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Editors

Multimedia Services in Intelligent Environments

Advances in Recommender Systems

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Foreword

I have always believed that the most fertile ground for innovation is the "valley" between two or more active research areas. This belief has shaped my research activity so far, guiding me in exciting journeys between machine learning and personalization, among others. The editors of this book, and its three predecessors in the series, share the same enthusiasm for cross-fertilization of different research domains. Having themselves contributed significantly in different areas, ranging from pattern recognition to user modeling and intelligent systems, they decided to present different views upon *Multimedia Systems and Services, including tools and methodologies*, *software development*, s*ystem integration and now recommender systems*.

Recent advances in Information and Communication Technologies (ICT) have increased the computational power of computers, while embedding them in various mobile devices, thus increasing enormously the possibilities of communication and transfer of data. These developments have created new opportunities for generating, storing and sharing multimedia, such as audio, image, video, animation, graphics, and text. YouTube for example, has more than 1 billion unique visitors each month, uploading 72 hours of video every minute! Providing the infrastructure to make this possible was clearly the first step, but at this volume of data one needs to urgently address the issue of retrieving the most suitable information for each user efficiently. Failure to do so may result in disappointment of the users in the near future and a major set-back in this revolutionary social development.

Personalization is among the most convincing proposals in addressing this problem of information overload. In particular recommender systems provide simple and very effective ways of understanding the needs and interests of individuals and selecting the content they would be more interested in. Such systems have been used to assist users in selecting movies, music, books and content in various other forms. The blending of the two very different research areas, multimedia systems and recommender systems, seems to be providing a new very fertile field for innovation.

In this book, the editors and the authors of the individual chapters present recent advances in designing and applying recommender systems to multimedia systems and services. I consider this particularly timely, as the need to address the overload with multimedia information has sparked research activity throughout the world. Therefore, the book is expected to provide a good overview of current research to newcomers in the field and help them gain insights on how to add value to multimedia systems and services through intelligent content recommendation. An exciting research and innovation arena that is still being shaped.

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Preface

Multimedia services are now commonly used in various activities in the daily lives of humans. Related application areas include services that allow access to large depositories of information, digital libraries, e-learning and e-education, e-government and e-governance, e-commerce and e-auctions, e-entertainment, e-health and e-medicine, and e-legal services, as well as their mobile counterparts (i.e., *m-services*). Despite the tremendous growth of multimedia services over the recent years, there is an increasing demand for their further development. This demand is driven by the ever-increasing desire of society for easy accessibility to information in friendly, personalized, and adaptive environments. With this view in mind, we have been editing a series of books on *Multimedia Services in Intelligent Environments* [1–9].

Specifically, this book is a continuation of our previous books [1–3]. In this book, we examine recent *Advances in Recommender Systems*. Recommender systems are crucial in multimedia services, as they aim at protecting the service users from *information overload*. The book includes nine chapters, which present various recent research results in recommender systems. Each chapter in the book was reviewed by two independent reviewers for novelty and clarity of the research presented in it. The reviewers' comments were incorporated in the final version of the chapters.

This research book is directed to professors, researchers, application engineers, and students of all disciplines. We hope that they all will find it useful in their works and researches.

We are grateful to the authors and the reviewers for their excellent contributions and visionary ideas. We are also thankful to Springer for agreeing to publish this book. Last, but not least, we are grateful to the Springer staff for their excellent work.

Piraeus, Greece — George A. Tsihrintzis
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Adelaide, Australia — Lakhmi C. Jain

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Contents

Multimedia Services in Intelligent Environments: Advances in Recommender Systems

George A. Tsihrintzis, Maria Virvou and Lakhmi C. Jain

Abstract Multimedia services are now commonly used in various activities in the daily lives of humans. Related application areas include services that allow access to large depositories of information, digital libraries, e-learning and e-education, egovernment and e-governance, e-commerce and e-auctions, e-entertainment, e-health and emedicine, and e-legal services, as well as their mobile counterparts (i.e., m-services). Despite the tremendous growth of multimedia services over the recent years, there is an increasing demand for their further development. This demand is driven by the everincreasing desire of society for easy accessibility to information in friendly, personalized and adaptive environments. With this view in mind, we have been editing a series of books on Multimedia Services in Intelligent Environments [1-4]. This book is the fourth in this series. In this book, we examine recent Advances in Recommender Systems, which are crucial in multimedia services, as they aim at protecting the service users from information overload.

