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REGULAR PAPER

Broadcasting and personalization of user-generated contents in DVB-H mobile networks

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Abstract During the last years, we have witnessed the boom of the digital market due to the proliferation of emergent audiovisual services and the increasing number of broadband networks. In this scenario, users insistently demand innovative services for exchanging and sharing their own audiovisual contents. In order to meet these needs, in this paper, we propose a system that broadcasts user-generated audiovisual contents for handheld devices in a mobile network based on the DVB-H broadcasting standard. Besides, our system offers diverse value-added services to these new active users, such as: (1) annotation, sharing and personalized distribution of audiovisual contents, (2) multi modal access, via Web or by client applications running locally in the handheld device, and (3) exploitation of return channels to transmit interactive contents that enhance the user's experience. To achieve these goals, our system adopts well-known technologies for broadcasting and semantic annotation of audiovisual contents, as well as emergent technology from Web 2.0 and Semantic Web. We have carried out tests involving a group of students from the University of Vigo, who were satisfied with the personalization capabilities offered by our TV system for mobile settings.

Keywords Mobile TV · Web 2.0 · DVB-H · Personalization · User-generated content · Interactivity

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1 Introduction

In recent years, we have witnessed a boom of the digital market, an effect that stems from the proliferation of emergent audiovisual services and the increasing number of broadband networks. In this scenario, the users demand more and more active and collaborative roles, encouraged by the powerful new ways of communicating that arose within the World Wide Web. This new scenario has favored an enhanced networked effect among Internet users that is changing the way people communicate, where and how they congregate, and the way they seek and share information [3]. This focus on a social Web does lay the foundations of the so-called Web 2.0, a new initiative that boosts active participation and collaboration among users [17]. In fact, Internet users are increasingly visiting social networking sites—sites that promote networks of relationships around users and information [10]—for entertainment and news, business relationships, consumer product reviews, connecting with friends, and more. But the users are doing more than just visiting; instead, they contribute content in the form of journal entries, photos, videos, and weblogs, becoming producers and authors. Definitively, the value of these sites is derived not from the contents provided by the site's owners, but from the emergent relationships among users and the contents they create and consume.

This process of user-driven content generation is firmly supported by the development of consumer electronics, which has given rise to a new generation of handheld devices that enable to create contents easily, and to access them from any location at any time. In this paper, we harness the momentum that these devices have gained in the context of the mobile TV, where users will be able to watch content with which they are familiar from traditional broadcast television on their mobile devices. Mobile TV will offer more than just a "*television on the move*" consisting of merely broadcast traditional television content on mobile devices. Mobile TV will increasingly be delivered by a device with multiple multimedia functions. Features such as radio, music player, camera and video recorder are already available on mobile devices. With these and new multimedia functions, mobile TV will offer a more interactive and personal viewing experience than that of traditional television.

People are likely to watch mobile television to fill empty spaces in their day, such as traveling and commuting, unoccupied slots during the day (e.g. lunch breaks), or waiting situations [18]. This short usage time forces mobile TV contents to meet two requirements:

- On the one hand, these contents have to be fresh, attractive and suitable for "*snacking*" in order to accommodate users' limited attention span, the scarce sustained times they have available, and the reduced life of the battery of their handheld devices. The short duration of these contents helps mobile TV users avoid feeling fatigued from staring at the small screen for too long. In the report presented in [18], Dr. Orgad points out two types of mobile TV contents: fragmented programs consisting of small made-for-mobile episodes that cater to bite-sized portions of content while on the go (the so-called mobisodes), and user-generated contents (UGC items). As explained in [18], "*the current trend of UGC, as seen by the phenomenal growth of YouTube, is a key feature of mobile TV. As consumers increasingly will use their mobile devices to create video content, new broadcast platforms will emerge to distribute this content to other mobile users.*[1]"
- On the other hand, the selection of contents offered to mobile TV users must be *personalized*: when the user turns his/her portable device on, he/she should be provided with a personalized list of potentially interesting contents, thus avoiding a tedious manual search process in the broadcast stream.[2] This list must be as accurate as possible and include few TV programs, because (1) the users do not have long chunks of time to browse the programs available in the broadcast stream and (2) the small screens of their devices cannot show a lengthy list of recommended programs. For both reasons, it is especially important to increase the quality of the recommendations (automatically) identified for mobile TV users, including a reduced number of interesting TV programs to be viewed in little time. In traditional *recommender systems* [2], the identification of the appealing programs to each user is driven by recommendation strategies that match his/her personal preferences against the broadcast contents, merely doing *syntactic* comparisons between the attributes of the programs. Consequently, traditional strategies disregard a huge amount of knowledge hidden behind the *semantics* of the user's preferences and attributes of the broadcast programs, thus impoverishing the recommendation accuracy.

Taking into account the two requirements above, in this paper we propose to move from the traditional mobile TV to a new system endowed with enhanced personalization capabilities. Specifically, the contribution of our system is the confluence in a mobile setting of the following features:

– *Broadcast of UGC* items to handheld devices for any-time-and-anywhere TV access: these contents are fresh, attractive and are usually adapted to short viewing times, thus becoming very suitable for a mobile TV environment.
– *Personalization functionalities based on reasoning techniques* borrowed from the Semantic Web. Our system includes a novel recommendation strategy that reasons about the semantics of the available UGC items, going beyond the syntactic comparisons adopted in traditional approaches (e.g. our strategy matches a program about *flora* to another about *fauna*, because both are related to the *nature*, although their respective attributes are different). These reasoning techniques uncover extra knowledge about the user's preferences, thus leading to much more accurate recommendations than those offered by traditional syntactic strategies.
– Provision of capabilities borrowed from Web 2.0 (hereafter, *Web 2.0-related functionalities*) in such a way that the mobile TV users can participate actively by sharing their creations and, at the same time, providing our system with information useful for our personalization tasks: specifically, the users rate the available UGC items and annotate them by freely chosen tags that will be exploited by our recommendation strategy.

This paper is organized as follows: Sect. 2 describes mobile TV broadcasting trials and personalized TV expe-

[1] The United States TV channel, CurrentTV, is a good indicator of the future with 30% of its programming consisting of UGC.

[2] Actually, when the programs relevant for a given user are ready to be broadcast from the head-end, he/she is notified of their availability in a specific channel and time; next, the user can either enjoy a live broadcast or record those contents in his/her device for viewing at a later time.

riences that have taken place in several countries, highlighting the differences with our system. Section 3 focuses on the technologies gathered together in our approach to personalized mobile TV. Next, Sects. 4 and 5 detail the main functionalities and architecture of the system, respectively. The results from preliminary experiments are described in Sect. 6. Finally, Sect. 7 concludes the paper.

