Towards Personalised Multimedia Applications
A Literature Review

Sebastian Sastoque H.[1], Oscar Avila[1] and Marcela Iregui[2]
[1]*Department of Systems and Computing Engineering, School of Engineering, Universidad de los Andes, Bogota, Colombia*
[2]*ACCEDER Research Group, Faculty of Engineering, Universidad Militar Nueva Granada, Bogota, Colombia*

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Abstract: Multimedia applications are now commonly used in daily life for several domains as marketing, health, learning and entertainment, among others. As the number of available applications increases, a competitive factor is the level of alignment to personal preferences. Indeed, the role of multimedia content has been crucial to generate user centred applications. However, multimedia content personalisation requires complex systems that execute diverse tasks such as representation, modelling, annotation and retrieval. Research on this field has been focused on content annotation and retrieval perspectives. Despite this, these domains do not address two of key personalisation factors, i.e., considering personal preferences and contextual knowledge. This work presents a literature review aimed to identify theoretical elements related to personalisation purposes, which could be integrated to the most common approaches. As a result, a road map for future research is established.

1 INTRODUCTION

Nowadays the development of new technologies and the expansion of the Internet have broadened the range of applications and systems that use multimedia content. Diverse fields such as education, medicine, entertainment, marketing and business, among others, have benefited from this phenomenon. While the number and variety of applications are growing, users change their needs, expectations and demands, looking for ever further personalised experiences (Lu et al., 2011). For instance, users prefer watching movies of their favourite genres, reading news about their interest topics or listening music according to their mood. In this context, multimedia content personalisation has become a crucial factor to enrich the user experience. For example, Facebook became the main leader of social networks apps, thanks to personalised social interactions through multimedia content, that was its main differential within the existing competitors at the moment.

The concept of personalisation can be defined as the process of customising data output in order to reflect users interests, preferences and situations and meet their requirements (Boll, 2003). Multimedia content itself is not enough for personalizing applications. Thus, complex systems are needed for representing, modelling, indexing, retrieving and presenting media content according to user needs and the application domain (Lu et al., 2011). This is known as the *semantic gap*, which constitutes one of the main challenges in multimedia research (Lew et al., 2006).

Aiming at filling this gap, proposals are presented in two different areas: content features extraction and annotation, and content retrieval (Lu et al., 2011). Although, research in these fields contributes to personalisation, they do not address the user preferences knowledge domain, which is a key factor in user centred applications. Therefore, some complementary areas could contribute to this field by extending the main functionalities obtained by using approaches only based on annotation and retrieval.

Some approaches have adopted an holistic perspective of the problem (Sastoque et al., 2014; Giordano et al., 2011; Alduán et al., 2011; Scherp et al., 2007). However, these works do not present an exhaustive review of the literature to present their proposals. In fact, after a preliminary searching process, it was not found a work aimed to review personalised multimedia applications research field. The found reviews are focused on the area of Multimedia Information Retrieval (Lu et al., 2011; Sebe and Tian, 2007; Lew et al., 2006).

Accordingly, this work presents a literature review

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aimed (i) to identify the research process behaviour in the domain of personalised multimedia applications and (ii) to establish which approaches from complementary areas could be adapted for personalisation purposes. The results of this review are used to determine what are the main challenges and open research questions in the area.

The remaining of the paper is organised as follows: Section 2 presents related works and introduce the mains concepts for the review. Section 3 introduces the methodology of literature review and the results of the two first steps, namely, *planning* and *Conducting and Material Collection and Evaluation*. Section 4 presents a qualitative and quantitative analysis of the review, which corresponds to the third step of the methodology. Section 5 presents the challenges related to the area. Finally, section 6 concludes the paper.

2 RELATED WORKS

Given the variety of contributions in the field of personalisation in Multimedia Information Retrieval, this section summarises some reviews aimed to synthesise the literature in this area to bring an overview of the related works.

