traffic

Figure sources: http://hamdikavak.com/, https://www.anylogic.com/road-traffic/, https://urbanapi.eu/, https://www.gfdl.noaa.gov/climate-modeling/

Models …

- inform decision makers
  - E.g.: COVID-19 models, climate models
- illuminate unforeseen implications

- but also confuse people

This coronavirus model keeps being wrong. Why are we still listening to it?

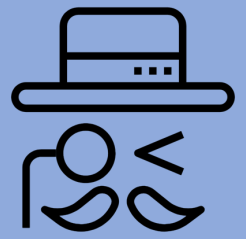
A model that the White House has relied on has come under fire for its flawed projections.

By Kelsey Piper | May 2, 2020, 8:00am EDT

Source: https://www.vox.com/future-perfect/2020/5/2/21241261/coronavirus-modeling-us-deaths-ihme-pandemic

Learning objectives of this class

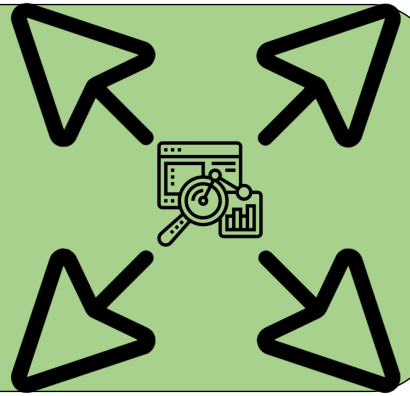
Get trained to critique computational models and their outcomes



be Popperian

Develop a methodological understanding for model evaluation

Extend verification and validation beyond simulation models



Become a more "Ethical Modeler"

Why such a class?

- Couldn't we study V&V within model development?
  - Anecdotal experience: we are not doing it enough
- Well…, nobody else have taught a complete V&V course as far as I know
  - either it was a bad idea
  - or nobody looked at this topic holistically (*betting on this*).
- We are awash with easy-to-use model development tools.
  - We can develop models way faster than verifying and validating them.
- As researchers, we need to follow robust methodological principles not focused on mastering tools.

Is this the right class for you?

- Recommended qualifications
  - Basic statistics knowledge
  - Model design experience (machine learning, simulation, mathematical, …)
  - Programming experience

If you are comfortable with one of the above qualifications and have an idea about another, this course should be suitable for you. Otherwise, you may need to catch up on many topics at once.

Weekly meetings

- We will mostly have two parts
  - **Part 1** => 4:30 PM — 5:40 PM

    Break => 10 minutes

  - **Part 2** => 5:50 PM —7:00 PM
- Lectures will be face-to-face only

We may have some exceptions

Contingency plan

- If we have another health emergency like COVID-19, we will switch to online-synchronous classes via Zoom.

- If we have a temporary emergency on our class day and the university is closed, we will cancel that week's class and have a make up lecture. No online meeting.

Timeline

- Weeks 1-6 (Aug—Sep): Basics

Week # (Date)	Topic
Week #1 (08/21)	• Course Introduction • Models in Science
Week #2 (08/28)	• Verification and Validation Fundamentals
Week #3 (09/04)	LABOR DAY - No lecture
Week #4 (09/11)	• Statistics and Visualization Techniques for Verification and Validation
Week #5 (09/18)	• Lightweight, Feedback-Driven Runtime Verification
Week #6 (09/25)	• Computational Techniques to Support Simulation Model Validation

Timeline

- Weeks 7-13: Specialization

Week # (Date)	Topic
Week #7 (10/02)	• Verification and Validation of Agent-Based Models • (1 student presentation)
Week #8 (10/10) **TUE**	• Verification and Validation within Cognitive Modeling of Individuals • (1 student presentation)
Week #9 (10/16)	• Safer Reinforcement Learning • (1 student presentation)
Week #10 (10/23)	• Validation of Machine Learning Models: Basics • (1 student presentation)
Week #11 (10/30)	• Validation of Machine Learning Models: Bias, Fairness, and Assurance • (2 student presentations)
Week #12 (11/06)	• Validation of Statistical Models • (1 student presentations)
Week #13 (11/13)	• Validation of Network Models • (1 student presentations)