2 Related works

According to what we commented in introduction, in order to find works related to our research it is necessary to explore two fields: mobile TV and traditional recommendation strategies.

2.1 Background on mobile TV experiences

Mobile TV has been commercially launched in several countries (e.g. Japan, Singapore and Finland) where consumers can receive broadcast material targeted to mobile terminals. In addition to mobile television broadcasts, 3G mobile networks are capable of carrying streaming videos as unicast services. And further, even without any network, consumers can buy media players, such as iPod, and enjoy content that has been downloaded to the player prior to leaving home or work.

In Tokyo, the Terrestrial Broadcasting Pilot Project [13] is testing fixed and portable reception of digital broadcasting. In addition to television at home, digital terrestrial broadcast signals reach portable receivers, which enable users to access the Internet, get detailed information about the contents they are watching, and use interactive services.

Other trial to enhance the TV experience outside the home boundaries has taken place in Singapore, where a system named TVMobile delivers high-quality mobile TV programs to public commuters.[3] This system keeps commuters up-to-date with broadcasts of real-time financial data, news, weather reports and entertainment contents.

Lastly, note that in Finland there is also a great deal of interest in the use of mobile devices and, in particular, the possibilities offered by 3G phones. In 2000 Sonera Mspace sets up the first consumer trial—PMA pilot—that simulated next-generation mobile services. They used a device consisting of a pocket PC and a GSM phone to deliver daily news flashes, personalized movie information and trailers, music videos, sports highlights, and map services. Other similar project (named Mstation) was launched in 2001, in which the users employed a device combination of a PDA and a mobile phone connected with Bluetooth. The aim was to study the usability aspects and challenges related to future mobile applications. This way, the users tested, for example, a user interface control based on movement of the mobile device. Mstation applications covered areas such as wireless games, messaging, on-line betting and lottery services.[4]

Other mobile TV trials in Finland were Mobile TV and PodRacing. Mobile TV offers theme channels, management of favorite contents, games and delivery of diverse interactive services [22]. In PodRacing, the aim was to test different media formats (e.g. text, audio and video) and delivery methods (broadband, 3G and podcasting). The first trial concentrated on news service. The first prototype used on-demand delivery and 3G network. The second trial focused on comparing 3G and a broadcast network. In the third trial, the users had media players, such as iPod, and enjoyed content that has been downloaded to the player prior to leaving home or work [19].

Differently from our proposal, the systems used in the previous trials do not allow the users to: (1) upload their own creations, (2) share them with other individuals, (3) rate the generated contents, and (4) annotate them by freely chosen tags. We can find similar functionalities in YouTube or See Me TV, which permit users to upload and broadcast their own videos directly to the websites from their mobile devices and network with others who are interested in viewing these contents. Both systems support UGC but personalization functionalities are still missing. Finding works related to such functionalities requires to explore the recommender systems proposed in the field of domestic DTV.

2.2 Background on personalized traditional TV

DTV recommender systems have mainly adopted two well-known recommendation strategies: content-based filtering and collaborative filtering.

Content-based filtering consists of suggesting to a user programs similar to those he/she liked in the past. This approach has been adopted in several DTV systems for a domestic setting, such as TV Advisor^{TM} [7], TV Show Recommender [25], and the personalized EPG (*Electronic Programming Guide*) proposed in [1]. Content-based filtering requires a metric to quantify the similarity between the users' profiles and the target programs. To define such a metric, appropriate descriptions of the contents are required, whose generation is usually a complex and time consuming task. Due to the use of syntax-focused similarity metrics, content-based methods tend to suggest programs too similar to those ones known by the user, which leads to limited diversity in the recommendations (i.e. *overspecialized recommendations*).

On the contrary, *collaborative filtering* is based on recommending to a user those programs appealing to other

[3] Mobile TV, http://www.corporate.mediacorp.sg/tvmobile/.

[4] Additional information about PMA-pilot and Mstation projects can be found in http://www.sonera.fi/en/.

like-minded viewers (named *neighbors*). In order to form the user's neighborhood, traditional collaborative approaches create a *rating vector* for each user including his/her level of interest in each program available in the system.[5] Next, the rating vectors are correlated, in such a way that two users are neighbors when they have rated the *same* programs and with similar ratings. As experienced in systems such as Bellcore Video Recommender [12], MovieLens [16], TV Scout™ [4], and Moviefinder™ [20], this lack of flexibility to estimate the similarity among users leads to the so-called *sparsity problem*. In this case, as the number of contents in the system increases, the probability that two users have watched the same content gets lower. This reduced overlapping among the users' profiles hampers the discovery of users with similar preferences, a critical step in collaborative approaches. Besides, the increase in size of available contents leads also to *scalability*-related problems. Other limitations in traditional collaborative approaches are related to the fact that a specific content must be rated by a significant number of users before it can be suggested by a collaborative system. Thereby, significant *latency* is observed since a new content arrives at the system till it is suggested to some user, as it is necessary that a significant number of users have previously rated it. This is especially critical in the TV field, as we will have a large number of programs disappearing from the broadcast stream, staying in the system for a short time.

In order to fight these limitations in our personalized mobile TV system, we explore novel recommendation strategies where synergies among traditional personalization paradigms (content-based and collaborative filtering) and semantic reasoning techniques are exploited.

3 Technological landscape

To provide the functionalities mentioned in the previous sections, our system adopts well-known technologies from a variety of fields that will be reviewed in the following subsections.

3.1 Delivery of contents to handheld devices

Relaying TV and video-on-demand services to a handheld device involves a lot more than building an analogue or digital TV tuning system into a mobile setting. The cellular networks must turn to new technologies to meet the requirements of portable devices. To this aim, Digital Video Broadcasting consortium has proposed *DVB-H* (*Digital Video Broadcasting-Handheld*), a standard that allows the handheld terminals to receive data from the network while a return channel is required for data and interactive applications [8]. For that purpose, DVB-H resorts to IP DataCast (IPDC), a system for the delivery of digital contents and services using IP-based mechanisms, which comprises a unidirectional DVB broadcast path and a bidirectional mobile path for interactivity purposes. Specifically, DVB-H is based on specifications for terrestrial broadcasting (DVB-T) and only adds new functionalities in order to consider special conditions of handheld devices (e.g. limited battery life). In this regard, DVB-H uses a technique called *time-slicing*—where burst of data are received periodically—that allows the device to power off when it is inactive, thus leading to significant power savings.

