UNIVERSITÀ DI PISA

DIPARTIMENTO DI INGEGNERIA DELL'INFORMAZIONE

Dottorato di Ricerca in Ingegneria dell'Informazione

Doctoral Course

"Recommender Systems Applications in Industry 5.0"

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Short Abstract:

Recommender Systems have transformed user experiences across industries such as e-commerce, media streaming, and healthcare [1]. This course, tailored for PhD students, offers a comprehensive introduction to RS algorithms, covering foundational concepts like collaborative filtering and matrix factorization, emphasizing how Recommender Systems use user data to generate personalized recommendations. The course will delve into the synergy between AI and Recommender Systems, teaching machine learning techniques for Recommendation and introducing deep learning for complex user preferences and item relationships [2].

The course will also showcase the power of Recommender Systems in specific fields, demonstrating their practical applications and impact.

In Telecommunications [3,4,5], Recommender Systems can be employed to personalize network resource allocation by analyzing user profiles and traffic patterns, ensuring efficient and user-specific network management.

In Biosciences [6,7,8], Recommender Systems can assist in drug discovery by recommending promising drug candidates based on complex data analyses, or be implemented for personalized medicine, where targeted therapies are suggested according to individual patient profiles, leading to more effective treatments.

In the field of Automation Engineering [9,10,11], Recommender Systems are utilized to analyze sensor data, predicting component degradation and recommending maintenance schedules to ensure optimal performance and longevity of devices.

By the end of the course, students will gain a thorough understanding of Recommender Systems principles and their applications in diverse research domains. They will be equipped with the practical skills and tools necessary to implement and evaluate their own recommender systems using Python libraries such as NumPy, Pandas, Scikit-learn, and TensorFlow/PyTorch for deep learning applications.

Course Contents in brief:

1. **Foundational Concepts:**
    - Define Recommender Systems and their impact across various industries.
    - Explore core algorithms like collaborative filtering, Markov chains, and hybrid approaches.
    - Discuss scalability challenges and optimization techniques for large-scale implementations.
    - Analyze case studies of successful implementations from diverse domains.
2. **Machine Learning and Neural Networks for Recommendations:**
    - Learn key AI techniques used in Recommendation: matrix factorization, neighborhood methods, and an introduction to deep learning for recommendations.
    - Understand the role of neural networks in building advanced recommender systems that capture complex user preferences and item relationships.
    - Explore various neural network architectures commonly used for recommendations, such as Recurrent Neural Networks and Transformers.
3. **Telecommunications:**
    - Personalization of network resource allocation based on user profiles and traffic patterns.
    - Optimization of content delivery with recommendation of appropriate caching strategies.
    - Development of recommender systems for suggesting network service plans tailored to individual customer needs.
4. **Biosciences:**
    - Analyze vast patient data and molecular structures using Recommender Systems for drug discovery, recommending promising drug candidates.
    - Implement systems for personalized medicine by recommending targeted therapies based on individual patient profiles.
    - Utilize Recommender Systems to recommend targeted interventions for disease prevention and management.
5. **Automation Engineering:**
    - Utilize Recommender Systems to analyze sensor data and recommend maintenance schedules based on predicted component degradation.
    - Implement Recommender Systems to recommend optimal component sourcing and production strategies based on real-time demand and inventory data.
    - Design Recommender Systems to recommend product configurations tailored to individual customer needs and specifications.

The course will leverage Python for practical implementation of RS concepts. Students will be introduced to essential libraries like: NumPy, Pandas, Scikit-learn, TensorFlow and PyTorch.

Total # of hours of lecture: 20 hours

References:

[1] Lü, L., Medo, M., Yeung, C. H., Zhang, Y. C., Zhang, Z. K., & Zhou, T. (2012). Recommender systems. Physics reports, 519(1), 1-49.

[2] Mu, R. (2018). A survey of recommender systems based on deep learning. Ieee Access, 6, 69009-69022.

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[4] Fu, Y., Salaün, L., Yang, X., Wen, W., & Quek, T. Q. (2021). Caching efficiency maximization for device-to-device communication networks: A recommend to cache approach. IEEE Transactions on Wireless Communications, 20(10), 6580-6594.

