Methodologies and Trends in Multimedia Systems: A Systematic Literature Review

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Abstract. The studies about systematic literature review (SLR) related with Multimedia and produced between 2011 and early of 2018, we found that are focused in the Multimedia Systems (MS) development for health sciences mainly. No SLR results were found centered in studies about methodologies or frameworks used for their development, practices and tools applied for this purpose, or the study about validation processes. Neither are research focused on the characterization, and recent formulation, of taxonomies about MS.

This findings led to the realization of the present study in order to identify, which methodological approaches or frameworks are focused with the development of MS, Interactive and Multimodal Systems (IS and MMS, respectively). Due to the large number of results, we made the revision of 1506 studies found in 7 consulted databases, focusing the SLR in 32 documents closely related with five research questions.

This research evidences a limited number of methodologies or frameworks related specifically with the development of MS; and the wide use of generic practices for its development, mainly influenced by System Engineering, Software Engineering and Human-Computer Interaction disciplines, through the use of Interactive System (IS) development methodologies, where the attributes and specificities of the MS are not covered at all.

Keywords: Multimedia systems methodologies · Multimedia Systems · Interactive systems · Multimodal Systems

1 Introduction

The digital media industry is one of the main sectors showing a highest contribution growth, in the economy of the leading countries, producing increasing benefits to its gross domestic product (GDP). This is a trend evidencing the way how the digital media are displacing the traditional media, being not exclusive direction for the first world economies: Latin America has been registered as the region with the highest

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global growth in the digital media industry with 12.8%, followed by the Asia-Pacific region with 7.9% [1].

In Colombia, for example, the information provided by PriceWatherHouseCoopers [2] related with the advertising through multiple digital media, reports a growth in digital advertising investment of 30.2% between 2016 and 2017, although its contribution to the national economy is still significantly lower, than the one offered by the traditional mass media. In consequence, the country must be continue making efforts towards the development of its digital media industry.

In the other hand, the survey produced by Lang and Barry [3], although it is not a recent research, reveals several trends since early the 2000's acting as a barrier to achieve this purpose: one of them, the predominant use of methodologies and practices "in-house" for MS development in the industry of the first world economies, phenomenon that feeds the increasing gap and affects the competitiveness of the digital media industries belonging to the third world countries.

This trend about "in-house" practices for MS development in the industry, can be an influence for found a limited number of published methodologies focused in MS development currently, according with the findings of this SLR. Most of these methodologies are outdated compared with the new trends about several practices and standards of the industry. Actually, this has produced the use and adaptation of generic methodologies centered in IS development, to guide the MS development, leaving several gaps in their design process.

The objective of this work, is to carry out a research using a SLR method, focusing in methodologies and frameworks, practices and tools used, validation processes produced and trends, related with the MS development, including the research about studies centered in the characterization, differentiation and relationship between the MS, IS and MMS.

2 Background

The term "multimedia" was used for first time in July 1966 by music writer and artist Bob Goldstein, referring to the nature of the technological argument used to present his show "LightWorks at L'Oursin" in New York, being popularized in the publication of magazines like Variety [4]. However, Smith et al. [5] appropriated the phrase of MS, to refer to the use of different media, such as audiovisual media, as being part of a teaching-learning method, where both the teacher and the student are active participants.

Meanwhile, the IS concept emerges to differentiate up-and-coming interactive computing by early the 1960s [6], including user interfaces for the first time, from the batch processing. With the interactive computing, a human can interact with the system using a command line console, producing a difference from the batch processing systems, where a series of tasks are executed, without user intervention along the computing process [7].

In the 1980s, with the dawn of the personal computer and the possibility of accessing the Internet as a global public network, the conditions for moving towards a convergence of the Information and Communication Technologies industry (ICT) are met [8],

leading to the mass media industry - represented by radio, film, television and photography - to access an ideal scenario for producing the multimedia convergence [9].

This digital media convergence led to the development of IS which make use of interactive multimedia information, by different kind of hardware and software interfaces. This allowed the generation of new digital products and services, where the MS are commonly defined as systems that lets the deployment in an integrated way, of different sorts of interactive digital media, allowing storage, capture, generation, recovery, processing, transmission and presentation of multimedia information [10].

Meanwhile, the IS are defined as technologies based on computer systems and peripherals that, through the user interaction, performs a set of tasks [11]. This is a broader concept than the MS, however, the relationship and differences between both systems, it is not widely studied in the related literature.

