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Personalized and mobile digital TV applications

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Abstract The introduction of mobile and broadband networks in complement to the existing satellite, cable, and terrestrial platforms, opens new opportunities for interactive TV (ITV) applications. In addition, the widespread adoption of multimedia computing has enabled the processing of TV content on personal devices such as mobile phones and PCs. The above developments raise novel issues and require the adoption of new multimedia standards and application frameworks. In particular, the explosion in the amount of available TV channels over digital television platforms (broadcast or internet protocol) makes searching and locating interesting content a cumbersome task. In this context, personalization research is concerned with the adaptation of content (e.g. movies, news, advertisements). Personalization is achieved with the employment of algorithms and data collection schemes that predict and recommend to television viewers content that match their interests. In addition, the distribution of TV content to mobile devices over broadband wireless raises the issue of video quality. Video quality depends on many aspects of the video encoding systems, such as bit rate and algorithms that model human perception of video on small screens. In this article, we examine contemporary research in personalized and mobile digital TV applications. Moreover, we present a critical survey of the most prominent research and provide directions for further research in personalized and mobile digital TV (DTV) applications.

Keywords Digital TV · Interactive TV · Personalization · Mobile TV

1 Introduction

Multimedia distribution and presentation technology has been gradually employed in TV products and services. At the distribution level the introduction of mobile and broadband

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internet protocol (IP) networks in complement to the existing satellite, cable, and terrestrial platforms has enabled the use of multimedia content on personal devices, such as mobile phones and PCs. digital video recorders and high-end set-top boxes with powerful processing capabilities support interactivity and development of sophisticated applications. Moreover, the adoption of high-level middleware, such as the Multimedia Home Platform (MHP), and the wide adoption of standard digital video broadcasting specifications (DVB-S/C/T/H for satellite, cable, terrestrial, and mobile TV respectively) provide a common platform for broadcasting and application development independently from the distribution infrastructure. On the other hand, consumer needs are continuously evolving leading to new requirements for applications and services in support for a wide spectrum of activities including entertainment, information, communication, and transactions.

Previous ITV research has been focused on video on demand, video encoding and video distribution systems. However, the articles in the special section are a showcase of alternative applications and emerging approaches for the widely deployed ITV systems. In the past, ITV technology has been employed for broadcasting, but the focus was on the low level, such as Asyncronous Transfer Modulation (ATM), bi-directional cable [4], internet multicasting [5], and video compression [6]. At a higher level, there is a need for development of useful and usable multimedia programs that run on advanced set-top boxes. For example, personalized TV research promises to reduce the information overload related to program selection. Moreover, the availability of multiple TV distribution networks and mobile user terminals emphasize the role of cross media publishing, where ITV productions are deployed over TV sets, mobile phones, and personal computers [7].

In this special section, we investigate the opportunities offered by ITV systems, with a particular focus on personalized and mobile digital TV (DTV) applications. We define ITV as a class of software applications that runs on video and multimedia servers, advanced set-top boxes, home media computers, and mobile phones. An important implication of the above definition is that ITV applications and services are not limited to the traditional TV device and broadcast delivery. In addition, alternative and complementary devices and distribution methods are considered, such as mobile phones and broadband networks. In the next section, we present emerging types of ITV applications. Then, we explore the state of the art in mobile and personalized digital TV applications. We conclude with directions for further research in this important area.

2 Emerging types of digital TV applications

2.1 Personalized TV

The adoption of digital broadcast and digital receivers has introduced novel challenges in content searching and requires the development of easy-to-use consumer-level applications for efficiently browsing through audiovisual libraries. For example, the explosion in the amount of available channels over DTV platforms makes searching and locating interesting content a cumbersome task. Electronic Program Guide (EPG) applications have proven of limited efficiency in content searching and need to be supported by intelligent applications that personalize the content according to the user's interests. The issue of information overload is also evident in the case of TV advertisements, which create advertising clutter and decrease the efficiency of the communication channel [3]. Personalization of advertisements provides the opportunity to increase advertising effectiveness by reaching the users who are most likely to respond positively to the advertising message. Overall, per-

sonalization research in ITV is concerned with the recommendation of content (e.g., movies, news, advertisements) and aims at the design and development of algorithms and applications that predict and recommend to television viewers content that match their interests and/or needs [1].