[5] Zhang, Z., Lin, H., Liu, K., Wu, D., Zhang, G., & Lu, J. (2013). A hybrid fuzzy-based personalized recommender system for telecom products/services. Information Sciences, 235, 117-129.

[6] Sosnina, E. A., Sosnin, S., Nikitina, A. A., Nazarov, I., Osolodkin, D. I., & Fedorov, M. V. (2020). Recommender systems in antiviral drug discovery. ACS omega, 5(25), 15039-15051.

[7] Gräßer, F., Beckert, S., Küster, D., Schmitt, J., Abraham, S., Malberg, H., & Zaunseder, S. (2017). Therapy decision support based on recommender system methods. Journal of healthcare engineering, 2017(1), 8659460.

[8] Hors-Fraile, S., Rivera-Romero, O., Schneider, F., Fernandez-Luque, L., Luna-Perejon, F., Civit-Balcells, A., & de Vries, H. (2018). Analyzing recommender systems for health promotion using a multidisciplinary taxonomy: A scoping review. International journal of medical informatics, 114, 143-155.

[9] Durbhaka, G. K., & Selvaraj, B. (2016, September). Predictive maintenance for wind turbine diagnostics using vibration signal analysis based on collaborative recommendation approach. In 2016 International conference on advances in computing, communications and informatics (ICACCI) (pp. 1839-1842). IEEE.

[10] Dadouchi, C., & Agard, B. (2021). Recommender systems as an agility enabler in supply chain management. Journal of Intelligent Manufacturing, 32(5), 1229-1248.

[11] Pereira, J. A., Matuszyk, P., Krieter, S., Spiliopoulou, M., & Saake, G. (2018). Personalized recommender systems for product-line configuration processes. Computer Languages, Systems & Structures, 54, 451-471.

CV of the Teachers

Nicola Tonellotto is associate professor at the Department of Information Engineering of the University of Pisa. From 2002 to 2019 he was researcher at the Information Science and Technologies Institute “A. Faedo” of the National Research Council of Italy. His main research interests include Cloud Computing, Web Search, and Information Retrieval, with a particular focus on efficient data processing and neural information retrieval. He co-authored more than 100 papers on these topics in peer reviewed international journals and conferences. He is honorary research fellow in the College of Science & Engineering of the School of Computing Science of the University of Glasgow since 2020 and distinguished member of the ACM since 2023.

Federico Siciliano is a postdoctoral researcher at Sapienza University of Rome, having recently completed his PhD in Data Science at the same university, with a thesis on Architectural Components of Trustworthy Artificial Intelligence. His research includes Information Retrieval, Recommender Systems and Explainable Artificial Intelligence. He partnered with numerous world-renowned institutions, including Cambridge University, Meta, Amazon, and University of Pisa, among others. His teaching experience encompasses five years as a Teaching Assistant for the Data Mining Technology course at Sapienza University of Rome. He further expanded his teaching expertise by teaching a Data Mining course for the Bank of Italy.

Final Exam:

- Project Proposal and Presentation: Students will develop a project proposal focusing on applying Recommender Systems concepts to a chosen domain relevant to their PhD field. The proposal (4-7 pages) should outline: specific Recommender Systems application and domain focus, data acquisition strategy (if applicable), chosen Recommender Systems techniques and algorithms, evaluation metrics for success, expected outcomes and impact. Students will present their proposals (15 minutes, including Q&A) and explain how their project would contribute to the field. The proposal and presentation will be evaluated based on originality, feasibility, technical execution plan, and understanding of Recommender Systems principles within the chosen domain.

Room and Schedule

Room: *Aula Riunioni del Dipartimento di Ingegneria dell’Informazione, Via G. Caruso 16, Pisa – Ground Floor*

Schedule:

5/5/2025 – 14:30-18:30

6/5/2025 – 14:30-18:30

7/5/2025 – 14:30-18:30

8/5/2025 – 14:30-18:30

9/5/2025 – 14:30-18:30