Chapter 1
Introduction to Recommendation Systems

Abstract Recommendation systems nowadays are widely used in various industries, including healthcare, finance, social media, business, IT, Pharmacy, government, etc. Along with the development and thriving of WWW and other important computer software and hardware techniques, such as IOT, neural networks, and quantum techniques, the breadth and depth of the use of recommendation systems have improved significantly. In this chapter, we highlight the evolution of recommendation techniques and systems, from traditional recommendation systems such as collaborative filtering, content-based recommendation systems, knowledge-based recommendation systems, and ensemble recommendation systems to deep-learning-based recommendation systems such as neural collaborative filtering, deep neural recommendation networks; from traditional standalone recommendation systems to web-based large-scale recommendation systems used nowadays. Then, we introduce the main applications of recommendation systems in our daily lives and beyond in various industries and academies. Finally, we discuss several important advanced topics in this area. Including how to handle context to improve recommendation performance, hybrid recommendation techniques, explainable recommendation techniques, privacy-preserving recommendation techniques, how to handle cold-start problems, dynamic environments in recommendation systems, and ethical considerations. Properly handling these problems and integrating related techniques is critical to the design and implementation of effective and efficient recommendation systems.

Chapter 2
Traditional Recommendation Systems

Abstract Traditional recommendation systems rely on statistical models and machine learning algorithms to predict user preferences and suggest relevant items. These systems typically fall into four main categories: collaborative filtering, content-based filtering, knowledge-based filtering, and ensemble recommendation systems. Collaborative filtering is further divided into user-based collaborative filtering that recommends items based on similarities between users, item-based collaborative filtering that recommends items based on similarities between items. hybrid collaborative filtering that combines user-based and item-based approaches. Content-Based Filtering recommends items based on their attributes and a user's preferences. Knowledge-based recommendation systems leverage domain-specific knowledge to improve the accuracy and relevance of recommendations. These systems incorporate external information, such as ontologies, taxonomies, or rules, to provide more informed suggestions. Ensemble recommendation systems combine multiple recommendation algorithms to leverage their strengths and address their weaknesses. By combining different approaches, these systems can provide more accurate, personalized, and robust recommendations. In this chapter, we describe in detail these four types of recommendation systems or techniques and present the mathematical foundations that builds these systems.

Chapter 3
Deep Learning for Recommendation Systems

Abstract Deep learning has revolutionized the field of recommendation systems, offering unprecedented accuracy and personalization. By leveraging neural networks to learn complex patterns and relationships within vast datasets, these systems can effectively predict user preferences and provide highly relevant recommendations. In this chapter, we introduce deep learning foundations that build deep learning techniques used in recommendation systems, including neural network architectures, general training processes, and important training components such as loss functions and optimization methods. The main kinds of neural network architectures are described in detail: feedforward networks, recurrent neural networks, and convolutional neural networks. Particularly, we describe the detailed architectures, benefits, and challenges of each of these kinds. Then, we describe several advanced deep-learning techniques that are frequently used in the design and implementation of deep-learning-based recommendation systems, including Neural Collaborative Filtering, Deep Embeddings, Attentions, and Transformers, etc. Finally, we highlight the applications of deep learning in real-world recommendation systems with a focus on those in E-commerce, social media, streaming services, content creation, etc.

Chapter 4
Deep-Learning-Based Recommendation Systems

Abstract Deep-learning-based recommendation Systems, sometimes also called Deep Recommendation Systems leverage the power of deep neural networks to enable enhanced user experience that traditional recommendation systems might fail to provide. In this chapter, we describe several main deep recommendation models that are frequently used in the design and implementation of deep recommendation systems, including Feedforward-based recommendation models, RNN-based recommendation models, CNN-based recommendation models, Deep RL-based recommendation models, and Depp LLM-based recommendation models. Then, we describe in detail several examples of popular end-to-end deep recommendation systems, including Neural Collaborative Filtering, Wide and Deep Recommendation Networks, Deep Factorization Machines, and Variational Autoencoders. These recommendation systems are the core components of modern recommendation systems. Challenges and considerations in the design of implementation of these systems and the attempted solutions are discussed in detail. In real-world recommendation systems, one or multiple deep recommendation models may be used for different functionalities. Finally, we introduce the main modules using deep recommendation systems or techniques in real-world recommendation systems.

Chapter 5
Advanced Recommendation Systems

Abstract Advanced recommendation systems are developed to conquer specific challenges in real-world recommendation problems. These recommendation systems or techniques may not be generalized to solve all recommendation problems but usually can outperform their counterparts on recommendation problems that they are designed to handle. These advanced recommendation systems include contextual recommendation systems which utilize the context of users and items to improve the recommendation performance, dynamic recommendation systems which address dynamic environments that usually change continuously during user interactions, Privacy-Preserving Recommendation Systems that focus on preserving users' privacy, Recommendation Systems for Cold-Start which focus on performance improvements during the system cold-start stage, Explainable Recommendation Systems which try to enhance the explainability of the recommendation systems, Recommendation Systems with Ethical Considerations that ensure they are developed and deployed in a responsible and ethical manner, and Hybrid Recommendation Systems that combine two or two components of these advanced recommendation systems. In the meantime, we focus on the deep-learning solutions to these recommendation systems and present detailed examples of each type.

Chapter 6
Real-Wolrd Recommendation Systems

Abstract Recommendation systems have become an integral part of our daily lives, influencing our choices in everything from movies and music to products and services. In this chapter, we delve deeper into some real-world examples and their impacts in multiple industries, including E-commerce and Retail, Content Streaming, Social Media, and Gamming. Then, we describe several real-world recommendation systems that are serving millions to billions of users world-wide. Example systems include Google Image Recommendation System, Youtube, Google Content Recommendation System, Amazon Product Recommendation System, Facebook Social Networking System, Linkedin Job Recommendation System, and Wiki Knowledge-based Recommendation System.

Chapter 7
System Performance Evaluations

Abstract Evaluating recommendation systems is crucial to ensure their effectiveness and relevance. There are various metrics and techniques used to assess the performance of these systems. In this chapter, we describe the key performance evaluation metrics for evaluating recommendation systems of different types, and present detailed examples of performance evaluation using these metrics. These metircs include precision, recall, F1-score, Mean Reciprocal Rank (MRR), Normalized Discounted Cumulative Gain (NDCG), Click-Through Rate (CTR), Conversion Rate (CVR). Then, we describe evaluation techniques that use these metrics for system performance evaluation. Two main types of evaluation techniques are frequently used: offline evaluation and online evaluation. Offline evaluation include methods such as splitting data, predicting ratings, and comparing predictions. Online evaluation include methods such as A/B testing, Bandit algorithms and Interleaving.

Chapter 8
Advanced Topics

Abstract Recommendation systems have been studied on for tens of years, yet challenges still exist and are not completely solved in the design and implementation of real-world recommendation systems. In this chapter, we re-catch and discuss in detail several advanced topics in recommendation systems, and summarize and propose tentative solutions to improve the effectiveness and efficiency of recommendation systems. These topics include context sensitivity, time and location sensitivity, sociality and trust, attack resistance, fair recommendation, privacy preservation, and personalization. Finally, we briefly discuss the ongoing research in this area and future directions of recommendation systems.