1 Introduction

The term *Multimedia Services* has been coined to refer to services which make use of coordinated and secure storage, processing, transmission, and retrieval of information which exists in various forms. As such, the term refers to several levels of data processing and includes such diverse application areas as digital libraries, e-learning, e-government, e-commerce, e-entertainment, e-health, and e-legal services, as well as their mobile counterparts (i.e., *m-services)*. As new

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multimedia services appear constantly, new challenges for advanced processing arise daily. Thus, we have been attempting to follow relevant advances in a series of edited books on multimedia services in intelligent environments. This is the fourth volume on the topic. In our earlier books [1–3], we covered various aspects of processing in multimedia services.

More specifically, in [1] we were concerned mostly with low level data processing in multimedia services in intelligent environments, including storage (Chap. 2), recognition and classification (Chaps. 3 and 4), transmission (Chaps. 5 and 6), retrieval (Chaps. 7 and 8), and securing (Chaps. 9 and 10) of information. Four additional chapters in [1] presented intermediate level multimedia services in noise and hearing monitoring and measuring (Chap. 11), augmented reality (Chap. 12), automated lecture rooms (Chap. 13) and rights management and licensing (Chap. 14). Finally, Chap. 15 was devoted to a high-level intelligent recommender service in scientific digital libraries.

In [2], we were concerned with various software development challenges and related solutions that are faced when attempting to accommodate multimedia services in intelligent environments. Specifically, [2] included an editorial introduction and ten additional chapters, as follows: Chap. 2 by Savvopoulos and Virvou was on "Evaluating the generality of a life-cycle framework for incorporating clustering algorithms in adaptive systems." Chapter 3 by Chatterjee, Sadjadi and Shu-Ching Chen dealt with "A Distributed Multimedia Data Management over the Grid." Chapter 4 was authored by Pirzadeh and Hamou-Lhadj and covered "A View of Monitoring and Tracing Techniques and their Application to Service-based Environments." Chapter 5 by Bucci, Sandrucci, and Vicario was devoted to "An ontological SW architecture supporting the contribution and retrieval of Service and Process models." Chapter 6 by D'Ambrogio dealt with "Model-driven Quality Engineering of Service-based Systems." Chapter 7 by Katsiri, Serrano, and Serat dealt with "Application of Logic Models for Pervasive Computing Environments and Context-Aware Services Support," while Chap. 8 by Patsakis and Alexandris covered "Intelligent Host Discovery from Malicious Software."

In [2], we also included three chapters on new theoretical results, development methodologies and tools which hold promise to be useful in the development of future systems supporting multimedia services in intelligent environments. Specifically, Chap. 9 by Fountas dealt with "Swarm Intelligence: The Ant Paradigm," while Chap. 10 by Artikis dealt with "Formulating Discrete Geometric Random Sums for Facilitating Intelligent Behaviour of a Complex System under a Condition of Major Risk." Finally, Chap. 11 by Artikis dealt with "Incorporating a Discrete Renewal Random Sum in Computational Intelligence and Cindynics."

In [3], we presented various integrated systems that were developed to accommodate multimedia services in intelligent environments. Besides the editorial introduction, [3] included thirteen additional chapters, as follows: Chaps. 2 and 3 were devoted to multimedia geographical information systems. Specifically, Chap. 2 by Gemizi, Tsihrintzis, and Petalas was on "Use of GIS and Multi-Criteria

Evaluation Techniques in Environmental Problems," while Chap. 3 by Charou, Kabassi, Martinis, and Stefouli was on "Integrating Multimedia GIS Technologies in a Recommendation System for Geotourism." Chapters 4 and 5 covered aspects of e-entertainment systems. Specifically, Chap. 4 by El-Nasr and Zupko was on "Lighting Design Tools for Interactive Entertainment," while Chap. 5 by Szczuko and Kostek was on "Utilization of Fuzzy Rules in Computer Character Animation". Chapters 6, 7 covered aspects of education and e-learning systems. Specifically, Chap. 6 by Nakatani, Tsumaki, and Tamai was on "Instructional Design of a Requirements Engineering Education for Professional Engineers," while Chap. 7 by Burdescu and Mihăescu was on "Building Intelligent e-Learning Systems by Activity Monitoring and Analysis." Chapters 8, 9 were devoted to medical diagnosis systems. Specifically, Chap. 8 by Schmidt and Vorobieva was on "Supporting the Search for Explanations of Medical Exceptions," while Chap. 9 by Aupet, Garcia, Guyennet, Lapayre, and Martins was on "Security in Medical Telediagnosis."

