Computational Methods for Designing Human-Centered Recommender Systems: A Case Study Approach Intersecting Visual Arts and Healthcare

Bereket A. Yilma
bereket.yilma@uni.lu
University of Luxembourg
Luxembourg

ABSTRACT

Recommender Systems (RecSys) are essential tools in sectors like e-commerce, entertainment, and social media, providing personalized user experiences. Their impact is also growing in education, healthcare, tourism, transport, and logistics, enhancing decision-making and user engagement. Hence, designing modern RecSys requires a multi-disciplinary approach, incorporating machine learning, information retrieval, and human-computer interaction (HCI). This course focuses on human-centric RecSys design, emphasizing both computational methods and user-centered principles. Participants will learn fundamental concepts, advanced algorithms, and practical implementation, with case studies linking visual arts and healthcare applications.

CCS CONCEPTS

• **Human-centered computing**; • **Information systems** → **Personalization**; **Recommender systems**;

KEYWORDS

Recommendation, Personalization, Machine Learning

ACM Reference Format:
Bereket A. Yilma. 2024. Computational Methods for Designing Human-Centered Recommender Systems: A Case Study Approach Intersecting Visual Arts and Healthcare. In *ACM Conference on Recommender Systems (RecSys'24), 14–18 October 2024, Bari, Italy*. ACM, New York, NY, USA, 3 pages. https://doi.org/XXXXXXX.XXXXXXX

1 MOTIVATION

Recommender Systems (RecSys) are revolutionizing several sectors, including e-commerce, entertainment, and social media, by providing personalized experiences to users [5]. Their impact extends far beyond these traditional domains. RecSys applications are gaining momentum in diverse fields such as education, industry, healthcare, tourism, transport, and logistics, where they enhance decision-making processes, improve user engagement, and drive business success. Designing and developing modern-day RecSys is a multi-disciplinary effort that benefits from advancements obtained in different computer science fields, particularly Machine learning, Information retrieval and human-computer interaction (HCI)[2]. To harness the full potential of RecSys engines, professionals and researchers must equip themselves with a holistic understanding of not only the computational methods enabling the design and development of these systems but also the know-how to ensure human aspects are the centre of the design [1]. Hence this course approaches Recsys from a human-centred perspective, looking at the interface and algorithm studies that advance understanding of how system designs can be tailored to users' objectives and needs while taking into account external factors such as commercialization. By participating in this course, attendees will acquire a comprehensive understanding of the computational methods to design human-centric RecSys, encompassing fundamental concepts, advanced algorithms, and practical implementation with a more emphasis on putting humans at the heart of the design process. This course takes a case study approach to RecSys from an HCI perspective intersecting visual arts with healthcare application.

RecSys'24, 14–18 October 2024, Bari, Italy
2024. ACM ISBN 978-1-4503-XXXX-X/24/05…$15.00
https://doi.org/XXXXXXX.XXXXXXX

2 INTENDED AUDIENCE

This course is designed to accommodate a broad range of participants, including researchers and practitioners interested in Human-centric RecSys, graduate students and academics new to RecSys or exploring RecSys as a research topic as well as professionals working in industries where human-centred RecSys applications are relevant.

3 PREREQUISITES

The course has no special prerequisites. However, examples and practical exercises will be given in Python. Specifically Python notebooks will be used to interactively learn to use models and provide ground for the attendees to learn to develop different RecSys engines. Thus, basic Python programming knowledge is recommended. In addition, familiarity with Machine Learning, and basic skills in Linear Algebra and Probability Theory are also beneficial.

4 CONTENT

This course adopts a comprehensive top-down approach, strategically structured to provide students with a profound understanding of personalization within the context of smart interactive environments. It begins by establishing a robust theoretical foundation grounded in systemic thinking and the modelling of users in smart interactive environments. Central to this framework is the incorporation of concepts from the domain of Cyber-Physical-Social Systems (CPSS), which encapsulate environments where humans coexist with sensor-enabled smart devices [14]. Smart Cities, Smart Homes, Schools, Offices, Museums, and medium to large-scale industries are among the main examples where the CPSS notion has gained momentum [3, 4, 12]. This first segment of the course lays the foundations for modelling users and guides students on how to

formulate personalization problems at varying levels of complexity within smart interactive systems. This is achieved by employing the CPSS analogy and fostering systemic thinking.