A third kind of system related with the MS are the MMS, which foundations are based on the modality concept. The modality concept comes from the psychology, where Charwart's definition [12] were referenced, specifying it, as a perception that proceeds through one of the three channels: visual, auditory or tactile. This is the basis for technocentrism MMS definitions, such as the proposed by Möller et al. [13], which defines it, as a system in which Human-Machine Interaction is enabled, through the media, using different sensorial channels.

The deployment of interactive experiences generated through the development of MS, has traditionally allowed the integration of digital media based on audio, video and images as we can see in [14] and [15], offering at the user, to access at multimedia content focused on visualization techniques, for example, experiences based on projection mapping and augmented reality as recognized in [16].

In the 1980s, Shavelson and Salomon and Hawes in their works, coined the term "interactive multimedia" [17–19], referring, not only to the options that a MS can offer for visualization of multiple digital media, but also, for possibilities of interaction between the system user and the multimedia content. This multimedia content interaction, is one of the most important attributes in the design of MS, having an important role in the process development as a set of requirements for the system [20].

3 Research Methodology - SLR Justification

This paper is based on a methodology suggested by Kitchenham and Charters [21], for performing systematic literature review in software engineering, following a procedure to identify, analyze and summarize the information which has been documented, about previous research in Multimedia, specifically on aspects concerning with methodologies or frameworks formulated for the development of Multimedia, Multimodal and Interactive Systems, the tools, practices and validation processes performed along the MS development, trends in MS involving emerging technologies; and previous studies related with the characterization, differences and relationships between MS/IS/MMS.

The terms Multimedia, Interactive and Multimodal, were included in the search patterns of the SLR, due the wide use of these terms by many authors in its publications, related with systems that supports the deployment of multimedia content for the user.

Thanks to the previous study about SLR produced between 2011 and early 2018, were found publications related with MS and IS; and its application in different case studies in sectors like the Health Care [22–30], Education [31], Telecommunications [32] and Sports [33]. We concluded that about the 75% of the articles presented as systematic reviews related to multimedia and interactive systems and its applications, are closely related with the Health Sciences, without evidence of SLRs produced, focused on methodologies, practices and trends about MS development.

The subsequent steps to carry out this SLR are presented as follow:

3.1 Research Questions

The research questions and their basis against the study, are presented in Table 1.

Table 1. Research questions for the SLR.

Number	Question	Basis
RQ1	¿What methodologies or frameworks have been used or are susceptible to being adapted for the development of Multimedia Systems?	This RQ is the basis for this SLR, since it allows us to study the references related with studies that have been proposed previously, being a requirement to study those methodologies or frameworks related to Multimedia System and its relationship with methodologies for the development of IS and MMS
RQ2	¿What practices and tools are the most commonly used to guide a process of development for Multimedia, Multimodal and Interactive Systems?	The scope of this RQ require the recognition about the practices and tools that supports the different methodologies or frameworks studied in the previous question, in order to study their approaches in relation to the Multimedia field
RQ3	¿What are the trends related with the development of Multimedia Systems based on emerging technologies?	This RQ is necessary to know if there have been validation processes recognized in the methodologies and practices studied
RQ4	¿What are the trends related with the development of Multimedia Systems based on emerging technologies?	This RQ wants to recognize some of the main trends in MS development based in emerging technologies and, in the other hand, to contrast them with the scope of the methodologies and practices studied
RQ5	¿What studies are related with the characterization, foundations, relationship and differences between the concepts of Multimedia, Multimodal and Interactive Systems?	This last RQ is focused on the foundations about the MS, IS and MMS, studying aspects about its relationship and differentiation, in order to understand the scope of the methodologies and frameworks studied

3.2 Information Resources and Search Strategies

The search protocols were created through the literature review of different papers and book chapters, both in English and Spanish, produced in the last fourteen years (2004-early quarter 2018), with the purpose of achieving the greatest coverage possible related with methodologies, trends and foundations about MS, MMS and IS development.

The following are the databases consulted during the review process, in English:

- SCOPUS (https://www.scopus.com/home.uri)
- IEEEXplore (http://ieeexplore.ieee.org)
- ACM Digital Library (http://dl.acm.org)
- Springer (http://link.springer.com)
- Science Direct (http://www.sciencedirect.com)

The sources in Spanish:

- e-libro (http://www.e-libro.com/)
- Redalyc (http://www.redalyc.org/)

In the produced searches, the root terms used were: "multimedia system*", "interactive system*", "multimodal system*"; "mulsemedia", and "cyber-physical multimedia system*" were included for question RQ4, as result of previous searches produced in the chosen databases, using the root term: "multimedia research" protocol and whose findings are included in the analysis of results.

These root terms were associated with words as "design", "framework", "develop*", "method*" and "process", as second terms that must be associated in the recovered documents with MS, IS and MMS development methodologies and its validation process.

