University of Cologne · Institute for Theoretical Physics · 50937 Cologne

Universität Bonn
Fachgruppe Physik/Astronomie

Prüfungsamt

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Vorlesung "Complex Networks and Energy Grids"

Sehr geehrte Damen und Herren,

Aarathi Parameswaran hat im Sommersemester 2023 erfolgreich an der Lehrveranstaltung „Complex Networks and Energy Grids" an der Universität zu Köln teilgenommen. Die Lehrveranstaltung umfasst 2SWS Vorlesungen, 1 SWS Übungen plus Selbststudium und wird mit 4,5 ECTS-Punkten bewertet. In der mündlichen Prüfung am 29.9.2023 hat sie die Note

sehr gut (1,3)

erreicht. Ein Protokoll der Prüfung und eine Agenda des Kurses sind angehängt.

Aarathi Parameswaran has successfully completed the course "Complex Networks and Energy Grids" at the University of Cologne in the summer term 2023. The course consisted of two hours of lecture and 1 hour of tutorial per week plus independent studies and is rated with 4,5 ECTS points. In an oral examination on the 29.9.2029 she received the grad

very good (1,3).

Minutes of the exam and a syllabus of the course are given below.

Best regards,

Prüfungsprotokoll

Mündliche Prüfung von: Aarathi Parameswaran
Datum und Uhrzeit: 29.9.2023, 11:00 am – 11:30 am
Prüfer: Prof. Dr. Dirk Witthaut
Beisitzer: Philipp Böttcher

Inhalt:

- Graph Theory: definition of distance, BFS and Dijkstra-Algorithms to find shortest path
- Real-life social networks: Small-world properties, clustering coefficient, power-law degree distribution
- Models for social networks: comparison to random networks (ER), definition and explanation of the Watts-Strogatz and Barabasi-Albert model, discussion of their small-world properties
- Communities in networks: definition of communities, Girvan-Newman algorithm and definition, explanation of betweenness
- Centrality measures: degree, Katz-centrality with definition and explanation
- Percolation: phase transition to the existence of a giant connected component (GCC) in the ER random graph model, analytic method to determine the critical value
- Epidemiology on networks: aviation network, SIR-model with definition and explanation, extension from a well-mixed population to SIR on a network

The student confirms that the performance of the examination was not affected by technical problem that might have resulted from the online exam.

Die Prüfung wurde als sehr gut (1,3) bewertet.

Syllabus of the course:

1. Elements of Graph Theory
2. Complex Networks:
    a. Lattices vs. Random Graphs vs. Complex Networks
    b. The small-world effect in social networks
    c. The Watts-Strogatz model: Combining small-world and high clustering
    d. The degree distribution of random networks
    e. Hubs, power laws and the Barabasi-Albert model
3. Centrality measures
    a. Motivation: Characterizing the role of individual nodes
    b. Degree Centrality
    c. Katz Centrality
    d. Betweenness
    e. Closeness
    f. Page Rank and the Random Surfer Model
    g. Application: The social network of Game of Thrones
4. Large-scale Components and Communities
    a. Components, Weak vs. Strong Connectivity
    b. Communities: Examples and Basic Ideas
    c. Finding Communities via the minimum cut method
    d. The Girvan-Newman algorithm
    e. Modularity
5. Cliques, cores and motifs
    a. Cliques
    b. k-plexes and k-cores
    c. Rick-Club organization
    d. Network Motifs
6. Percolation and Random Graphs
    a. Fundamentals: What is percolation and what is a giant connected component (GCC)?
    b. A first look at the GCC in the Erdös Renyi random graph G(n,p)
    c. The self-consistency equation for the size of the GCC in G(n,p)
    d. Solutions of the self-consistency equation: The percolation phase transition
7. Percolation and Network Robustness
    a. The configuration model
    b. Generalization of the self-consistency approach
    c. Solution via generating functions
    d. Robustness: Self-consistency approach with random node removal
    e. Outlook: Explosive Percolation
8. Epidemic Spreading
    a. Compartment models for epidemiology: SI, SIR, SIS
    b. The SIR model on complex networks
    c. Spreading via the global aviation network
    d. The effective distance approach to epidemic spreading
    e. Compartment models for Covid-19: Including containment and quarantine
9. Supply networks and electric power grids
    a. Fundamentals of AC power grids
    b. The AC load flow equations and its linearization
    c. What limits power transmission in AC power grids?
    d. Cascading failures and blackouts
    e. Impact of line outages in the linear power flow approximation
    f. Fundamentals of Power System Dynamics
10. The swing equation
    a. Synchronization in power systems
    b. Load-Frequency Control
    c. (Deterministic) Frequency Deviations
11. Elements of Energy Systems Analysis
    a. Electricity Markets and the Merit Order Principle
    b. Optimization Methods in Energy and Power Systems
    c. Energy System Models and Energy Scenarios