Chapters 10, 11 were devoted to telemonitoring systems. Specifically, Chap. 10 by Żwan, Sobala, Szczuko, and Czyzewski was on "Audio Content Analysis in the Urban Area Telemonitoring System," while Chap. 11 by Dalka, Szwoch, Szczuko, and Czyzewski was on "Video Content Analysis in the Urban Area Telemonitoring System." Chapter. 12 by Karapiperis, Stojanovic, Anicic, Apostolou and Despotis, was on "Enterprise Attention Management." An additional chapter, namely Chap. 13 by Raij and Lehto, was on "e-Welfare as a Client-driven Service Concept." Finally, Chap. 14 by Panoulas, Hadjileondiadis, and Panas was on "Brain-Computer Interface (BCI): Types, Processing Perspectives and Applications."

The book at hand is a continuation of our coverage of multimedia services in intelligent environments. In particular, this book is devoted to a specific class of software systems, called *Recommender Systems*, which are analyzed in the following section.

2 Recommender Systems

Recent advances in electronic media and computer networks have allowed the creation of large and distributed repositories of information. However, the immediate availability of extensive resources for use by broad classes of computer users gives rise to new challenges in everyday life. These challenges arise from the fact that users cannot exploit available resources effectively when the amount of information requires prohibitively long user time spent on acquaintance with and comprehension of the information content. Thus, the risk of information overload of users imposes new requirements on the software systems that handle the information. Such systems are called *Recommender Systems* and attempt to provide information in a way that will be most appropriate and valuable to its users and prevent them from being overwhelmed by huge amounts of information that, in the absence of recommender systems, they should browse or examine [4].

Besides the current editorial chapter, the book includes an additional eight (8) chapters organized into two parts. The first part of the book consists of Chaps. 2, 3, 4 and 5. In this part, we address various aspects of recommender systems which form the core of recommendation services. Specifically, Chap. 2 by Lampropoulos and Tsihrintzis is on "A Survey of Approaches to Designing Recommender Systems." Chapter 3 by Nguyen and Santos is on "Hybrid User Model For Capturing a User's Information Seeking Intent." Chapter 4 by Lamb, Randles and Al-Jumeily is on "Recommender Systems: Network Approaches." Chapter 5 by Felfernig, Jeran, Ninaus, Reinfrank, and Reiterer makes contributions "Towards the Next Generation of Recommender Systems: Applications and Research Challenges."

The second part of the book consists of four chapters and presents various new theoretical results and tools that are expected to be incorporated in and improve recommender systems and recommendation services. Chapter 6 by Toledo, Sookhanaphibarn, Thanwonmas, and Rinaldo is on "Content-based Recommendation for Stacked-Graph Navigation," while Chap. 7 by Sakamoto and Kuboyama is on "Pattern Extraction from Graphs and Beyond." Chapter 8 by Kinoshita is on "Dominant Adaptive Hierarchical Process as Measuring Method of Service Values," while, finally, Chap. 9 by Artikis and Artikis is on "Applications of a Stochastic Model in Supporting Intelligent Multimedia Systems and Educational Processes."

3 Conclusions

To avoid the risk of information overload of users, new requirements are imposed on the software systems that handle the information. Such systems are called *Recommender Systems* and attempt to provide information in a way that will be most appropriate and valuable to its users and prevent them from being overwhelmed by huge amounts of information that, in the absence of recommender systems, they should browse or examine. In this book, we have investigated recommender systems and attempted to both survey the field of methodologies incorporated in current recommender systems and look at future recommender systems and new, more advanced recommendation methodologies.

As the field of recommendation cannot be covered in one volume, we have devoted our next book in this series to *Recommendation Services* [4]. In there, we examine a variety of specific recommendation applications, from fields such as biology and medicine, education, mobile computing, cultural heritage, tourism, etc.

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A Survey of Approaches to Designing Recommender Systems

Aristomenis S. Lampropoulos and George A. Tsihrintzis

Abstract The large amount of information resources that are available to users imposes new requirements on the software systems that handle the information. This chapter provides a survey of approaches to designing recommenders that address the problems caused by information overload.

1 Introduction to Recommender Systems

Recent advances in electronic media and computer networks have allowed the creation of large and distributed repositories of information. However, the immediate availability of extensive resources for use by broad classes of computer users gives rise to new challenges in everyday life. These challenges arise from the fact that users cannot exploit available resources effectively when the amount of information requires prohibitively long user time spent on acquaintance with and comprehension of the information content. Thus, the risk of information overload of users imposes new requirements on the software systems that handle the information. One of these requirements is the incorporation into the software systems of mechanisms that help their users when they face difficulties during human-computer interaction sessions or lack the knowledge to make decisions by themselves. Such mechanisms attempt to identify user information needs and to personalize human-computer interactions. (Personalized) Recommender Systems

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(RS) provide an example of software systems that attempt to address some of the problems caused by information overload.