Therefore, the inclusion of these chains in the search protocols, together with the root terms, offers an articulated approach between the concepts of methodologies, frameworks, validation processes, practices and tools; allowing to examine, through an integrated approach, the research questions RQ1, RQ2 and RQ3.

For question RQ5, the words: "definition", "classification" and "taxonomy" were used in order to look for documents centered in foundations about MS, IS or MMS, which can create a connection between concepts.

SCOPUS

This database allows the search by title, abstract and by keywords in the document. The search was made by title, summary and keywords.

Once the search protocol was designed using the root terms and the keywords, a total of 317 documents were found for the search protocols related with the questions RQ1, RQ2 and RQ3.

With the given results obtained in the e-libro database, we proceeded to search in SCOPUS for documents by abstract, title and keywords with the term "MPIu+a" as a development methodology focused on IS under usability and accessibility practices. With this search criteria, we found a total of 4 additional documents.

For question RQ4 a total of 84 documents were retrieved, using searching by title, summary and keywords, due to the small amount of existing publications recovered in the preliminary search. For question RQ5, 44 documents were recovered.

Springer
Following the same criteria defined in the search protocol for questions RQ1, RQ2 and RQ3, we used the words "multimedia system*" or "interactive system*" in the title, and making sure that in the document it contained the words "design", "framework", "method*", "process or develop*" since this database does not allow searches by title and abstract, recovering 337 documents.

For question RQ4, three searches protocol was produced as follow: the first one, with the word "mulsemedia"; the second, using the exact phrase "multiple sensorial media"; and the third, "cyber physical system*" in its title; and including the word "multimedia" within the document. A total of 40 documents were retrieved.

In question RQ5, 2 documents were recovered using the search protocol: "multimedia system*", "interactive system*" and "multimodal system" in the title.

IEEE Xplore
Using the command search option in the advanced settings, 144 related documents were retrieved for the questions RQ1, RQ2 and RQ3, where the keywords were found at the title level of the document and words contained in the summary.

For question RQ4, the search was divided into two parts: the first, including the terms "multiple sensory media" and "mulsemedia" by document title, recovering 9 documents. The second search included the term "cyber physical system*" by document title and the term multimedia by summary, without returning search results. For question RQ5, 7 documents were recovered.

ACM Digital Library
An advanced search was produced for questions RQ1, RQ2 and RQ3, which included the terms "multimedia system *" or "interactive system *" in the title and any of the terms described in the search protocols showed below, in the whole content of the document, recovering a total of 126 documents.

For question RQ4, a search was designed by document title, with the word "mulsemedia" and the term "multiple sensorial media". Likewise, it was carried out with the term "cyber physical system*" and the search for the word "multimedia" in the entire document. A total of 35 documents were recovered. No results were found for question RQ5.

Web of Science
Due to the few results obtained using the terms defined for questions RQ1, RQ2 and RQ3, a broader search was carried out using the terms "multimedia system", "interactive system" or "multimodal system" at the title level, without the associated words defined for these questions in order to access as many possible documents related to the subject in this database. We found a total of 326 documents.

For question RQ4, searching protocols were applied at the title, summary and keywords level, recovering 11 documents.

Finally, and for question RQ5, a search protocol was designed according to the established terms, without finding documents that met the search criteria at the level of title, summary or keywords.

e-libro

For the search related with questions RQ1, RQ2 and RQ3, in e-libro in Spanish language, the search protocol was designed with the terms "sistema multimedia" and "sistema interactivo" in the title; in addition to: "diseño", "desarrollo", "modelo", "metodología", "proceso" and "framework", as words to be searched in text fields and key fields. Three results were obtained, without results for "sistema multimodal".

For question RQ4, we included the terms "mulsemedia", "sistemas ciberfísicos" and "sistemas multisensoriales", at the text level, document title and search in all fields respectively, in order to expand the search as much as possible, without results.

For question RQ5, we proceeded with a search protocol that linked the words "definición", "clasificación" and "taxonomía" within text fields and key fields of the document, as well as the terms "sistemas multimedia" and "sistemas interactivos" in their titles, recovering 2 documents.

Redalyc

Because the database does not allow searches with filters or use operators such as AND/OR, it was decided to search through the Google engine, where filters can be applied by site and file type. Through the applied search protocol, which on this occasion did not include the words "metodología" and "proceso" for the questions RQ1, RQ2 and RQ3, since they are usually included within the word "desarrollo" (for example, "metodología para el desarrollo de sistemas multimedia"), a total of 6 documents were recovered. For question RQ4, we found 9 documents using the Google engine.