The most popular approaches to personalization are: (1) collaborative filtering and (2) content filtering. Collaborative filtering (CF) is based on the assumption that users who have agreed in the past in their subjective evaluation on observed items (as expressed through their ratings) will eventually agree in the future [10]. Collaborative filtering is characterized by its independence from item's features, which makes it applicable to almost any type of content. Content-based filtering (CBF) is an information retrieval technique that makes predictions upon the assumption that a user's previous preferences are reliable indicators for future behavior. CBF performs a selection of items relevant to the ones that the user has found interesting in the past and therefore requires the analysis of the content into features. CBF is typically applied in domains with structured data [2, 9].

2.2 Mobile TV

For some time television has been the only major media format that has been missing from mobile phones. Technological advancements in wireless broadband (e.g. WiFi, 3G, 4G) and multimedia mobile terminals (e.g. multimedia mobile phones) have made a reality the reception of digital TV on the move. Historically, mobile TVs have been available for many years, without ever becoming very popular. The proposition of digital mobile TV has a major difference with the analog predecessor. Most notably, it has the potential to offer localized and interactive programs and not just the same broadcasts as seen in living-room TV. Besides TV watching on-the-move, mobile TV has significant potential, both as a personal TV set and as a tool to establish a closer interaction with the television programs. Mobile TV broadcasts transmit content to all mobile terminals within the footprint of a base-station. The presence of multiple base-stations is the main advantage of digital broadcasting, because the content could be personalized to fit both the terminal and the physical location preferences.

Digital mobile TV systems have been designed to complement mobile networks with broadcast and multicast capabilities for spectrum-efficient delivery of multimedia services on mobile devices in both outdoor and indoor environments. In particular, the DVB-H standard is based on the widely deployed series of DVB standards (DVB-S/C/T) and includes enhancements for mobile terminals, such as reduced power consumption and reception while on the move. Although the technical standards are suitable for mobile TV reception, it is clear that mobile TV prospects should be examined as a complementary service to traditional living room TV. This is because the perceived quality of TV on a mobile phone and the solitary experience are not favored mode of watching TV.

There are many services that aim to provide users with a TV-like experience while on the move. Although many of these services sound appealing, the end-users' subjectively perceived quality is an important factor for their success. The properties of video quality have many similarities between the different application domains (e.g. internet, broadcast), but the characteristics of mobile devices define a special set of constrains. The biggest differences to other application domains are the limited bandwidth, which leads to high-level requirements of compression and the limitations of the mobile devices such as display size, power resources, processing capabilities and memory. In addition, the wireless transmission of the content is error prone. Accordingly, the production of video under these special requirements should regard the possible distortions in the subjectively perceived quality.

For this reason, subjective quality evaluation tests during product development are necessary, in order to ensure acceptable quality of service. In particular, the subjective quality of service for mobile TV depends on the perceived audio-visual quality of the consumed content and the interaction through which the user has to go to access it (e.g. the delay between selecting content and start of play). In this special issue, we focus on the former aspects of quality. In mobile TV, there is a trade-off between the screen size and the portability of the device. Users might want as large a screen as possible for viewing, but they do not want their phones to be too big. For this purpose, we examine alternative encoding algorithms and video resolutions that could offer a balanced trade-off between screen-size and video quality.

3 State of the art

3.1 Personalized TV

In this special section, we describe applications and systems related to the recommendation of content. The challenges addressed by the articles are discussed in terms of the methods employed in the recommendation process and in terms of the data collection technique.

3.1.1 Recommendation process

In the past, the recommendation process has been extensively applied in personalized Web-based applications. Most recently the recommendation process has been adjusted for the ITV domain by taking into account the particular characteristics of the medium, such as the low-involvement environment, input devices, viewing distance, group viewing etc. The typical recommendation process takes as input ratings/preferences on previously observed content items (or item features) and/or user data, which are used to develop the user model (or profile). The input data are loaded on a recommendation engine that produces predictions concerning the interestingness of a user for unobserved items. The presentation of the results to the user depends on the type of the application typically including a ranked list or a limited list of the top-n interesting items.