But DVB-H is not the only TV-on-the-move technology: the alternative is known generically as video streaming, which has the advantage that it can operate across multiple mobile standards, ranging from 2.5G (GPRS) right through to 3.5G. However, video streaming is not really suitable for real-time TV transmissions due to the relatively low speeds currently available on 3G networks [11].

3.2 Annotation of audiovisual contents

In order to reason about the semantics of audiovisual contents we need annotations defining their main attributes. *TV-Anytime* metadata specification [23] is a suitable option for that purpose, as it provides detailed descriptions of audiovisual contents in terms of intended audience, content, format, intention, or involved credits, just to name a few. Specifically, TV-Anytime standardizes multimedia services based on digital storage in consumer platforms, combining the immediacy of the television with the flexibility of the Internet. This way, for instance, TV-Anytime specifications allow the user to find, navigate and manage contents from a wide variety of sources, including traditional broadcasting, interactive TV, Internet, and local storage in a PDR (*Personal Digital Recorder*). Besides these functionalities, nowadays, media personalization using TV-Anytime is gaining momentum as a promising mechanism that lays the foundations of novel business models in the provision of personalized services for TV viewers, whose utility is undoubted in view of the content overload available in the broadcast stream.

3.3 Annotation and classification of UGC

Although TV-Anytime defines a common format to describe audiovisual contents, it is interesting to let the users annotate and categorize the UGC items in a free way, without knowing the internals of any metadata specifications. For that purpose, we adopt emergent technologies from the Web 2.0, whose foundation is the creation of *virtual communities* that establish links among individuals who share common characteristics or interests. A virtual community or *social network* represents a structure of the relationships (edges)

[5] A rating 0 is assumed for programs that have not been rated by the user.

existing among the users (nodes). The language commonly used to model social networks is FOAF,[6] a simple technology that permits to share and use information about people and their activities (e.g. photos and weblogs) to transfer information between websites, and to automatically extend, merge and re-use it online.

In a social network, the annotation process gathers the efforts of the community of users to create a shared collection of metadata, whose expressive richness and quality improve progressively. As each individual chooses freely a set of labels for a resource, the collection evidences both the social aptitudes of the community and a shared organization of the target annotation space. This community-managed classification process was coined by Thomas Vander Wal with the term *folksonomy*, referring to a progressive and collaborative definition of the categorization and organization of the content.

3.4 Semantic reasoning

Despite the power of folksonomies, the use of a vocabulary without a common semantic substratum prevents from carrying out the reasoning processes that we want to exploit in order to select accurate recommendations for mobile TV users (see Sect. 1). To mitigate this limitation, we borrow from the Semantic Web a structure called *ontology* that is defined as "*a formal, explicit, shared conceptualization of a domain*" [9]. Specifically, an ontology about the TV domain allows to formalize the semantic descriptions of audiovisual contents and the relationships existing among them. The use of semantic reasoning techniques with this conceptualization permits our system to learn knowledge about the users' preferences, thus improving its recommendation accuracy.

In summary, our mobile TV system brings together:

- a *DVB-H mobile network*: compared with 2G/3G networks, broadcasting is a highly cost-effective way to reach a large audience;
- a *FOAF folksonomy*: as this structure allows the users to categorize the UGC items by freely chosen tags, they provide the system with numerous high-quality annotations that will be especially useful for our personalization functionalities;
- an *ontology compliant with TV-Anytime* that is automatically created from the user-defined FOAF folksonomy: the tandem ontology-TV Anytime permits automatic access and sharing of very detailed annotations of the UGC items, two features essential for our reasoning-based personalization capabilities.

[6] http://www.foaf-project.org.

4 Main functionalities

Having delimited the technological context of our system, we now focus on describing its appealing functionalities, including *user-driven content generation*, *planning of theme channels* and *personalization* capabilities.

4.1 User-driven content generation and planning of theme channels

The users of our system congregate in social networks, where they take advantage of last-generation consumer devices (e.g. digital video cameras and mobile phones) to create their own audiovisual contents in a flexible and easy way. These contents are shared with the remaining users of the social network through a website where the UGC items can be uploaded, published, viewed, rated, and even recommended to other individuals.[7]

According to what we commented in the previous section, in the context of the social network, the UGC items are annotated progressively by means of freely chosen tags. In this tagging process, the users may specify a set of generic classification categories along with more specific subcategories (e.g. NEWS: national, economy; SPORTS: athletics, cycling; MUSIC: jazz, rock, etc). Besides, users may define attributes for these contents, such as the credits involved and geographical/time information.

Starting from these shared annotations, we create automatically a TV ontology where the contents are formalized and described semantically as per TV-Anytime metadata specifications. For that purpose, we combine lexical databases with logics-based reasoning mechanisms as follows:

- First, we resort to a translation process driven by *WordNet* [14], a semantic lexicon for the English language that includes synonyms and defines semantic relationships between concepts. Thanks to this lexicon, we relate the tags entered by the users to TV-Anytime metadata, and detect associations between the annotated contents (e.g. by WordNet, we can categorize under a common category two programs annotated by the tags *humor* and *comedy*).
- Next, the concepts and relationships resulting from the WordNet-driven process are analyzed by *Pellet* [21], a Java-based logic reasoner by which we (1) discover equivalent concepts and remove redundancy from the obtained ontology, (2) automatically categorize concepts in clas-

[7] Since these contents may come from a wide variety of coding technologies, sources, and formats, we incorporate transcoding processes so that the contents can be broadcast through the DVB-H channels of the system.