In question RQ5, the words "definición", "clasificación" and "taxonomía" were applied to each of the terms: "sistemas interactivos", "sistemas multimedia" and "sistemas multimodales", without obtaining documents that met the search criteria.

3.3 Management of Studies and Inclusion/Exclusion Criteria

For classification purposes of the documentation retrieved, some exclusion criteria are established to determine which of the found studies will not be included in the review. These exclusion criteria are:

- EC1: Document not available for download.
- EC2: Document not available in English or Spanish language.
- EC3: The document describes the development of a multimedia/multimodal/interactive system, with not focusing on the process methodology or practices for its development.
- EC4: The document describes the development of interactive or multimodal system, without any relationship with multimedia systems.

Likewise, the studies selected for the SLR meet the following including criteria:

- IC1: The study was published between 2004 and early quarter 2018.

- IC2: The study is focused on the proposal of a methodological process or practice related with the design or development of multimedia/multimodal/interactive systems, or its use for the development of a specific solution.
- IC3: If the document focuses on aspects related with the IC2, even if it is in a language other than English or Spanish.
- IC4: Studies related with the state of the art, about emerging technologies in MS.
- IC5: The document is related with fundamentals of Multimedia/Multimodal/Interactive Systems and its relationship.

3.4 Data Retrieving

For the data extraction, an instrument in excel was used for preserving relevant information about main papers. After applying the inclusion and exclusion criteria to the base of the consulted sources, the classification of the documents is produced with the following information: (a) Database name, (b) Search term, (c) Inclusion criteria, (d) Research question(s) related to the document (e) Document ID, (f) Authors, (g) Document title, (h) Keywords, (i) DOI, (j) ISBN, (k) Year of Publication, (l) Name of the conference or journal from which the study proceeds, (m) Source of Publication such as book chapter, journal paper or conference paper.

The search for the systematic literature review was conducted between June 2017 and March 2018. A total of 1,506 results were retrieved from all the databases, subsequently filtered by title and abstract revision. Once the exclusion and inclusion criteria were applied, only 32 documents of interest were chosen for the review process, which are closely related to the research questions.

After reviewing the documents, 3 of them are related with the same methodology for the IS development: the first, related with the approach of the MPIu+a as methodology for IS development [34], the second, which offers a variant in the proposed methodology, describes the integration of practices focused on the development of user interfaces, focusing on usability and accessibility [35]; and the third, about a validation process for educational software in the treatment of children with disabilities [36].

The same happens in the studies presented by Basnyat et al. and Navarre et al., because the first one [37], is the basis that leads the formulation of the GIMF framework, which is discussed in the second document [38]. Table 2 presents the summary of the results.

Table 2. Search results summary.

Database	Search results	Duplicated documents	Relevant documents
SCOPUS	449	4	14
Springer	379	–	5
IEEE Xplore	160	4	7
ACM Digital library	161	2	4
Web of Science	338	1	–
e-Libro	5	–	2
Redalyc	15	–	–
Total	1506	11	32

4 Results Analysis

After reviewing the selected documents, a classification was made based on the research questions:

The recently paper produced by Olivera et al. [39], is a good reference for beginning the result analysis, mainly those related to the research questions RQ1, RQ2 and RQ3 and IS development methodologies, because their study is not only focused on the analysis of different proposals and approaches formulated by different authors related with the design, specification and verification of IS; and also makes an study about the fundamentals of those proposals, offering a classification related to informal, semi-formal and formal methods for IS development.

The study privileged an analysis centered, mainly, on the evaluation of the quality of IS, through the use of different formal techniques for modeling the system and its properties, evaluating the strengths and weaknesses of each described proposal. The application of these models is highly dependent on the experience and knowledge of the designers in relation to the protocols used in each model. This can be seen in the verification of models, the theorems proofing and the verification of equivalence, where the use of specialized software tools for such verification, is usual in the majority of proposals exposed in the paper.

Related with questions RQ1, RQ2 and RQ3, we find the papers [34–36], based on the same methodological proposal of MPIu+a, for IS development.

Some remarkable aspects of MPIu+a are related with its formulation under a generic approach based in an adapted evolutionary and iterative lifecycle process from Software Engineering based in prototypes. The user is involved from early stages of the process development, with special emphasis on practices related with the evaluation and the prototyping of the solution. The practices centered in Usability and Accessibility, are permeated along all the lifecycle process of the methodology.

MPIu+a flexibility has allowed different adaptations in its core, for example, the adaptation done by Villegas et al. [35], using OpenUP as a development process framework and a specification language as SPEM 2.0, for merge a methodology for User Interfaces development (CIAF) and the MPIu+a methodology for IS development. On the other hand, the use of the methodology has made possible its application for the development of multimedia educational software, in the treatment of children suffering of dyslexia, using a tablet as a deployment device of the experience [36].