Lu et al., (Lu et al., 2011) present a survey aimed to overview the current research in multimedia annotation, relation and visualisation. The survey analyse a sequence of applications useful for content-based multimedia retrieval. Then, the authors select the best models and techniques used to represent context and user preferences, conceptualise ontologies, display content and retrieve multimedia information. Finally, the selected models and techniques are mixed to propose the concept of *Intelligent Multimedia Content*. Sebe et al., (Sebe and Tian, 2007) present an analysis of the topics related to personalisation in Multimedia Information Retrieval aimed to identify the common tendencies to achieve personalisation. Particularly, this work addresses two issues related to: (i) the users preferences for personalised access to the content and (ii) the devices capabilities and applications to display content. The authors conclude that there exist challenges in personalisation related to Multimedia Collaboration, Interactive Search with Agent Interfaces and Folksonomies, i.e., the use of crowd wisdom to annotate and retrieve the content. Lew et al., (Lew et al., 2006) review a set of 100+ published articles before 2006 in the area of content-based multimedia information retrieval. They studied the effect of search paradigms, affective computing, learning, semantic queries and evaluation techniques in content-based retrieval. The authors conclude that the important challenges are: (i) semantic search in media with complex backgrounds, (ii) multimodal analysis, (iii) exploration of media collections, (iv) interactive search and (v) evaluation methodologies.

Although these reviews are a great contribution to the state of the art in the multimedia field, they only are focused on the retrieval area and how to represent the user preferences. It leaves a gap related to the current state of the development of personalised multimedia applications and what are the main challenges to achieve next level of personalisation, which are the most relevant topics of this work.

3 LITERATURE REVIEW

A literature review is a systematic and reproducible design to identify, evaluate and interpret a set of existing documents (Seuring and Müller, 2008). The reviews usually aim two objectives: (i) to summarise the existing research of a field by identifying issues, patterns and contributions and (ii) to identify the conceptual framework of a field and contribute to its development (Webster and Watson, 2002). The design of a literature review should follow a methodology that ensures the comprehension and analysis of the content, where quantitative and qualitative analysis should be addressed to describe the research field (Seuring and Müller, 2008). In this work the selected methodology was based on the model proposed by (Mayring, 2014) and adopted the best practises proposed by (Webster and Watson, 2002). Thus the literature review followed the next steps: *Planning* (section 3.1), *Conducting and material collection and evaluation* (section 3.2) and *Descriptive review analysis* (section 4).

3.1 Planning

This step defines the review questions, the criteria to conduct the search, the delimitation of the material and the method to validate contributions. According to the review objectives introduced in section 1, the proposed review questions are: (i) What are the main contributions of the different approaches?; (ii) What are the approaches field of application?; (iii) How multimedia content is related to the user domain context?; (iv) Which techniques are used to represent and store content annotations? and (v) How personalisation is addressed?

Regarding the material delimitation to reduce the number of proposals to analyse, the review process is based on the following considerations: (i) the analysis

scope includes only peer-reviewed publications written in English; (ii) the main area of the review is *models for personalised multimedia applications*; (iii) the following complementary areas are included to identify the common approaches: personalised content retrieval and personalised content annotation, (iv) only those works focused in models, architectures, platforms, software, systems or frameworks are included, (v) the proposals are in the design, development or implementation stage (vi) to ensure the objectivity of the review the work selection is performed by the authors separately and (vii) the works are published until April of 2016.

3.2 Conducting and Material Collection and Evaluation

In this step it is performed a comprehensive and exhaustive search for primary approaches using the criteria defined in the previous step. Then, a validation and assessment process is performed to select the set of approaches that will be included in the review.

The search of related publications was conducted as a structured keyword search. The search process used the Scopus database (Burnham, 2006). This database was selected because it indexes quality perreviewed works presented in journals and conferences of main scientific publishers, such as, IEEE Explore, ACM, Elsevier, among others (Burnham, 2006). The query used in the search was: *(TITLE-ABS-KEY("Personalised multimedia application")) OR (TITLE-ABS-KEY("Application" OR "Model" OR "Architecture" OR "Framework" OR "System" OR "Platform" OR "Software") AND TITLE-ABS-KEY("Personalization" OR "Personalisation" OR "Personalized") AND TITLE-ABS-KEY("Multimedia Content" OR "Multimedia" OR (("Media" OR "Content" OR "Multimedia") AND ("Retrieval" OR "Annotation"))) AND TITLE-ABS-KEY("Design" OR "Implementation" OR "Development"))*

