Moysey Brio Proposal for Special Topics Courses for Fall 2023

Title: Spatial Dynamics on the Networks with Applications

Networks are found everywhere, from economics to engineering, from social science to biology, transportation, web and so on. Unlike traditional network science courses, this course will spend about half time on metric graphs that emphasizes spatial dynamics including coupling of the networks and surrounding domain when both are described by partial differential equations. In this course, the students learn the fundamentals and applications of network science learn to write code for using networks. Homework problems will combine theoretical problems with programming assignments in their area of interest.

Expected Learning Outcomes. At the end of the course, the student should be able to:

- To identify, construct, and analyze networks and dynamical process on the networks using mathematical concepts, appropriate network models and algorithms
- Learn to write code (network algorithms and visualization tools) for using networks in their areas of interest
- To learn about applications of network in epidemiology, engineering and economics

Prerequisites: An upper-division undergraduate level of probability, statistics, linear algebra, partial differential equation, programming in Python or similar high level programming language.

Tentative Class Schedule:

(Week 1-3) Overview of the Network Theory
Week 1: Introduction to networks, small worlds, hubs
Week 2: Network measures and metrics
Week 3: Random networks

Week 4: Project proposals presentations

(Week 5-9) PDEs on Metric graphs

Week 5: Introduction to Metric Graphs
Week 6: Spectra of quantum graphs
Week 7: Localization
Week 8: Heat, wave and reaction-diffusion equation on the graphs
Week 9: Spatial coupling of the pdes on the network with the pds of the surrounding domain

Week 10: Project Progress Report Presentations

(Week 11-14) Applications
Week 11-12: Examples of Optimization and Control
Week 13: Applications to Gas Flow Networks
Week 14: Applications in Economics
Week 15: Final project presentations

Grading:

- **Homework:** 35%
- **Midterm Project Report:** 25%
- **Final Exam:** 40%

Optional Texts: (Lecture notes will be provided)

1. Newman, Mark. Networks. Oxford university press, 2018.

2. G. Berkolaiko and P. Kuchment. Introduction to Quantum Graphs, volume 186 of Mathematical Surveys and Monographs. AMS, 2013.

Introductory texts:

3. Menczer, Filippo, Santo Fortunato, and Clayton A. Davis. A First Course in Network Science. Cambridge University Press, 2020.

4. Barabasi, A.-L., Netweork Science, Cambridge University Press, Cambridge (2016).

5. Python tutorials and papers relevant to each application.