The next part will focus on a brief introduction of RecSys topic as a sub-domain of personalization. Here, students are introduced to state-of-the-art approaches, the fundamental principles and concepts that underpin RecSys and modern RecSys paradigms. Then, the course will dive into the RecSys pipeline taking a case-study approach. Particularly this part focuses on an interesting sequence of RecSys scenarios building a story from visual arts and entertainment domain gradually moving to healthcare application based on a series of papers recently published by the lecturer at SIGCHI [8, 9] and UMAP [10, 13]. It begins with smart museum scenarios which feature a case study from the National Gallery in London [11]. Within these immersive scenarios, students encounter instances where pure personalization is paramount, as well as situations that necessitate departing from a sole optimization of user satisfaction to bring multi-stakeholder awareness [13]. Building upon these, a second case study from [8] extends the first part to the domain of healthcare showcasing how Recsys engines can be utilised to support Post Intensive Care Syndrome (PICS) intervention. The multifaceted nature of the case studies allows students to learn how to leverage various computational methods and Machine learning algorithms to effectively design Human-centered RecSys engines as well as evaluation techniques beyond offline measures. This will focus on different aspects of conducting user studies and validating RecSys performance on user-centric measures. All case studies will be complemented by a practical session that will further enhance the understanding of the presented concepts by allowing students to implement various RecSys engines and utilise pre-trained models [7–10] in an interactive mode using a unique visual art dataset from the National Gallery in London.[1]

5 COURSE AGENDA

The course is structured in 3 parts (a total of 180 minutes) subject to modifications depending on available slots:

- **Part 1:** Introduction [**45 mins**]
  - Foundation: Personalization, Cyber-Physical-Social Systems (CPSS) & RecSys
  - Why Human-centred RecSys?
  - The Recsys Pipeline & a framework for modelling.
- **Part 2:** The RecSys Pipeline: A case-study approach [**90 mins**]
  - **Case-study 1**: Personalized Visual Art Recommendation
    - Problem formulation
    - Solutions: Computational methods
      - Data Representation learning (Unimodal & Multimodal)
      - Transfer learning (Convolutional Neural Networks)
      - Topic Modelling Latent Dirichlet Allocation (LDA)
      - Neural topic modelling (Sentence Transformers)
    - Evaluation Techniques & Results
      - Offline Experiments
      - User Studies
      - Online Experiments
  - **Case-study 2**: Personalized Visual Art & Path Recommendation: A multi-stakeholder aware approach
    - Problem formulation
    - Solutions: Computational methods
      - Mixed-Integer Linear Programming (MILP) Algorithms
    - Evaluation Techniques
      - Offline Experiments
      - User Studies
      - Online Experiments
  - **Case-study 3**: Visual Art Recommendation Systems for Post-Intensive Care Syndrome (PICS) intervention.
    - Problem formulation
    - Solutions: Unimodal & multimodal VA Recsys engines
    - Ensuring safe and sensitive deployment
    - User evaluation & Results
    - Lessons learned
- **Part 3:** Hands-on: Practical excesses on the case studies with Python Jupyter notebooks [**45 mins**]

6 INSTRUCTOR BACKGROUND

Dr. Bereket Yilma is a Computer Scientist specializing in optimization and applied Machine Learning. He holds a PhD in Automatic Signal and Image Processing, and Computer Engineering. Currently, he works as a researcher within the Computational Interaction (COIN) research group at the University of Luxembourg and is a Lecturer in the Department of Computer Science. He also serves as the instructor of Recommender Systems in the Doctoral School of Computer Science and Computer Engineering. His research focuses on various aspects of Human-Centered Artificial Intelligence, including Recommender Systems, Adaptive User Interfaces, and Personalization in the context of Smart Interactive Environments aka Cyber-Physical-Social Systems (CPSS). He also actively contributes to Brain-Computer Interfaces (BCI) research within the framework of the BANANA project, Brainsourcing for Affective Attention Estimation[2]. As an Associate Chair of SIGCHI, Dr. Yilma plays a key role in the HCI community. He is an Instructor at the SIGCHI CIX Summer Schools and serves as a PC member and reviewer for flagship HCI/ML venues, and ACM Conferences, such as CIKM, IUI, SIGIR, AAAI, LOD, ICML, ICLR, and NeurIPS.

7 RESOURCES

This course is a compressed version of a 2 ECTS Doctoral course, *Recommender Systems: an overview* that is being offered as part of PhD training in the Doctoral School of Computer Science and Computer Engineering[3] at the University of Luxembourg since 2022. All information about content can be found on the course websites first edition and second edition. A special version of the course has been previously offered at the 7^{th} CIX Summer School on Computational Interaction.[4] The course materials are available on the summer school's official GitHub repository.[5] Resources for this RecSys 2024 tutorial are available at the tutorial Website .

[1] https://www.nationalgallery.org.uk

[2] https://project-banana.eu/

[3] https://www.uni.lu/research-en/doctoral-education/dsse/computer-engineering/

[4] https://cixschool2023.engin.umich.edu/

[5] https://github.com/cixumich23/CIXSummerSchool2023

Projects and other related materials, (Source code, dataset and pre-trained models) by the instructor that make use of computational methods in the context of RecSys that will also be employed in this course are publicly available:

- https://github.com/Bekyilma/VA_RecSys
- https://github.com/Bekyilma/MRL_VA_RecSys
- https://github.com/Bekyilma/Multi-Stakeholder_RecSys
- https://github.com/Bekyilma/RecSys-an-overview

8 ACCESSIBILITY

The course has been previously offered following the accessible presentation guidelines of SIGACCESS[6]. Furthermore, the practical session makes heavy use of Python notebooks, which offer a large range of accessibility tools such as the Accessibility Toolbar (AT4N) which supports users who are dyslexic or visually impaired.

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