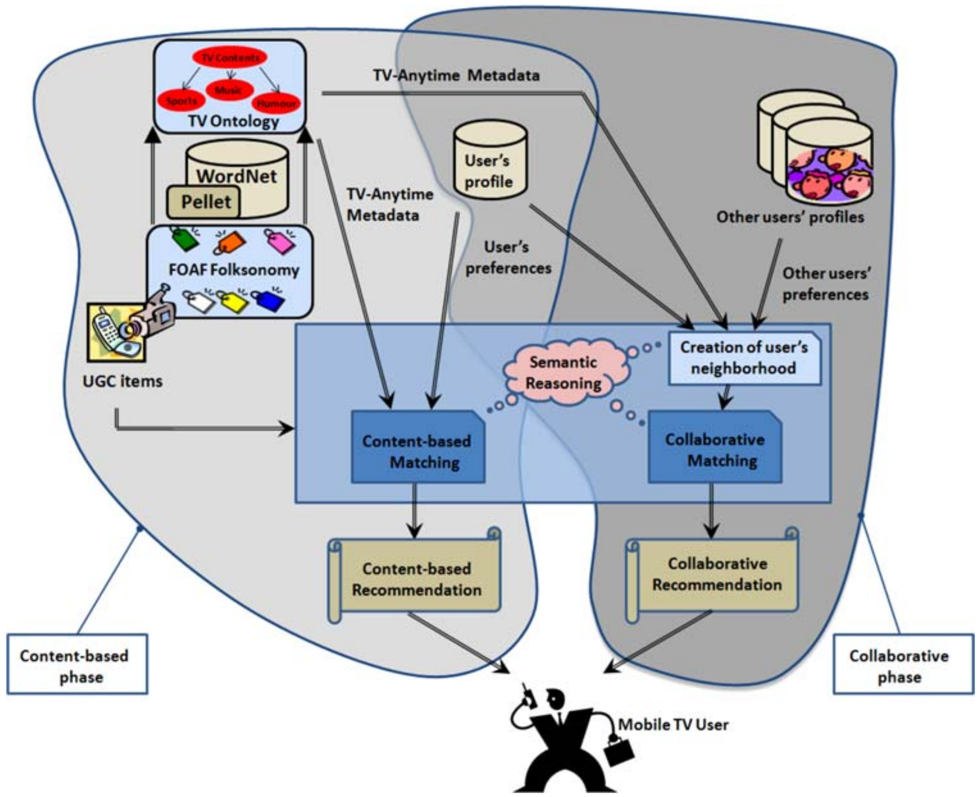


Fig. 1 Our two-phase hybrid recommendation strategy

ses and (3) check the consistency of the knowledge represented in the resulting conceptualization.

This ontology contains the concepts and relationships typical in the TV domain, which are represented as hierarchies of classes (referred to, for instance, *Genre*,*Credits*, *IntendedAudience* of the contents) and properties (e.g. *hasGenre*, *hasCredits*, *hasAudience*), respectively. Along with the hierarchies of classes and properties, our TV ontology includes specific instances that identify (1) the audiovisual contents the users have generated[8] and (2) their attributes (e.g. *topic*, *geographical* and *time information* associated to the contents).

These UGC items are arranged into theme channels and broadcast through the DVB-H mobile network. Specifically, the UGC items are categorized as per multiple criteria, including the ratings given by the users, the metadata associated to these contents in the TV ontology, and the kind of audience expected during the different time frames. Combining these criteria, our system provides the users with very diverse broadcast channels, including for example the favorite UGC items for most of the users (i.e. those with the highest ratings), contents classified under a specific genre (e.g. *Sports*, *Sciences*, *Humor*, *Music*), programs aimed at specific audiences (e.g. children under 12, young couples without kids), and contents about a particular topic (e.g. natural disasters, animals).

[8] In order to prevent the TV ontology from reaching an unmanageable size, we periodically remove the UGC items that are not appealing to the audience. Specifically, we average the ratings that the users have given to each UGC, in such a way that the content (and its metadata) are removed when the average rating is below a given threshold.

4.2 Personalization functionalities

After planning the theme channels, our system automatically identifies the UGC items that best match the preferences of the users, who are notified about the availability of appealing contents in the broadcast stream.

As depicted in Fig. 1, this personalization process is driven by a *two-phase hybrid recommendation strategy* that combines content-based methods, collaborative filtering and semantic reasoning as follows: first, a *content-based phase* selects the appropriate UGC items for a user by matching his/her preferences against the TV-Anytime semantic annotations formalized in the TV ontology. Next, a *collaborative phase* recommends to each user the UGC items which his/her neighbors are interested in. The algorithmic internals of both phases are detailed in the next sections.

4.2.1 Content-based phase

The goal of this phase is to measure a *matching level* between a given user and a target UGC, in such a way that if the resulting value is greater than a threshold, this UGC is recommended to the user. The resulting *matching level* will be high when the target UGC is very similar to the contents the user enjoyed (i.e. rated positively) in the past. In order to measure this resemblance, we define a similarity metric enhanced by reasoning that detects that two UGC items are similar when they are (semantically) related. Specifically, two UGC items are similar if they:

- share a common ancestor in the hierarchies defined in the ontology (e.g. two UGC items classified as *Sports*);
- share identical attributes (e.g. two UGC items set in the city of *Madrid*); or
- share sibling attributes (e.g. a UGC whose *topic* attribute indicates that is about *boats* and another about *launches* are similar because both are associated with *Sea Transports*).

Leaving apart algorithmic internals (detailed in [5]), the higher the number of semantic relationships inferred between the target UGC and the user's preferences, the greater the resulting *matching level*.

4.2.2 Collaborative phase

The goal of our collaborative phase is to predict the level of interest of the user in the target UGC, by exploiting his/her neighbors' preferences and the TV ontology. If the predicted value is greater than a configurable threshold, the target UGC is finally recommended to the user.

In order to form the user's neighborhood, we have defined a *taxonomy-based approach* that exploits the hierarchical structure of our TV ontology to discover overlap between the preferences of two users, even when both have viewed different UGC items. Specifically, our approach uncovers resemblance between the preferences of two viewers when they have rated UGC that are categorized under a *common ancestor* in the hierarchies of our TV ontology. For example, our approach detects that a viewer who has enjoyed a UGC where several students have recorded chemical experiments (classified as *Chemistry*), and a viewer who has liked a UGC about mechanical engineering (classified as *Physics*) are neighbors because both of them share interest in *Sciences* ancestor.

Leaving apart the algorithmic details, the higher the number of common ancestor between the profiles of two viewers, the greater the correlation value measured between their respective preferences. Finally, the individuals whose correlation values (with regard to the considered user) are greater that a given threshold, are selected as his/her neighbors.

Once the user's neighborhood has been created, our collaborative filtering predicts what would be his/her rating for the target UGC. To this aim, we average the level of interest of each neighbor in the target UGC, weighted by the correlation values measured between the user and those neighbors. Specifically, if a neighbor has rated the target UGC, we use his/her rating; otherwise, we predict the level of interest of the neighbor by computing his/her *matching level* with regard to this UGC (see Sect. 4.2).

From this explanation, it follows that the rating of the user in the considered UGC is high when this content is very appealing to the user's neighbors, and when their respective preferences are strongly correlated. In this scenario, the target UGC seems also to be appealing to the user.

4.2.3 Contributions to traditional recommendation strategies

Significant research contributions can be identified in the two phases of our recommendation strategy, which are reached thanks to the semantic reasoning capabilities.

On the one hand, our content-based phase greatly alleviates the *overspecialized nature* of traditional approaches that only include TV programs excessively similar to those the user already knows (see Sect. 2.2). Instead of suggesting UGC items similar to those the user liked in the past (which could dissuade the users from consuming mobile TV), our similarity metric recommends contents semantically related to his/her preferences. Such relationships allow to discover that some UGC items are appealing to the user even though they do not share the attributes of the contents viewed in the past, definitively helping to diversify the recommendations.

