MA 4027: GRAPH THEORY AND APPLICATIONS

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Learning Management System for the course: Microsoft Teams

Office Hours: By appointment or text me in Microsoft Teams any time.

Textbook: *A first course in Graph Theory*, by *G. Chartrand and P. Zhang (by Dover ISBN-13: 978-0-486-48368-9)* link

Course Description Any successful complex system started as a simple system! This course focuses on the traditional graph theory knowledge and analysis of simple graphs that model simple systems, preceding the complex networks course that model complex systems. The course presents a selection of commonly used topics and proof techniques, providing the basis for understanding and performing analysis of patterned networks. Graph theory provides a professional sandbox for the exploration of new terminology and results in discrete mathematics, and its results have applications in many areas of the computing, social, and natural sciences.

The physical representation of elements (objects or live entities) and relationships between them, may provide more insight than just the data itself (think of a map of airline flights versus a table display of the same flights), so one can think of graph theory as knowledge compression. Generally, graph theoretic representations of problems are useful when there is an emphasis on structure or structural properties of the graph modeled by the data. Algorithms and applications are included, but the focus is on understanding the structure of graphs and the techniques used to analyze the problems, thus solidifying the basics that learners can later expand on. The intellectual discipline of justifying an argument is valuable independently of mathematics so it is important for learner to further to develop this skill.

The course is designed to provide a comprehensive introduction to graph theory to students of operations research, electrical engineering, computer science, and mathematics. We will be studying what can today be regarded as classical graph theory.

Course Learning Outcomes and Objectives: Your goal for this class is to develop the mathematical sophistication needed to understand what properties to search for in graphs (simple networks), and prove results about them using the knowledge about graphs' structure. In doing this, you will

- Use definitions in graph theory to identify and construct examples and to distinguish examples from non-example.
- Apply theories and concepts to test and validate intuition and independent mathematical thinking in problem solving.

- Integrate core theoretical knowledge of graph theory to solve problems.
- Reason from definitions to construct mathematical proofs
- Evaluate and synthesize published research papers.
- Analyze new networks using the main concepts of graph theory.
- Read and write graph theory in a coherent and technically accurate manner.

The learning outcomes above are achieved through proving results, analyzing real data and creating the *Network Profile Summaries*, reading scientific papers and creating the *new content* to teach others. These learning objectives provide you the mathematical sophistication and confidence to use gained experience as situations arise.

Course Format and Schedule: We use a student-centric teaching style using a new platform called CHUNKLearning, which moves away from the static learning ecosystem towards a dynamic one that aims at personalized learning. Our class meets Mon-Thursday as follows

- Mondays and Wednesdays self guided learning: Explore and pass the assessment of each week's concepts using www.CHUNKLearning.net linked from the Microsoft Teams' class site. Each week we cover a new CHUNK Learning course that we then discuss and explore on Wed and Thu. I will be available in my office during class time for one-on-one 'interactions as needed.
- Tuesdays' problem based learning: discussions, problem solving and proof writing sessions to ensure understanding and theoretical practice of the concepts explored concepts of Monday and Tuesday (examples, proofs, graph analysis). On Microsoft Teams' general's channel, or in your personal folder, post questions that you have based on learning experience on Monday and Tuesday. What is unusual about what you learned? What is particularly difficult for you that you would like more information? What type of extra information would you require? Based on your knowledge, can you come up with an example or experience where you would use the learned concepts?
- Thursdays' data exploration: analyze the chosen dataset using Gephi. This analysis can be incorporated in the test's PPT slide for the *Network Profile Summary*. On Microsoft Teams's general channel or in your personal folder, post questions that you would like to pursue in understanding your data, based on learning experience on Monday and Tuesday. What questions can you ask to analyze your personal data? Ongoing activity to show knowledge integration: create a map of the CHUNKs (topics) as you learn them, acknowledging that each individual students might end up with a different map. Discussions on this map will inform changes of the Graph Theory view in on the CHUNK Learning website for future learning experiences.

Course Content: The course materials are available at www.CHUNKLearning.net, or if you prefer a linear view at https://nps.edu/web/faculty-rgera/ma4027. The schedule of the course and the homework list are the following:

Week 1 , Chapter 1: "Intro to GT" #4, 6, 10 (Section 1.1).

Week 2 , Chapter 1: "Intro to GT" #12, 13, 14, 16, 19, 26, 27 (Sections 1.2-1.4).

Week 3 , Chapter 12: "The Center of a Graph" #1, 2, 5 (Section 12.1).

Week 4 , Chapter 2 "Degrees in Graphs": #2, 3, 12, 22, 26, 32, 33, 34, 35, optional is # 37 (Sections 2.1-2.3).

Week 5 , Chapter 3 "Isomorphism": #3, 10, 11, 16, 18 (Sections 3.1. 3.2).

Week 6 , Chapter 4 "Trees": #1, 2, 6, 8, 9, 14, 18, 20, 22, 24 (Sections 4.1, 4.2).

Week 7 , Research week.

Week 8 , Chapter 5 "Connectivity in Graphs": #3, 5, 6, 9, 14, 18, 24, 28 (Sections 5.1-5.3).