The Scopus engine resulted in 851 candidate articles. The evaluation of the material process to limit the articles used the following filters: (i) Reading of the title and keywords reduced the numbers of works to 388. (ii) Reading of the abstracts to filter those ones that do not have hints to answer the review questions, limited the number of articles to 123. (iii) A full reading of the articles concludes the evaluation to the selection of a final set of 76 articles. In this work we synthesise the most common approaches and only cite the most relevant works for each approach.

4 DESCRIPTIVE REVIEW ANALYSIS

It assesses formal aspects of the material. Two kinds of analysis are performed for providing theoretical background from contributions or identifying open research challenges. The first analysis is quantitative, which provides information about the area trends, e.g., the number of publications per year. The second analysis is qualitative, corresponding to the main concepts descriptions regarding to predefined review questions, e.g., common methods and techniques used in one task.

4.1 Quantitative Analysis

Descriptive dimensions are defined for performing quantitative analysis and classification of each article. The dimensions are time dependant and answer the following questions: (i) how frequent are the publications?, (ii) which research methodologies are applied, (iii) what are common terms used in the works? (iv) what are the publications type?, and (v) which are the most common journals and conferences?. The results of the quantitative analysis using these dimensions are presented below.

After the first work, from 1991 to 2002, the publication frequency remained below one paper per year. The number of publications increased in 2005 and since then it varies between 2 to 9. However, it could be expected that with emerging technologies and devices, in the next future this frequency would show a significance increase.

The methodologies reported by the reviewed publications are among these four types: (i) theoretical and conceptual; (ii) based on case studies and domain dependant applications; (iii) modelling founded and (iv) literature reviews.

Figure 1: Common terms.

An analysis of the common terms used in the publications is presented in Figure 1. This analysis was performed with the tool (Sinclair and Rockwell,

2016). As expected the most common terms are *Multimedia* and *Content*. However, the broad use of terms such as *knowledge*, *semantic* and *ontology* shows that exists a trend in the different approaches to include semantic and knowledge representation issues. The most common media types addressed in the papers are *videos* and *images*. Finally, the works commonly present *frameworks* and *models* and the most frequent application is content *retrieval*.

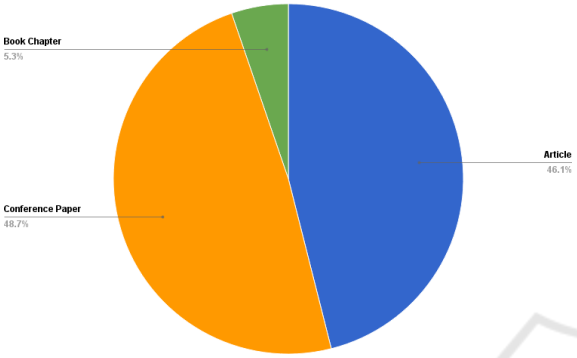

Figure 2: Publications per type.

The publications are equally distributed between conferences and journals (Figure 2). Although there is not a conference or journal that has a representative frequency of publications, the journal with the largest number of contributions is *Multimedia Tools and Applications*. The highest number of conferences related to the field publish their proceedings in *Lecture Notes in Computer Science*, *IEEE Conference on Multimedia* and *CEUR Workshop Proceedings*.

4.2 Qualitative Analysis

The qualitative analysis of the review is presented according to the questions introduced in section 3.1.

4.2.1 What are the Main Contributions of the Different Approaches?

The principal contributions of the approaches are divided in five categories: (i) design of architectures, (ii) methods for content representation, (iii) models for user profiling and development of applications, (iv) study cases and applications for personalisation in specific domains and (v) surveys and literature reviews.

Related to the category of design of architectures, the main contributions are associated with: the use of specific technologies and standards, such as cloud computing, big data and MPEG-7 (Zeng, 2016; Guo et al., 2015); handle, deliver, process, annotate and retrieve content (Alduán et al., 2011; de Fez et al., 2015); general purpose related with personalisation based on services or the definition of components (Scherp et al., 2007).