In the collaborative phase, semantic reasoning also contributes to overcoming the most severe limitations of traditional approaches:

- First, our taxonomy-based approach serves to fight the *sparsity problem* of existing collaborative proposals (see Sect. 2.2), because it allows to detect that the preferences of two users are similar even when their respective profiles do not contain the *same* UGC items. Recall that in our approach, it is only necessary that the categories of the considered UGC items share a common ancestor in the hierarchy defined in the TV ontology.
- Second, our taxonomy-based approach also brings benefits in terms of *scalability*. As mentioned in Sect. 2.2, the vectors used to compare the viewers' preferences contain their ratings in *all* the programs available in the recommender system [2]. Consequently, as new programs arrive to the system, the size of the rating vectors increases and therefore, the cost of computing correlations greatly rises. In contrast with this, as the number of available UGC items increases in our system, our rating vectors do not necessarily increase in size. This is due to the fact that many new UGC items can belong to the same hierarchical

classes in the ontology, thus reducing the computational complexity of our neighborhood formation process.
– Lastly, our process of neighbors' rating estimation enables to suggest (without unnecessary delays) UGC items that are completely novel for all the users in the system. Therefore, it permits to alleviate the *latency problem* of the traditional approaches, in which a program must be rated by many users before it can be recommended. This improvement is especially important in TV field, where a large number of programs are continuously appearing in and disappearing from the broadcast database, staying in the recommender system for a short time.

5 Our architecture

5.1 Locating the recommendation strategy

One of the critical parameters in the design of the architecture of our system is the location of the two-phase hybrid recommendation strategy. Such strategy could be executed either remotely in a centralized server or locally in the user's hand-held device (hereafter *server-based personalization scheme* and *receiver-based scheme*, respectively).

– In the first case, the ontology required for the reasoning techniques and the user profiles would be stored in a dedicated server, and the hybrid recommendation strategy would run remotely, too.
– In the receiver-based scheme, the personalization logic would be distributed between a server and the user terminal: on the one hand, the user's profile would be kept in the receiver, where the recommendation strategy is also locally executed; on the other, the TV ontology still has to be kept in the server, because it can be an enormous database, totally unmanageable for limited-resources devices.

Many existing approaches (surveyed in [6,22]) have opted for the receiver-based scheme due to the limitations derived from the server-based one. To begin with, the users could be unwilling to store their preferences in a server, fearing that details about their personal consumption histories could be revealed. Furthermore, server-based scheme forces the users to have a return channel to provide their preferences and feedback about the recommendations, a requirement that is not really critical nowadays in view of the generalized penetration and expansion rate of the 2.5G/3G mobile telephone networks [11].

In our approach, the choice of a personalization scheme is narrowly related to the accuracy of the recommendations: as mobile TV users tend to have short attention spans and brief chunks of time for content consumption, it is necessary to obtain very accurate recommendations in order to strengthen their confidence in the provided personalization capabilities. As pointed out in the introduction, for that purpose, our research work exploits the potential of semantic reasoning processes that cannot be executed in terminals with limited resources. This requirement forces our recommendation strategy to be run in a centralized server, where there are no pressing limits to the computational and storage power. This way, it is possible to run more complex reasoning-based filtering algorithms that lead to more fine-tuned recommendations.[9]

Bearing this into account, we have opted for a server-based personalization scheme against the receiver-based one. As usual, in order to deal with privacy concerns in this scenario, the users of our system sign a *service-level agreement* with the provider: the latter commits to the provision of trustworthy servers that never reveal the preferences and personal data of the users, while the users explicitly allow this information to leave their terminals. Besides, the server-based personalization scheme has the advantage that the execution of our hybrid recommendation strategy at the server side enables to better plan the UGC items to be broadcast as per the available audience. In other words, it is possible to harness our recommendation strategy to remove information that is irrelevant for the viewers who are watching TV at the moment, replacing it with UGC items potentially interesting for them.