Timeline

- Weeks 14-16: Wrapping-up

Week # (Date)	Topic
Week #14 (11/20)	• Ethics of Model Design and Use
Week #15 (11/27)	• Final project presentation
Week #16 (12/04)	• READING DAYS – No lecture
Week #17 (12/8)	Final project paper (No Meeting)

Assessment

- 20 pts: Ten weekly short writing assignments (SWAs), 2 pts each.
- 30 pts: Two paper presentations
- 50 pts: Final project

Final Mark	Corresponding Grade
>=97	A+
93.0 – 96.99..	A
90.0 – 92.99..	A-
87.0 – 89.99..	B+
83.0 – 86.99..	B
80.0 – 82.99..	B-
77.0 – 79.99..	C+
73.0 – 76.99..	C
70.0 – 72.99..	C-
<70.0	F

SWAs (20 pts – 2 pts each)

- Purpose: get familiar with the literature
- From week #5 to week #14
  - Read one of the assigned materials and write approximately (but not much more than) 500 words.
  - Address the following points:
    - What is the research question or research gap addressed by the author(s)?
    - How effective is the approach followed by the author(s) in addressing the research question or research gap posed by the author(s)?
    - If you were given the same research problem, what else would you try to make the research stronger?

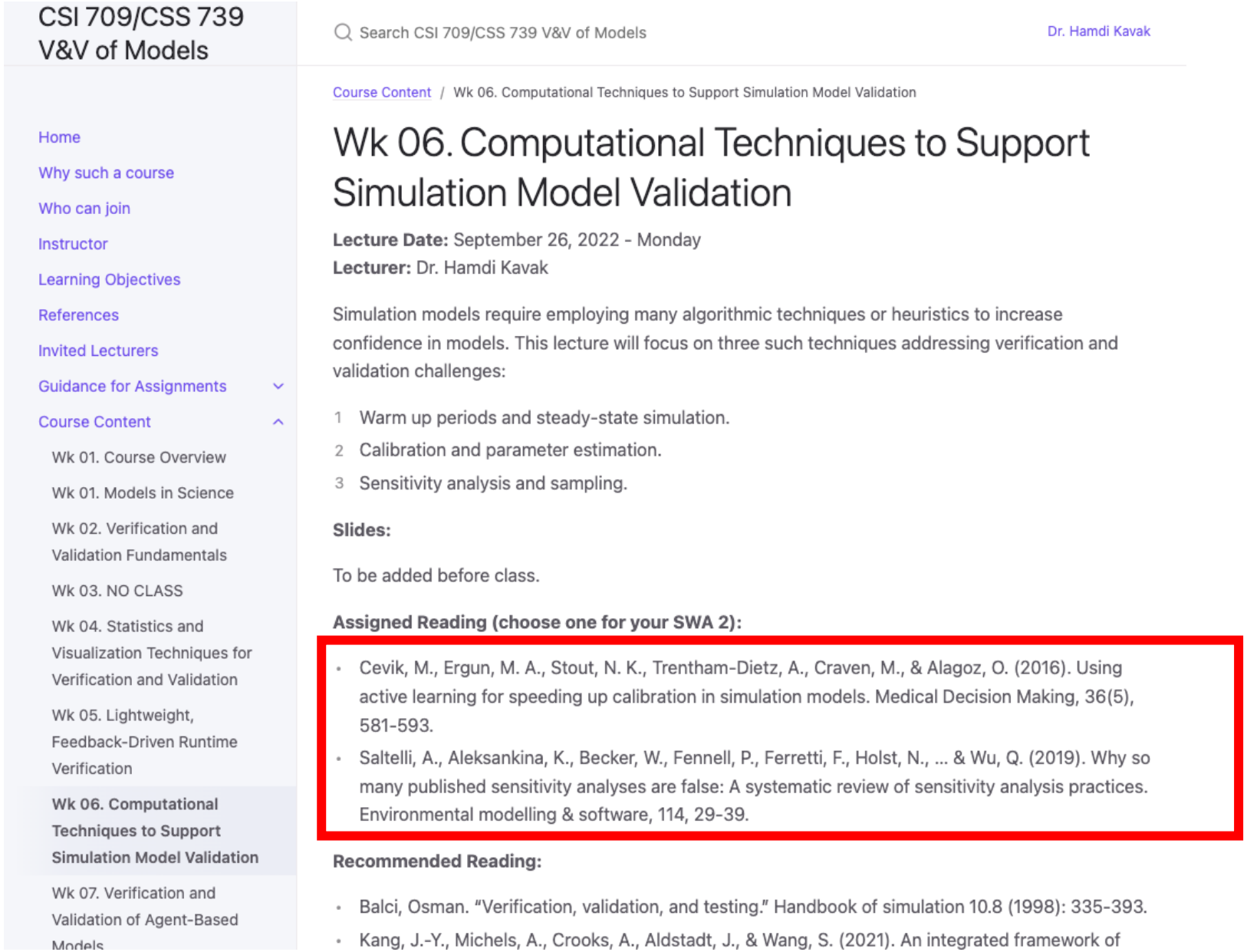
Check http://hamdikavak.com/course-v-and-v/docs/assignments