The approaches related to content representation commonly address two tasks: first, the representation of content using low level features, such as, visual structures, signal descriptors or descriptive languages (Rinaldi, 2014); and second, the semantic representation of the content by using meta-data and algorithms to relate low level features with semantics (Mallik et al., 2013).

The contributions corresponding to modelling category aim to model: user profiles for specific context applications (Park et al., 2012); applications for specific domains as museums, news, searches or sports (Appalla et al., 2016); techniques for content retrieval, annotation and semantic relation (Sun et al., 2011; Scherp et al., 2007; Sebe and Tian, 2007); frameworks to the development and implementation of applications (Weiß et al., 2008).

The articles that present study cases and applications have as main contributions: the definition of concepts and requirements for content distribution and personalisation (Evans et al., 2006); the implementation of applications for content digitization, management and processing (Chen et al., 2012); the use of domain knowledge in applications related to the context, such as, vigilance, georeferencing and digital museums (Xue et al., 2012; Mylonas et al., 2008).

Finally, a set of articles present literature reviews and surveys related to the state for multimedia retrieval, recommendation, personalisation and annotation (Lu et al., 2011; Lew et al., 2006).

4.2.2 What are the Approaches Field of Application?

The adjacent fields, that are related to multimedia content personalisation, presented in the review are: (i) retrieval, (ii) annotation and indexing, (iii) recommendation and (iv) adaptation and personalisation.

The multimedia content retrieval aims to the extraction of semantic information from multimedia data sources to retrieve content according to a query (Furht, 2008). The queries could be composed as textual keywords, content examples or mixing both techniques. The approaches that address retrieval commonly aims the inclusion of semantic relations to the retrieval process. The common methods have three principal steps: (i) feature extraction and content summarising , (ii) filtering and (iii) description (Alduán et al., 2011; Nie et al., 2016; Scherp et al., 2007; Sebe and Tian, 2007).

Annotation and Indexing techniques supports the content retrieval process. The multimedia content annotation refers to methods that allows semantic and low level descriptions of content (Furht, 2008). These annotations could follow specific frameworks or models related to domain context (semantic descriptions) and content features (low level descriptions) (Park et al., 2014; Mallik et al., 2013). Multimedia indexing refers to content pre-processing aimed to create indexes by using features (Mylonas et al., 2008). The indexation objective is to increase searching efficiency on large databases. This must support similarity queries, in which the similarity measure is defined previously by a domain expert.

Recommendation processes aim to represent users preferences with the objective of suggest unseen items (Furht, 2008). The final outcome of recommendation is a set of new elements for a specific person by employing a profile and information about other users and items features (de Fez et al., 2015). Another approaches seek to guide the user in a personalized way to elements of his interest in a large space of possible options (Karaman et al., 2014).

Personalisation and Adaptation present the content to the user in an individualised way according to their tastes and constraints. Personalisation process allows the adaptation of specific multimedia content in accordance to individual standards, tastes and preferences (Furht, 2008). Approaches that address personalisation seeks to extract user profiles and relates them to semantic descriptions of the multimedia content for presentation purposes (Dolbear et al., 2008). Adaptation is the process to transform a content to another representation that accommodates to restricted device input and output capabilities (Furht, 2008), e.g., converting images to text descriptions due to bandwidth constrains of mobile devices (De Vrieze et al., 2005).

4.2.3 How Multimedia Content is Related to the User Domain Context?

The reviewed works that address relation between multimedia content and user domain context use the following approaches: (i) ontologies, (ii) models and (iii) annotations.

An ontology is *"a formal, explicit specification of a shared conceptualisation"* (Studer et al., 1998). According to (Guarino et al., 2009), this conceptualisation refers to an abstract and simplified view of a domain that formally represent its knowledge by including entities and their relationships. In this context, ontologies are used to relate the content to specific domains by associating: low level features and descriptors with semantic categories; content description and annotations with semantic domain rules and; user profiles with semantic categories and content descriptors (Alduán et al., 2011; de Fez et al., 2015).