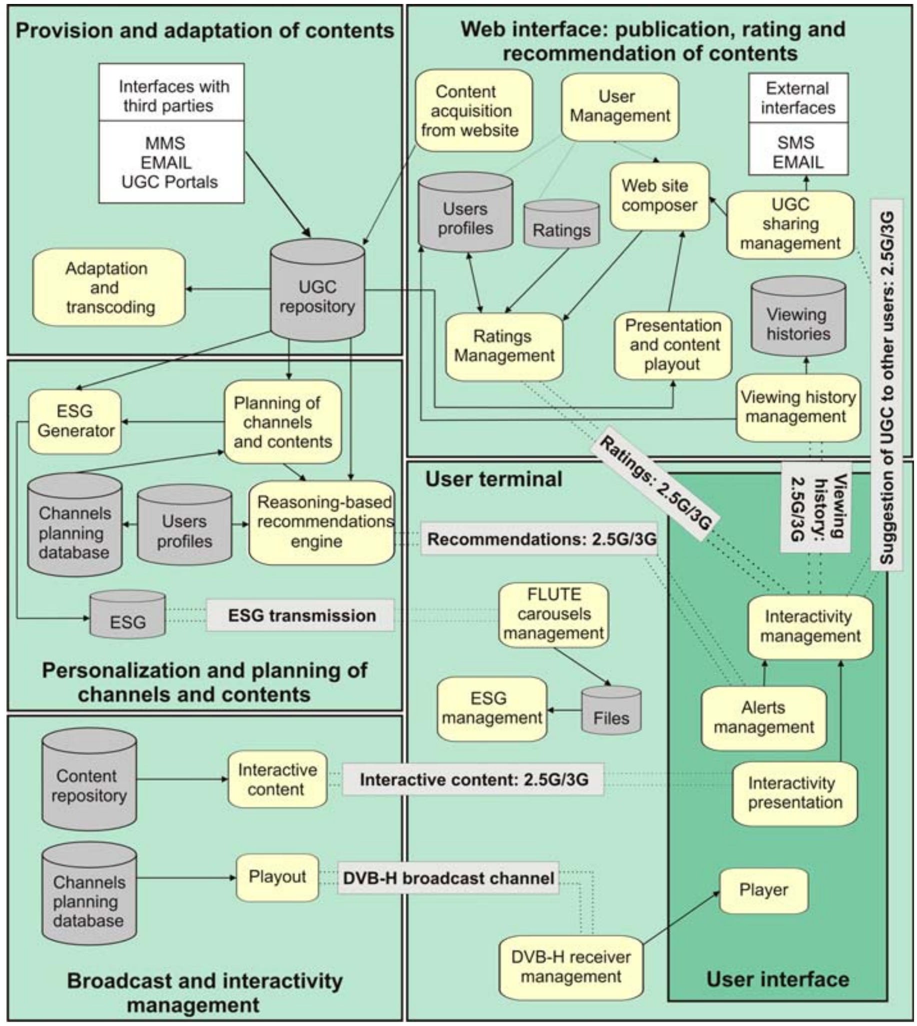
5.2 A modular architecture

After motivating the location of our recommendation strategy, the next step is to describe the architecture of the system in its entirety, whose design has been driven by modularity. This feature makes it easy to incorporate into our system both new functionalities appealing to mobile TV users, and future technologies that promote its generalized use. As shown in Fig. 2, the architecture is composed of the five functional blocks that are briefly described next: (1) provision and adaptation of UGC items, (2) Web interface, (3) personalization and planning of channels, (4) broadcast and interactivity management, and (5) user terminal.

– *Provision and adaptation of UGC items*: this block is in charge of acquiring UGC items (from well-known UGC portals and even via multimedia messages or e-mail), transcoding to the formats handled by the broadcast channels, storing these items in a content repository (where the FOAF folksonomy and TV ontology are included), and managing possible interactive services delivered by the system (e.g. new, stock price, on-line trading services).

[9] In literature, some approaches adopt personalization techniques based on *light* semantic reasoning at the side of user's terminal, but they lead to significant loss of recommendation accuracy (see [15]) that could become a trouble in a personalized mobile TV system.

Fig. 2 Architecture of our personalized mobile TV system



– *Web interface*: as depicted in Fig. 2, the website of our system is mainly focused on publishing UGC items and developing the mechanisms that the users need to upload and annotate their contents, send their viewing histories, rate the available UGC items and even share them with others through a return channel based on 2.5G/3G network. Note that these suggestions among users can be ordered from both the website and the user's handheld device, hence the fact that the block includes interfaces with external notification systems (e-mail, SMS) to report the users of the availability of appealing contents.
– *Personalization and planning of channels*: as shown in Fig. 2, the available UGC items are planned and arranged in the ESG (Electronic Service Guide), including schedule information about the contents broadcast through each theme channel. At the same time, the *reasoning-based recommendation engine* included in the block resorts to our two-phase hybrid strategy to identify the UGC items that are appealing to each user.
– *Broadcast and interactivity management*: this block encapsulates the information related to the planned theme channels to be delivered through the DVB-H stream, and transmits the interactive material via the return channel.
– *User terminal*: this last block includes all the modules required to compose the client application that allows the user to access our system from their handheld devices. These modules are in charge of receiving the ESG, presenting its information on the device, managing the browsing of channels and the selection of a specific UGC, and playing out the selected contents. Besides, as shown in Fig. 2, the user terminal also includes a module devoted to the *user interface*, which permits, for instance, to rate the available UGC items and annotate them using the own keypad of the handheld device.

6 Experimental evaluation

When it comes to evaluating our system, we distinguish between the functionalities bound to Web 2.0 and those related to personalization. In our opinion, the former are more critical than the latter: the active participation of users in the current Web 2.0 (see the precise figures of penetration in [24]) leads us to think that mobile TV users will be probably interested in creating their own contents, rating them, categorizing them and even sharing these UGC items with other individuals. However, asserting the interest of the individuals in our personalization functionalities requires to carry out tests where the accuracy of the semantic reasoning in a personalized mobile setting can be validated experimentally from the user-provided feedback. For that reason, before implementing a full prototype of our system, we started developing (and testing) only the blocks of the architecture directly related to personalization capabilities. The first results of some tests involving this preliminary prototype are described in this section.

Specifically, the developed prototype explores a set of 675 contents—extracted from well-known UGC portals and represented in a TV ontology containing about 20.000 nodes referred to UGC items, their attributes and hierarchies of classes, and selects those potentially interesting for a set of users by resorting to our reasoning-based recommendation strategy. Before discussing the obtained results, we detail the experimental design of our evaluation.

6.1 Experimental design

Our tests were carried out between February and September 2008, involving 60 users recruited among graduate/undergraduate students from the University of Vigo. These people belong to one of the social collectives who are most familiar with Web 2.0 technologies [18]. These users—not involved in our research work—were incentivized by the possibility of winning recharge vouchers for mobile phones or cash prizes. We ended up with an audience including nearly as many men as women (53% vs. 47%) and with ages ranging from 19 to 27 years old.

Our goals were (1) to measure the accuracy of the recommendations offered by our hybrid strategy and (2) to evaluate the users' global perception of our personalized mobile TV prototype.

Initially, the users logged in a web page by their e-mail and filled in a form to initialize their personal profiles, where they rated on a scale from 0 to 9 a set of classification CATEGORIES/subcategories (e.g. NEWS: national, economy; SPORTS: athletics, cycling; MUSIC: jazz, rock, etc). After processing these forms and modeling the users' profiles, our hybrid recommendation strategy selected automatically UGC items suited to their preferences. Next, we e-mailed the users in order to alert them of the availability of their personalized recommendations, including a brief description for each one of the recommended UGC items. After the notification, the users connected to our web server through

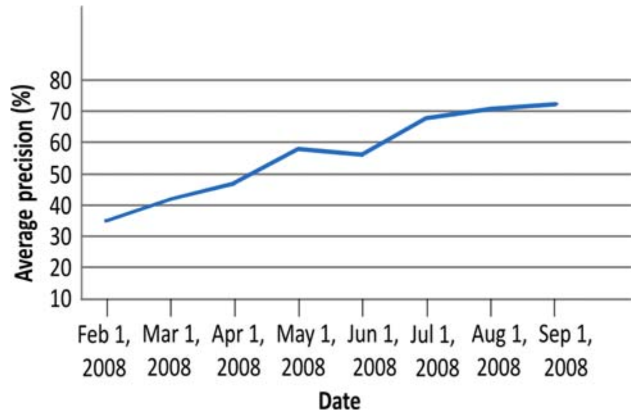


Fig. 3 Evolution of average precision values of our implicit recommendations along the 7-month testing period

diverse handheld devices (70% of users employed laptops, 20% mobile phones and 10% PDAs)[10] to query and view the suggested UGC items.

Lastly, the users rated these contents and provided us daily with relevance feedback about the recommendations. Specifically, the feedback included the ratings given by the user to each suggested content, along with an estimation of the time he/she spent with our personalization tool (e.g. viewing and rating the recommended UGC items, providing feedback, etc.). The ratings were employed to update the users' profiles and select new recommendations day after day. Regarding the usage time, we measured this parameter to detect possible dependencies between the time the users spent using our tool and the recommendation accuracy.