SWAs (20 pts – 2 pts each)

- To be completed individually.
- If you miss some SWAs, you can make up to two assignments by submitting two SWAs at once in the following weeks.
- SWAs are due on Blackboard by noon (12 pm) on the day of the class.

Check http://hamdikavak.com/course-v-and-v/docs/assignments

SWAs



CSI 709/CSS 739 V&V of Models

Search CSI 709/CSS 739 V&V of Models

Dr. Hamdi Kavak

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Wk 06. Computational Techniques to Support Simulation Model Validation

Lecture Date: September 26, 2022 - Monday
Lecturer: Dr. Hamdi Kavak

Simulation models require employing many algorithmic techniques or heuristics to increase confidence in models. This lecture will focus on three such techniques addressing verification and validation challenges:

1. Warm up periods and steady-state simulation.
2. Calibration and parameter estimation.
3. Sensitivity analysis and sampling.

Slides:

To be added before class.

Assigned Reading (choose one for your SWA 2):

- Cevik, M., Ergun, M. A., Stout, N. K., Trentham-Dietz, A., Craven, M., & Alagoz, O. (2016). Using active learning for speeding up calibration in simulation models. Medical Decision Making, 36(5), 581-593.
- Saltelli, A., Aleksankina, K., Becker, W., Fennell, P., Ferretti, F., Holst, N., ... & Wu, Q. (2019). Why so many published sensitivity analyses are false: A systematic review of sensitivity analysis practices. Environmental modelling & software, 114, 29-39.

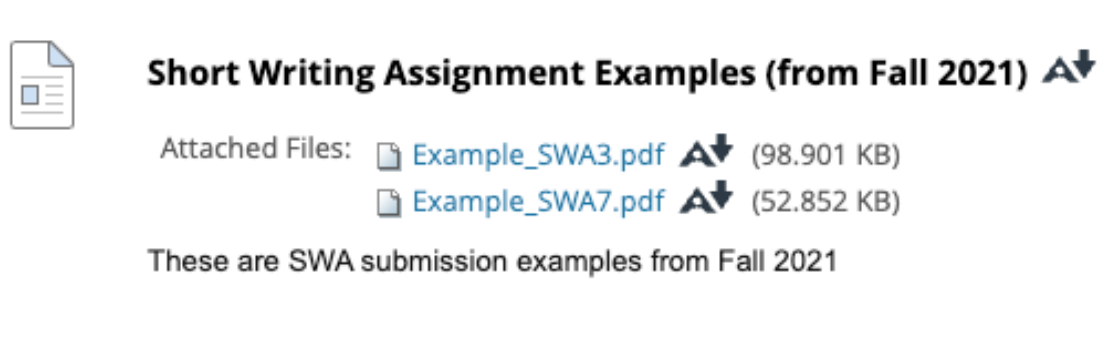
Recommended Reading:

- Balci, Osman. "Verification, validation, and testing." Handbook of simulation 10.8 (1998): 335-393.
- Kang, J.-Y., Michels, A., Crooks, A., Aldstadt, J., & Wang, S. (2021). An integrated framework of

http://hamdikavak.com/course-v-and-v/docs/content

How does a good SWA look like?