The approaches that propose models report a set of specific classes, attributes and methods for providing semantic representation of multimedia content. Specifically, some works propose domain models (Mylonas et al., 2008), others use graphs and semantic networks (Weiß et al., 2008), and those that propose existing models such as OWL triplets, SCORM elements or descriptive languages, etc (Nie et al., 2016).

Finally, the last set of approaches relate semantics to the content by meta-data annotations regarding domain concepts. These annotations are commonly stored in XML schemes attached to the content file or linked databases (Yang et al., 2014; Scherp et al., 2007).

4.2.4 Which Techniques are Used to Represent and Store Content Annotations?

Content annotations are commonly obtained by using automatic, semi-automatic and manual methods. The automatic ones refer at the extraction of features and descriptors by computational systems. In semi-automatic methods the systems extract some features, which are complemented by the user. In the manual method, the user is the responsible of annotate the content according to his knowledge. Regardless of the method used to extract features and descriptors, the annotations proposed by the reviewed works are represented by using (i) MPEG7, (ii) raw meta-data and (iii) models; and are stored by using (i) XML Schemes, (ii) raw data, (iii) ontologies and (iv) databases.

MPEG-7 is a Multimedia Content Description Interface that describes the features and meta-data of multimedia content through a standardized scheme (Furht, 2008). These scheme use different types of descriptors according to the content type, i.e., visual descriptors for images and videos or signal descriptors for audios and videos, among others. The storage of MPEG-7 descriptors in the reviewed works use databases, XML schemes attached to the binary files of the content and ontologies (Park et al., 2014; Sebe and Tian, 2007).

Other works used to create annotations is the storage of key and value pairs, in which each pair represent a feature or description of the multimedia content. These works store the annotations in databases, raw files, ontologies and XML schemes (Guo et al., 2015; Scherp et al., 2007; Alduán et al., 2011).

Finally, some approaches create models of the annotations according to the application needs. These

models represent low level and semantic descriptors. The models are stored in databases, XML schemes and ontologies (de Fez et al., 2015).

4.2.5 How Personalisation is Addressed?

Personalisation is addressed by the creation and development of user profiles. The latter are a set of attributes that represent users tastes, behaviour, preferences and patterns (Furht, 2008). The works reviewed address personalisation in two ways: first, by integrating user context information, and second by modifying content presentation. The first type of approaches integrates user context to recommend and provide a set of items that match the user profile (de Fez et al., 2015; Evans et al., 2006) or that match other user context data such as location, mental abilities or device capabilities (Karaman et al., 2014; Weiß et al., 2008). The second type of approaches present the content on an individual basis according to user profile. In these approaches the presentation of the content is the more important factor to address personalisation (Alduán et al., 2011; Mylonas et al., 2008; Sebe and Tian, 2007; Scherp et al., 2007).

5 OPEN RESEARCH CHALLENGES

Notwithstanding the significant progress of academic research on personalised multimedia applications, there has been little impact in the development of commercial applications that use these research results. Although advances in various complementary areas, such as annotation, representation and retrieval of multimedia content have contributed to the personalisation field, there are still open challenges ahead for increase the use of research results in industries.

5.1 Architectures and Models to Exploit the Advantages of New Technologies

With the rapid and steady evolution and expansion of new technologies, such as, Cloud Computing, Internet of Things and Big Data, in order to generate innovations in the media industry, these technologies must be considered to complement personalised multimedia applications. For example, with architecture models based on Cloud Computing technologies, the design and test of new applications could be easily addressed, allowing to developers undertaking, their new projects with few resources in relatively short time. In this context, personalisation could be easily addressed through Cloud Computing by permitting storage and content processing in a distributed manner, avoiding full installation, saving computation processing in the client side and reducing software upgrading and maintenance. Regarding Internet of Things, real-time multimedia communication could be applied in different contexts, increasing personalised experiences. For example, in emergency calls, user could share detailed information about an incident by transmitting images and/or videos from near cameras, permitting a real time analysis of the incident nature and severity.

Therefore, a current challenge in personalised multimedia applications development is the design of architectures models easily portable to the cloud, to take advantage of all its benefits and enable new possibilities for data analysis and new businesses development.