6.2 Experimental results

In order to assess the quality of our recommendations, we measured daily their precision for each user, defined as the percentage of suggested UGC items that were interesting for him/her (i.e. the ones that got a rating greater than 6 in the relevance feedback). Next, we averaged the precision values corresponding to all the users and represented the evolution of these values along the 7-month testing period, as shown in Fig. 3.

Analogously, we averaged the usage times measured for each individual. The progress of these daily average values during the testing period is depicted in Fig. 4.

Lastly, once the testing period had passed, we sent the users an e-mail with a questionnaire including questions such as: "*at what time, where and why did you use the tool?*", "*would you be willing to pay for receiving our recommenda-*

[10] Admittedly, these numbers may not be realistic in a DVB-H-based system because users tend to use 3G mobile phones and PDAs as handheld devices. In our testing scenario, most of the students used laptops for their convenience.

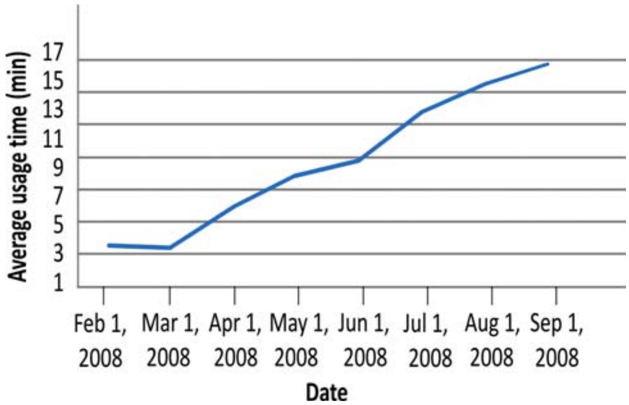


Fig. 4 Average usage time values during the testing period

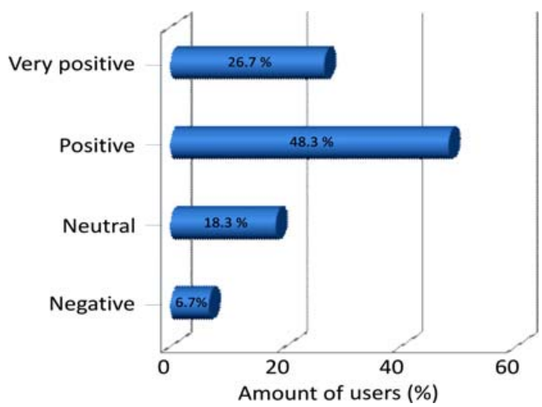


Fig. 5 Perception of the users about our reasoning-based recommendations

tions?", "*do you think that the recommendations were diverse or very repetitive?*", "*do you feel that the quality of recommendations improved over time*?", and "*how do you assess globally the personalization capabilities of the tool*?", just to name a few. From the users' answers, we could evaluate the global utility of our personalized TV tool in a mobile setting. Specifically, the results obtained for the last of the mentioned questions are depicted in Fig. 5.

The results presented in Fig. 3 show that the average precision of the recommendations elaborated by our reasoning-based strategy increases over time. This increase is undoubtedly achieved thanks to the feedback provided by the users after recommendations. This feedback helps our reasoning-enhanced strategy to know better the users' preferences, thus leading to more and more accurate suggestions.

As shown in Fig. 4, the maximum values of usage times of our personalization system coincide with those of average precision of the recommendation. According to these data, as the users receive high-quality recommendations, they start employing our system more and more during breaks and spare times. Indeed, the great number of high ratings gathered indicates that the users spent more and more time with our tool because they received more and more precise recommendations. In this scenario, the users viewed more and more UGC items (and entirely because they liked these contents), hence the fact that the usage times increased.

Lastly, as shown in Fig. 5, most of the users involved in our preliminary tests (75%) evaluated our personalization tool *positively* or *very positively*. On the other hand, just 25% of users either remained indifferent (*neutral*) or did not find appealing our personalization capabilities (*negative*).

Starting from the questionnaires provided by the users, we not only discovered that most of the users (81%) would be willing to pay for receiving our *non-overspecialized* recommendations, but also inferred interesting data related to the most popular content categories, and favorite times and places for mobile TV consumption. Regarding the categories, users enjoyed mainly UGC items classified as *Sports*, *Music*, *Humor* and *Sciences*. These users typically reviewed their recommendations during breaks from classes and when they relaxed at the university cafeteria (where the recommended UGC items were shared with other friends). Users also enjoyed our recommendations when they were at home because either *the television set was busy* or the UGC items were *more funny than programs on TV*.

In spite of the preliminary nature of our experimental tests, this evaluation has permitted us to check (1) good results of recommendation precision and (2) the users' acceptance about our reasoning-based recommendations in a mobile setting. The next step will be to finish the development of a full prototype, so that (1) all its functionalities can be validated in a more realistic scenario with a higher number of users, and (2) conclusive results can be drawn regarding to parameters such as scalability, performance or easy of use. For that purpose, we are currently participating in a research project where the University of Vigo cooperates with leading enterprises in audiovisual services technologies, which see our research as a possible means to develop an innovative product that enables to increase market share and gain customers loyalty.

7 Conclusions

In this paper, we have described the main functionalities and architecture of a mobile TV system that enhances the viewers experience outside the home boundaries. Our system is inspired by the principles of participation and sharing between individuals promoted by the so-called Web 2.0. For that reason, the users gather together in social networks where they create, annotate, rate and share audiovisual contents.

We have opted for broadcasting of User-Generated Content (UGC) items in our system because these contents adapt perfectly to the new medium of mobile TV, where the users have an appetite for interacting but need to be motivated by attractive content: something that feels fresh, rewarding, and is adapted to shorter viewing times. UGC items meet perfectly each one the aforementioned features, what turns our system into a potentially appealing tool where the users can employ mobile TV as a way for self-expression and creation, thus shaping a new "*self-authored TV*".

Along with the *user-driven content generation* and *ubiquitous access* via handheld devices, our mobile TV system enhances the viewing experience on the move by offering: (1) *interactivity options* through a return channel based on 2.5G/3G network and (2) *personalization functionalities* to recommend potentially appealing UGC items to each user. Specifically, our system includes a recommendation strategy that automatically identifies which of the broadcast UGC items could be most appealing to each user (as per his/her preferences and viewing history). To this aim, our strategy combines traditional filtering mechanisms with semantic reasoning techniques borrowed from the Semantic Web that allow to exploit additional knowledge about the users' preferences, thus leading to improved recommendations.