Kim et al. in the Target Advertisement System (TAD) use a three-stage classifier to group users by their gender and age based on explicit television usage data monitored through weekdays. They propose a novel metric that computes at the same time correlation and distance between user profiles represented by vector features. The advertising content, described by the TV-Anytime metadata, is then matched to the extracted groups in order to deliver the advertisements in a personalized manner.

Tsunoda and Hoshino, propose two methods for the recommendation of television programs. The first one called “Indirect Collaborative Filtering,” computes similarities among users upon a set of “expected” user preferences added to the set of actual (available) user preferences. This approach reduces the number of missing preference value for each user leading to more accurate predictions. The second method called “Automatic Metadata Expansion” expands the EPG-based program description (e.g. genre, actor etc.) by metadata extracted by additional sources. This method aims to improve the quality of recommendations through by searching for similar programs to the ones that the user has preferred in the past upon the extended (and more descriptive) set of features.

Lekakos and Caravelas develop a movie recommendation system which implements collaborative filtering, content-based filtering, and two hybrid algorithms that combine

the above methods. The hybrid algorithms initially perform collaborative filtering and switch to the content-based, in the case that the predictions could not be produced by the former. This may occur when few ratings are available or when very few similar users can be traced for the user that prediction is being made. Besides prediction accuracy this approach is also concerned with the recommendation coverage (the number of items that prediction can be made) as well as with the time required to make run-time predictions in realistic systems.

Aroyo et al.'s system (called Blu-IS) aims to serve as a home media system that personalizes the viewing experience of single and multiple users using heterogeneous media sources and devices (television, mobile, audio-video players etc.). The personalization effect is achieved through the delivery of content in formats and on media that match the user's profile, context of use and preferences. The authors' approach is to enrich the TV-Anytime content metadata definition through semantics and enable personalized searching and recommendations combining several personalization techniques such as collaborative and content-based filtering, context filtering, keyword matching, etc.

Wang et al introduce Tribbler, which is a personalized peer-to-peer (P2P) television system that automatically recommends, records, or downloads content from peers in a social network. The identification of a social network in a P2P system with traditional techniques such as collaborative filtering faces difficulties, because there is no centralized ratings database. For this reason the authors developed a novel algorithm called BuddyCast, appropriate for distributed recommender systems and is based on the principles of exploitation (periodically connect to peers) and exploration (search for new peers by a random connection and evaluation of similarity).

Beyond traditional user modeling and recommendation techniques, which mainly rely on some form of user-driven interaction data, Fink et al. exploit the fact that the television content consists of audio data as well. The authors propose four applications (personalized information, social communities, real-time ratings, and TV-based bookmarks) based on a real-time ambient audio identification approach, discussing the parameters that may affect the performance of the audio identification algorithms. Their approach offers an unobtrusive way of collecting viewing and contextual information and can be utilized in several applications (e.g. e-health, or e-security services for elderly and disabled persons).

The vast amount of available multimedia content through different sources and/or media makes content personalization one of the most important applications towards the emerging interactive digital television era. In this special issue, data collection methods, new algorithms and new forms of personalization applications are discussed in the articles of this special section (Table 1).

3.1.2 Implicit and explicit data collection

The input data concerning the user's preferences can be collected either implicitly or explicitly. Implicit data collection can be performed by monitoring, for example, the user's zapping and viewing behavior, similarly to the monitoring of the browsing behavior in Web-based applications. On the other hand, preference data such as ratings on items (e.g. movies) can be collected explicitly by asking users to provide their ratings for the observed items, for example in a one to five scale through the EPG application.