5.2 Evolution of User Profiles

Other current challenge is the proposal of advanced models for user profiles. Models may include context information of the content as well as attributes that represent users context. User models need to include elements to describe demographic and personal information, local settings, interests, skills, goals, tastes, behaviours, patterns and individual characteristics. These types of information should be interrelated with knowledge representation to enable contextual reasoning between the multimedia content, the application domain and the user profile. Therefore, as the user context is highly changing, user profile should evolve over time and should be dynamically updated and refined to reflect external events, including the user interaction history.

5.3 Discovery of Data Semantic Concepts and Knowledge Base Evolution

Multimedia applications should have the capability to add new content for personalising user experience. In this sense, the applications should have the capability to discover the semantics of new incoming content, update the knowledge base and determine relationships. This can be achieved by using low-level features in conjunction with machine learning techniques to identify high level content semantics. In addition, the knowledge base should be adaptable to the application domain and the user profile. User modelling deals with individual abilities, such as, cognitive, social and linguistic skills and personal and environmental circumstances. In this sense, an open challenge is the personalisation of knowledge bases

in conjunction with easy maintainability and interoperability.

5.4 User-centred Design of Applications

Although today literature refers to ubiquitous, mobile, pervasive, social and personalised applications, advances in research and development are still far from achieving them. Most common technologies and applications are unfriendly, cultural biased, unnatural and difficult to use. Thus, a gap between user needs and personalised applications development is pointed out. For example, cognitive science has shown the benefits of multi-modal interfaces to improve, user understanding and interactions, due to the apparent parallelism on the brain in response to multiple input stimulus (Dumas et al., 2009). This means, from an application development standpoint that it is useful design meaning interfaces that exploit this kind of advantage. However, most of the reviewed works do not include these kind of considerations in the content personalisation. Accordingly, it is important to create new frameworks that include user-centred design approaches to personalised multimedia applications development.

5.5 New Types of Content and Data

Most analysed works only focus the personalisation on audio, images, text or video. However, new types of multimedia content are now present in the literature, e.g., multimedia presentations, interactive documents, geo-referenced maps or 3d models. Therefore, personalisation research should focus on the analysis of new media types and techniques for multimedia integration. Important questions remain regarding methods for effective content selection, media allocation, and modality selection.

6 CONCLUSION

Personalisation of Multimedia Applications in an emerging research area that has received growing attention in the research community over the past decade. This work presents a literature review that identify the contributions of complementary areas to personalisation fields. The results of the review make evident that indeed exists two classical work areas aimed to address personalisation (annotation and retrieval). Although some works try to mix them to achieve personalisation (Giordano et al., 2011; Alduán et al., 2011), they only address the extraction and annotation of semantic features for content retrieval purposes. The following complementary areas that supports personalisation were identified at the review: (i) knowledge representation, (ii) user profiling, (iii) recommendation, (iv) content adaptation, (v) content retrieval, (vi) content annotation and indexing, and (vii) user-centred software methodologies. Even thought some proposals for multimedia personalisation are in the intersection of several of these areas, there are no works implementing an holistic approach that include all of them filling the existing gap.

From the reviewed works, those that have reached a higher level of maturity are in the areas of content retrieval and annotation, knowledge representation and user profiling. However, their influence on the development of multimedia personalised application are still low and frameworks and architectures that includes all their benefits deserves more research effort. From there, a set of open research challenges were identified: (i) architectures and models to exploit the advantages of new technologies such as cloud computing and Internet of things; (ii) evolution of user profiles; (iii) discovery of data semantic concepts and knowledge base evolution; (iv) user-centred applications design; and (v) new types of content and data.

Future work are related to fulfil the open challenges and to the proposal of methodologies, frameworks and architectures that allows the implementation of personalised multimedia applications. In this way, the development of multimedia applications should be based on contributions that support personalisation by: (i) relating the content with its semantic significance, (ii) knowing the user patterns and preferences, (iii) presenting the content according to the capabilities of the devices and user cognition abilities, and (iv) managing the annotation, storage and retrieval of multimedia files.

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