RS are defined in [1] as software systems in which “people provide recommendations as inputs, which the system then aggregates and directs to appropriate recipients.” Today, the term includes a wider spectrum of systems describing any system that provides individualization of the recommendation results and leads to a procedure that helps users in a personalized way to interesting or useful objects in a large space of possible options. RS form an important research area because of the abundance of their potential practical applications.

Clearly, the functionality of RS is similar to the social process of recommendation and reduction of information that is useless or uninteresting to the user. Thus, one might consider RS as similar to search engines or information retrieval systems. However, RS are to be differentiated from search engines or information retrieval systems as a RS not only finds results, but additionally uses its embedded individualization and personalization mechanisms to select objects (items) that satisfy the specific querying user needs. Thus, unlike search engines or information retrieval systems, a RS provides information in a way that will be most appropriate and valuable to its users and prevents them from being overwhelmed by huge amounts of information that, in the absence of RS, they should browse or examine. This is to be contrasted with the target of a search engine or an information retrieval system which is to “match” items to the user query. This means that a search engine or an information retrieval system tries to form and return *a ranked list* of all those items that match the query. Techniques of active learning such as *relevance-feedback* may give these systems the ability to refine their results according to the user preferences and, thus, provide a simple form of recommendation. More complex search engines such as *GOOGLE* utilize other kinds of criteria such as “*authoritativeness*”, which aim at returning as many useful results as possible, but *not* in an individualized way.

A learning-based RS typically works as follows: (1) the recommender system collects all given recommendations at one place and (2) applies a learning algorithm, thereafter. Predictions are then made either with a model learnt from the dataset (model-based predictions) using, for example, a clustering algorithm [2, 3] or on the fly (memory-based predictions) using, for example, a nearest neighbor algorithm [2, 4]. A typical prediction can be a list of the top-*N* recommendations or a requested prediction for a single item [5].

Memory-based methods store training instances during training which are can be retrieved when making predictions. In contrast, model-based methods generalize into a model from the training instances during training and the model needs to be updated regularly. Then, the model is used to make predictions. Memory-based methods learn fast but make slow predictions, while model-based methods make fast predictions but learn slowly.

The roots of RS can be traced back to Malone et al. [6], who proposed three forms of filtering: cognitive filtering (now called content-based filtering), social filtering (now called collaborative filtering (CF)) and economic filtering. They also suggested that the best approach was probably to combine these approaches into the category of, so-called, *hybrid* RS.

1.1 Formulation of the Recommendation Problem

In general, the recommendation problem is defined as the problem of estimating ratings for the items that have not been seen by a user. This estimation is based on:

- ratings given by the user to other items,
- ratings given to an item by other users,
- and other user and item information (e.g. item characteristics, user demographics).

The recommendation problem can be formulated [7] as follows:

Let U be the *set of all users* $U = \{u_1, u_2, \ldots, u_m\}$ and let I be the *set of all possible items* $I = \{i_1, i_2, \ldots, i_n\}$ that can be recommended, such as music files, images, movies, etc. The space I of possible items can be very large.

Let f be a utility function that measures the usefulness of item i to user u,

$$f : U \times I \rightarrow R, \tag{1}$$

where R is a totaly ordered set (e.g. the set of nonnegative integers or real numbers within a certain range). Then, for each user $u \in U$, we want to choose an item $i' \in I$ that maximizes the user utility function, i.e.

$$\forall u \in U, i'_u = \arg\max_{i \in I} f(u, i). \tag{2}$$

In RS, the utility of an item is usually represented by a rating, which indicates how a particular user liked a particular item, e.g., user u_1 gave the object i_1 the rating of $R(1,1) = 3$, where $R(u,i) \in \{1,2,3,4,5\}$.

Each user u_k, where $k = 1, 2, \ldots, m$, has a list of items I_{u_k} about which the user has expressed his/her preferences. It is important to note that $I_{u_k} \subseteq I$, while it is also possible for I_{u_k} to be the null set. This latter means that users are not required to express their preferences for all existing items.

Each element of the user space U can be defined with a profile that includes various user characteristics, such as age, gender, income, marital status, etc. In the simplest case, the profile can contain only a single (unique) element, such as User ID.

Recommendation algorithms enhance various techniques by operating

- either on *rows* of the matrix R, which correspond to ratings of a single user about different items,
- or on *columns* of the matrix R, which correspond to different users' ratings for a single item.