Explicit and implicit data acquisition methods present advantages and disadvantages: implicit methods are considered unobtrusive to user's main goal in using a system, but explicitly acquired data are more accurate in expressing preferences or interests. In web-based recommender systems with rich interaction data available users are typically asked to

Table 1 Data collection methods and personalization algorithms

Article authors	Application (system)	Data collection	Algorithms
Kim et al	Target Advertisement System (TAD)	Implicit information of TV usage history: viewing date, viewing time, and genres for TV programs.	3-stage classifier to infer users' age and gender. Match advertisements described by TV-Anytime metadata to the inferred groups
Tsunoda and Hoshino	TV program recommendations	Explicit and implicit preference data	Automatic Metadata Expansion, Indirect Collaborative Filtering
Lekakos and Caravelas	Movie recommendations (MoRe)	Explicit ratings	Collaborative, content-based filtering, hybrid algorithms
Aroyo et al.	Personalized Home Media System (Blu-IS)	Implicit and explicit data: User's characteristics, preferences and context.	Keyword matching, content-based filtering, collaborative filtering, group filtering
Wang et al.	Personalized P2P television system (Tribbler)	Implicitly collected zapping behavior data.	BuddyCast algorithm: implicit clustering of peers into social networks.
Fink et al.	Real time ambient audio identification system	Implicit ambient audio data	Algorithms for audio identification

rate observed items in a one to five scale (e.g. in Amazon.com or citeseer.org). In ITV, explicit ratings are usually restricted to a few applications (e.g. EPG), because the use of ITV is characterized by passive and group interactions. Instead, other types of data that could be collected implicitly are more appropriate in this context.

Kim et al. collect implicit usage data to build the users' profiles: viewing date, viewing time, and watched television program genres which are processed to produce gender and age information. Tsunoda and Hoshino combine both implicit and explicit preference data by monitoring program recording, browsing, and searching behavior. Moreover, they exploit explicit ratings on recommended programs and preferences (favorite genre, cast, keywords), which have been stated at registration with the personalized service. Lekakos and Caravelas' approach is based on explicitly provided ratings through the applications' GUI. Aroyo et al. model users upon three types of data collected either explicitly or implicitly: personal data (age, gender, etc.), media and content preferences; current contextual information (time, location, available devices, audience, mood of the user); behavioral data (programs watched and time watched). Wang et al. analyze implicitly collected zapping behavior and, finally, Fink et al. introduce real-time ambient audio identification that enables a wealth of information to be implicitly extracted and utilized for a number of applications.

3.2 Mobile TV

In this special section, the mobile DTV contributions operate on two levels (technical standard and subjective perception of video quality).

At the technical level, Gardikis et al. offer a comprehensive description of the DVB-H standard. The authors have managed to briefly present an overview of the most important

topics that have been introduced by the DVB-H standard (e.g. time slicing to avoid power consumption). In addition, their paper discusses the applicability of the standard in terms of new services. Their presentation comes in the form of differentiation of services based on the amount of user interactivity (only broadcast: DVB-H; limited interaction: SMS; fully interactive: GPRS).

At the video quality level, most of the research on the effect of screen sizes in the field of consumer electronics has examined the impact of increasing the image size in the viewer's visual field by means of large physical displays or projection areas. The results show that larger image sizes are more arousing, better remembered, and generally preferred to smaller ones. Nevertheless, there is little research about mobile video and about video perception on small screens. Indeed, in mobile DTV applications, the perceived visual and audiovisual qualities are critical factors in order to achieve wide adoption. These issues correspond to video encoding and are related to bitrate, framerate, and screen size of the terminal device. Although resolution, viewing distance and picture size are not independent of one another, the articles in this special section manipulate the resolution and bit rate of the video, in order to study subjective perception.

Overall, the articles in the mobile DTV special section take the first steps in addressing the above research issues. On the mobile video quality level there are two complimentary contributions that treat video-size and video encoding, respectively. For this purpose, they employ subjective evaluation measurements and lab-experiments with end-users. A subjective evaluation is a systematic study of human judgments of experienced material based on perception. In comparison to objective evaluation, subjective evaluation always combines different levels of human information processing from low level sensorial processing to cognitive processes, attitudes, expectations and emotions.