Week 9 , Chapter 6 "Traversability": #4, 6, 8, 12, 13, 16, 18 (Sections 6.1, 6.2).

Week 10 , Chapter 9 "Planarity in Graphs": #2, 4, 8, 9, 15, 22, 23, 26, 28 (Sections 9.1, 9.2).

Week 10 , Chapter 10 "Colorings in Graphs": #1, 2, 4, 6, 12, 17 (Sections 10.1, 10.2).

Week 11 , Research presentations.

Homework: Students are expected to read ahead or listen to videos to properly prepare for class, allowing the classtime to be spent on discussions and group work. Regular homework will be assigned, yet none will be collected. Check https://nps.edu/web/faculty-rgera/ma4027 for updated schedule and homework list. Each Friday a take-home test is due over the concepts learned the previous week. You have to turn in exactly 5 tests for the whole quarter (your choice of the 5 tests, and I will **not** pick the best 5). The take-home test is a choice between a narrated proof or a narrated PPT slide created for the Network Profile Summary combining the concepts learned up to that week (interest driven exploration of new concepts to be incorporated in the PPT slide is highly encourage).

Primary Analysis Software:

- NetworkX (https://networkx.github.io/) and igraph (http://igraph.org/redirect.html), two Python libraries developed for the study of graphs and networks. Python (https://www.python.org/) is an open source programming language with wide interoperability and many, varied tools.

- If you wish to explore on your own, you may use packages supporting R programming language as well: igraph (http://kateto.net/networks-r-igraph) or Statnet (http://www.statnet.org/ with a tutorial at: https://statnet.org/trac/raw-attachment/wiki/Resources/introToSNAinR_sunbelt_2012_tutorial.pdf).

Primary Visualization Software: Gephi (http://gephi.org/) which is open source graph visualization and manipulation software. Other software choices are available and welcome to use, here is a list: http://www.gmw.rug.nl/∼huisman/sna/software.html.

The following activities will support your learning:

Table 1: The breakdown of the points for the final grade

Activity	Points (of 100 total)
In-class participation	20
The 5 test questions of your choice	50
Research project	30

In class participation (20 points):
I have a very interactive teaching style that expects everyone to participate in classroom discussions. You are encouraged to be engaged in these discussions, but give everyone else a chance to participate as well. The in class conversations allows you to modify and improve your existing perceptions about the network science topics.

Assessments of learning: Participation is measured by evidence of class preparation, interactions during class (asking relevant questions, showing the ability to express critical thinking) and making connections even if they are not correct. These allow me to establish that you are actively engaged vs. checking out mentally.

Weekly tests (10 points each, must create 5):
You have two choices to turn in for each test for up to 10 points for either: (1) the weekly assigned proof over the content learned up to that week, or (2) Network Profile Summary PPT slide. The test must be narrated to ensure thorough explanations. Your presentation must be convincing, coherent, and cohesive, including the suggestions you have received throughout the quarter.

For the Network profile Summary PPT slide, choose a network that interests you, such as your social network from an existing social media or create your own (classroom time will be set aside for creating networks). You may then turn in a one PPT slide summarizing the network's analysis primarily using tools learned that week. You may use your thesis data, collect data, find an existing network/data, download a data set from https://www.kaggle.com/ or download a network from https://nps.edu/web/faculty-rgera/NetworkProfileSummaryResources. This project transitions from knowledge exposure to practice (without mimicking the instructor). During and outside the class you will have the opportunity to experiment on your network, exploring the variety of topics as they are presented and as your intellectual curiosity inspires you.

Assessment Rubric for Weekly Presentations (and final presentation slides): This knowledge, skill and ability assessment is formative for each quick, encouraging integration and connection to previous weeks' concepts.

Research (30 points):
We will be working on creating Section 2 of a research paper (the equivalent of Chapter 2 of a thesis), presenting a synthesis of existing work on a current open ended research topic. You will be paired up for this project, and the output consists of the written portion in Overleaf, and a presentation of your synthesis of that existing work during the last week of classes.

Assessments of learning: The assessment will be driven by the accuracy and clarity of the created content. The following should shape the presentations as well: helpful visual aids, clear, complete and organized presentation (labeled pictures/tables).

Academic integrity The honor code can be found in the NPS student handbook. If you need reasonable accommodations for a scheduled absence, please see me early in the quarter.

Criteria	Task	Detailed Step (0-10 points)
Content	An Analysis is Performed	Correct analysis synthesizing learned concepts
		A (9-10 points) Relevant & clearly explained findings, Insightful contextualization of findings, and thoughtful synthesis & interpretation of metrics.
		B (8 points) Minor errors
		C (7 points) Significant errors
		D (6 points) Major conceptual errors
		F (0-5 points) Little to no work of merit
Presentation	Results are presented	Clarity and style of graphics (Could they be presented in a more significant way)
		A (9-10 points) **Slide Deck** clear & succinct slides, correct spelling and mathematical notation figures and tables are labeled and have captions consistent in tense and active voice references are provided **Conveying the information** clear verbal explanation correct use of terminology while explaining clear and loud speaking
		B (8 points) Minor errors
		C (7 points) Significant errors
		D (6 points) Incoherent presentation
		F (0-5 points) Little to no work of merit

Table 2: Assessment rubric for slides and all the presentations