The combination of mobile TV and Web 2.0 principles will ultimately give way to a more personal and private TV experience than that of traditional broadcast TV, with big implications for users, content providers and advertisers.

– On the one hand, users are able to receive UGC items anytime and anywhere, to collaborate actively with other individuals, and to employ their handheld devices as a personal TV screen at home, either because they want to avoid other members of the household and have a private viewing environment, or because the television set is busy and they want to watch something else.
– Regarding content providers and advertisers, both of them can enlarge their target audience and tailor their offerings more specifically to the users thanks to our personalization capabilities. This strengthens the users' loyalty and therefore may lead to very profitable business opportunities.

Our personalization capabilities have been experimentally validated by a first prototype that allowed us to measure both the accuracy of our reasoning-enhanced recommendation strategy and the users' global perception of the suggested UGC items. Even though these results are preliminary, we think that they are a good indication of that our system offers an enhanced viewing experience, permitting the users to enjoy an unprecedented combination of broadcast and UGC items in a personal interactive mobile TV environment.

References

1. Ardissono, L., Gena, C., Torasso, P., Bellifemine, F., Difino, A., Negro, B.: User modeling and recommendation techniques for personalized electronic program guides. In: Personalized Digital Television: Targeting Programs to Individual Viewers, pp. 3–26. Kluwer Academics Publishers, London (2004)
2. Adomavicius, G., Tuzhilin, A.: Towards the next generation of recommender systems: a survey of the state-of-the-art and possible extensions. IEEE Trans. Knowl. Data Eng. **17**(6), 739–749 (2005). doi:10.1109/TKDE.2005.99
3. Akamai White Paper: Successful social networking and user-generated content: what your need to know. Available in http://www.akamai.com/dl/whitepapers/social-networking-wp.pdf (2006)
4. Baudisch, P., Bruekner, L.T.V.: Scout: guiding users from printed TV program guides to personalized TV recommendation. In: Proceedings of the 1st Workshop on Personalization in Future TV (TV-01), pp. 151–160 (2001)
5. Blanco-Fernández, Y., Pazos-Arias, J.J., López-Nores, M., Gil-Solla, A., Ramos-Cabrer, M.: AVATAR: An improved solution for personalized TV based on semantic inference. IEEE Trans. Consum. Electron. **52**(1), 223–232 (2006). doi:10.1109/TCE.2006.1605051
6. Carlsson, C., Walden, P.: Mobile TV—to live or die by content. In: Proceedings of the 40th International Conference on System Sciences, pp. 41–51 (2007)
7. Das, D., ter Horst, H.: Recommender systems for TV. In: Recommender Systems: Papers from the AAAI Workshop. Technical Report WS-98-08, pp. 151–160. American Association for Artificial Intelligence (2001)
8. Digital Video Broadcasting (DVB): Transmission system for handheld terminals (DVB-H). ETSI EN 302 304 V1.1.1. (2004)
9. Gruber, T.R.: A translation approach to portable ontologies. Knowl. Acquis. **5**(2), 199–220 (1993). doi:10.1006/knac.1993.1008
10. Hales, D., Arteconi, S.: Friends for free: self-organizing artificial social networks for trust and cooperation. Technical Report UB-LCS-2005-20. University of Bologna, Bologna (2005)
11. Harper, A., Buress, R., Lee, S., Huh, S.Y., McNiel, R.D.: Mobile Telephones: Networks, Applications and Performance. Nova Publisher Inc., New York (2008)
12. Hill, W., Stead, L., Rosenstein, M., Furnas, G.: Recommending and evaluating choices in a virtual community of use. In: Proceedings of International Conference on Human Factors in Computing Systems (CHI-95), pp. 194–201 (1995)
13. Kaneko, S.: Practical experiment on Digital Terrestrial Broadcasting in Japan: Tokyo Pilot Project (2002)
14. Lee, S., Huh, S.Y., McNiel, R.D.: Automatic generation of concept hierarchies using WordNet. Expert Syst. Appl. **35**(3), 1132–1144 (2008). doi:10.1016/j.eswa.2007.08.042
15. López-Nores, M., Blanco-Fernández, Y., Pazos-Arias, J.J., García-Duque, J., Ramos-Cabrer, M., Gil-Solla, A., Díaz-Redondo, R., Fernández-Vilas, A.: Receiver-side semantic reasoning for Digital TV Personalization in the Absence of Return Multimedia Tools and Applications (2008, in press). doi:10.1007/s11042-008-0239-7
16. Miller, B., Albert, I., Lam, S., Konstan, J., Riedl, J.: Movielens unplugged: experiences with an occasionally connected recommender system. In: ACM Conference on Intelligent User Interfaces (IUI-03), pp. 263–266 (2003)
17. O'Reilly, T.: What Is Web 2.0? Design Patterns for the Next Generation of Software (2005)
18. Orgad, S.: This box are made for walking. How will mobile television transform viewers' experience and change advertising? http://www.mobiletv.nokia.com/resources/files/RD1910NokiaGlobal_lowres.pdf (2006)

19. Oksman, V., Ollikainen, V., Noppari, E., Herrero, C., Tammela, A.: PodRacing: Experimenting with mobile TV content consumption and delivery methods. Multimedia Syst. **14**(2), 105–114 (2008). doi:10.1007/s00530-008-0118-0
20. Schafer, J.B., Konstan, J., Riedl, J.: Recommender systems in e-commerce. In: Proceedings of the 1st ACM conference on Electronic commerce (EC-99), pp. 158–166 (1999)
21. Sirin, E., Parsia, B., Grau, B.C., Kalyanpur, A., Pellet, K.Y.: A practical OWL-DL reasoner. Web semantics: science, services and agents on the world wide web. Softw Eng Semantic Web **2**(5), 51–53 (2007)
22. Soedergard, C.: Mobile Television—Technology and user experiences. Technical Report VTT- 506, VTT Technical Research Centre of Finland (2003)
23. TV-Anytime Specification Series S-3 on Metadata: In http://www.tvanytime.org (2001)
24. White, D.: SPIRE Project—Results and analysis of Web 2.0 services survey. http://www.jisc.ac.uk/media/documents/programmes/digitalrepositories/spiresurvey.pdf (2007)
25. Zimmerman, J., Kurapati, K., Buczak, A., Schafer, S., Gutta, S., Martino, J.: TV personalization system: design of a TV show recommender engine and Interface. In: Personalized Digital Television: Targeting Programs to Individual Viewers. pp. 27–51. Kluwer Academics Publisher, London (2004)