Knoche et al study the influence of low resolutions on the different shot types used in television content and how these would come across on small mobile devices. They suggest that tailor-made content for mobile TV might be more enjoyable as a whole when prepared without extreme long shots for football and with heavy use of close-ups for mobile soap-operas. Jumisko-Pyykko concentrates on comparing alternative codecs, bitrates, picture ratio and audio-video bit-rate ratio. The study had two main objectives: Firstly, she examined how codec, picture ratio and bit-rate affected the experienced visual video quality. Secondly, she studied the impacts of two audio-video bit-rate ratios on experienced audiovisual quality. There are two main findings: the limits of legibility of text due to picture ratio and importance of audio in low bit-rates Table 2.

4 Research agenda

The design and development of mobile and personalized applications for DTV should not be regarded solely from a technical perspective. The unique characteristics and the

Table 2 Mobile TV research issues and methods

Article	Research issue	Method
Gardikis et al.	Technology for Mobile TV broadcasting and interaction	Description of DVB-H standard and applications
Knoche et al.	Video bit-rate and resolution	Experiment
Jumisko-Pyykko	Video encoding bit-rate and algorithms	Experiment

multidisciplinary nature of the ITV applications pose additional requirements and issues that should to be addressed. These range from media-related issues: which applications and features would better satisfy viewers' needs? Which factors affect the adoption of new applications/services? to human–computer interaction: how television application interfaces should be designed for effective and efficient interaction in domestic environments? and to business/management issues: which changes are introduced in the current business model? which is their effect and which are the adoption factors for television stakeholders? Below, we provide directions for further research in the context of personalized and mobile digital TV.

4.1 Personalized TV

Typical research directions in the TV personalization/recommendation domain are related to the development of more accurate, effective, and efficient algorithms with particular focus on hybrid forms that combine the basic user modeling and the prediction methods. As a matter of fact, the ITV domain has inherited the limitations and drawbacks that affect personalization approaches in other domains. For example, the sparsity problem—limited user-driven data availability—significantly reduces the accuracy of certain personalization methods. Moreover, further research is required to emphasize group-modeling methods, because television viewing is mostly a group activity than a single-viewer experience [8]. On this end, a very promising area is the application of recommendation methods within small networks of affiliated groups of TV viewers (e.g. friends and family), in order to enhance the shared experience of TV. For example, future EPG systems should emphasize the suggestion of TV content that has been viewed by family members and close friends. This approach contrasts boldly with the currently dominant model of individualizing the viewing experience for each TV viewer.

It is also expected that the development of new applications and services that combine more than one distribution methods and the availability of broadband networks will be an exciting future research path, raising further standardization and technical issues. One significant advance is the release of standard metadata related to TV content by the TV-Anytime forum, which enable the development of content models and their utilization in the recommendation process. Moreover, knowledge-based approaches, may exploit knowledge concerning the item features, for example that a movie belongs in a certain genre, or functional knowledge concerning the mapping between a user's need and item(s) that may satisfy this need. Knowledge-based approaches in the ITV domain typically exploit ontologies, or other structural models and are particularly useful in the absence of sufficient behavioral data (e.g. user-driven interactions).

4.2 Mobile TV

Further research in mobile TV should investigate authoring tools that enable automatic post-production of video that is targeted for viewing on the move. Currently, mobile service providers encode and deliver existing broadcast material and interactive applications without additional editing, because it is more cost-effective than re-editing. Future research should improve on intelligent cropping mechanisms that present only a part of the original shot. On the application side, cross-media multimedia authoring tools should consider the diversity of screen formats and sizes in mobile devices. Future studies of user perception should take an integrated view to compression and transmission. The rationale is that in the

mobile DTV environment the transmission errors are very likely to happen. In technical domain, there is need for a comprehensible presentation of the programming environment of DVB-H. In addition, there is a need for a comparison between the DVB-H and other mobile TV standards.

Finally, mobile DTV presents many opportunities for converged personal communication and content services. In particular, the availability of broadband wireless technology is rather suitable for the delivery of content enriched communication services (e.g. active content sharing, synchronous or asynchronous co-viewing form a distance, discussion about shared content, etc). Wireless network operators have invested in broadband infrastructures, but most of the services offered are only video communication, or only video on demand. The design and evaluation of content enriched communication services is a worthwhile research direction, because it offers an excellent balance between the basic need of users to communicate with a mobile device and the need of network providers for increased revenue by added value broadband services, such as mass media content distribution.

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