- Go to:
  - BlackBoard
  - => Assignments
  - => Weekly Short Writing Assignments (10 total)



Paper presentation (30 pts)

- You will be assigned two papers from week #5 to week #14 and will provide in-depth reviews.
- Up to 30 minutes of presentation (25 mins presentation + 5 mins Q&A)
- You will provide your paper selection preferences and I will do my best to follow them.

Check http://hamdikavak.com/course-v-and-v/docs/assignments

Paper presentation (30 pts)

- What needs to be addressed?
  - If the paper is about a specific application domain, provide a bit of background about this domain.
  - Who are the researchers? What other projects have they worked on?
  - What is the research question(s) or gaps addressed by the paper?
  - Briefly summarize the methodology and results, including the conceptual model.
  - Pay more attention to explaining verification and validation techniques used in the paper.
  - Comment on how effectively the model methodology addresses the research question or gap posed by the authors, the strengths and limitations of the authors' approach, and improvements, extensions, or alternative applications of the model.
  - If possible, provide a demo of the source code of the paper.
  - Possibly propose some questions for discussion.

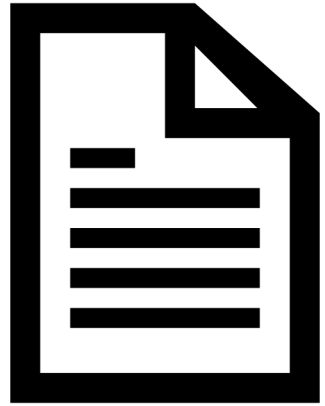
Check http://hamdikavak.com/course-v-and-v/docs/assignments

Final project (50 pts)

- Each student will complete a final project in their area of interest and will present the results to the class.
- The final project should showcase at least three verification and validation techniques on a model (developed by the student) or use an existing published model.
- Deliverables
  - Proposal: 10% (due Sep 18)
  - Presentation: 20% (due Nov 27)
  - Paper: 70% (due Dec 8)

Paper publishing?

- We can publish a set of collective scientific papers with your final projects.
- Potential venues:
  - Winter Simulation Conference 2024
  - Annual Modeling and Simulation Conference 2024
  - SBP-BRIMS 2024
  - Computer Science Conferences (AAAI, MDM, SIGSPATIAL…)
- Interested students can ping me once the semester is over



Student papers published from my classes

- **2021**
  - **Lapoff, M.**, & Kavak, H. (2021). Towards a Verification and Validation Framework for COVID-19 Forecast Models. In *2021 Annual Modeling and Simulation Conference (ANNSIM)* (pp. 1-12). IEEE.
- **2022**
  - **McGough, A.**, Kavak, H., & Mahabir, R. Revisiting Linus' Law in OpenStreetMap: An Agent-Based Approach. In *SBP-BRIMS (**Received best student paper award**)*. Springer, Cham, 2022.
  - **Petri, C.**, & Kavak, H. Evacuation in the Presence of Bad Actors. In *SBP-BRIMS*. Springer, Cham, 2022.
  - **Downes, J.**, & Kavak, H. Imitation Learning for Social Simulation. In *SBP-BRIMS*. Springer, Cham, 2022.
  - **Wang, C.,** & Kavak, H. (2022). A general epidemic model and its application to mask design considering different preferences towards masks. *Complexity*, 2022.
- **2023**
  - **Stine, A. A. K.**, & Kavak, H. (2023). Bias, fairness, and assurance in AI: overview and synthesis. *AI Assurance*, 125-151.
  - **Bishop, N.,** & Kavak, H. (2023, May). The Effect of Empathy on Happiness in Social Networks: An Agent-Based Simulation Study. In 2023 Annual Modeling and Simulation Conference (ANNSIM) (pp. 318-331). IEEE.

Just to keep in mind

- Attendance is not required but recommended
- You will get 10% less if you submit SWAs within 24 hours after the deadline.
- You can submit your assignments early.
- All your assignments are checked for plagiarism using the SafeAssign tool on BlackBoard.
- Try to start **the final project** as early as possible

Office hours

- Per appointment
- Email hkavak@gmu.edu w/
  - your preferred time to meet
  - meeting modality: online or in-person.

Questions from you