Cuevas et al. in [40] exposes his life-cycle for MS development based in a process model using prototyping techniques from the Software Engineering discipline and adapting it, with a set of practices from the User Centered Design (UCD). The author makes a special emphasis, about the importance of having a "multidisciplinary" work team to guide the MS development process, for example, anthropologists, psychologists and sociologists, between others, but not specify the involved roles and who, how, where and when intervene in the process development for MS.

The Model-Based Design (MBD) based in the "V" process model is used by Boy in [41], for both, the development of tangible and mission critical IS in the aerospace industry, and MS development for Human-In-the-Loop-Simulations. In the design process, the model refers at the Human – Systems Integration as a key concept,

consequence of the merge between the Human – Centered Design and the Technology – Centered Engineering.

This model involves the stakeholder's participation from the early stages of solution planning, which increases the use of resources at the beginning of the project, in contrast with the traditional MBD model from System Engineering. However, the use of resources are significantly reduced in the final stages of the process development, as result of the adapted model, optimizing the project resources and the risk management.

Another example of using MBD for MS development, is the job presented by Leonard in [42], related with the development of embedded systems for in-flight entertainment (IFE) at low cost. In this paper, the methodology is used to produce the design of the hardware-software architecture model for the embedded MS. The hardware subsystem includes the LCD touch screen and the used microcontroller (Arduino). A key point to choose the MBD process in this research, is related with the verification of the required standards by the authorities responsible for certifying the design of any type of system, where MBD adheres to strict compliance to the set normativity, DO-331 and DO-178C, related with the critical systems of the aerospace industry.

Same situation is presented in the design model for the development of mission critical IS showed by Navarre et al. in [38], named Generic Integrated Modeling Framework (GIMF) and also based in MBD, represented by a set of six phases, using a series of techniques and software tools based on IS modeling, including within its design, the UCD practices and the errors detection, when the user interacts with the IS, using the Security Modeling Language described by Basnyat et al. in [37]. The paper exposes the fact that interaction techniques applied to critical systems, increases the possibility of incidents or accidents when the user interact with them.

Centered in MMS, Barricelli et al. in [43] exposes a method for Ubiquitous Web-based Multimodal Interactive Systems development, using the Software Shaping Workshop (SSW) and including rapid prototyping as a task that must be carried out throughout the life cycle process development. The paper describes the use of the methodology for MS development with a graphical interface using images and text for medical diagnose; and a visual and auditory experience for geographical maps using a text-to-speech tool.

A hexagonal model for IS design based on the theory of activity, is presented by Döweling et al. in [44]. The development is guided along an iterative prototyping process, in which a regular evaluation about the solution applicability on different types of systems takes place through the combination of physical and technical elements, as well as human and social, mixed together with an integral perspective. The model not specify considerations about hardware-software, or interface's design. The model presented, has a high level of abstraction, given the conceptual application of the activity theory to produce its description.

Related with the MMS development, the Vilimek work in [45] describes a generic procedure that guides the developer through a process of eight phases, highlighting those related with the interaction design, defined by the choice of the modalities that must be included in the system in the phase 3 and the merge of these modalities in relation with the user interaction in phase 4, highly dependent of the modalities chosen before. This paper is relevant, because should suggest the need from a design process

for MS development, where includes phases for choice the kind of media content needed by the user and the multimedia content integration related with the user interaction with the system.

In contrast with previous authors, dealing with all the stages of the MS/IS/MMS process development, Bowen in [46] exposes a set of techniques and tools grouped in a semi-formal framework, focused in the Interaction Design (ID) in IS specifically, for interaction spaces design provided by the system and for the user.

Similar to Bowen and based on an MBD approach, the practice described by Brajnik in [47], for measure the ID before building the system using a software tool, representing different models of behavior in a User Interface by the use of a UML based graph, facilitating the specification and use of possible system-use scenarios, employing ID techniques. The tool allows the calculation of possible interaction pathways through a series of metrics based on possible routes that may, or may not, include user navigation errors. The practice suggested and applied through the use of this software tool, offers the possibility of producing the described design analysis, without the need to create system prototypes and a manual monitoring of the user's actions, allowing to improve the design before any type of User Interface (UI) prototype is built. However, it should not be used to draw final conclusions about the usability of the system, because the methodological practice is not aimed to examine all the scope involved in a complete Usability analysis of the system.

Hashim in [48] presents the evaluation method about factors involved along the process design for Immersive MS, but does not make reference to a methodology for MS development. The evaluation method describes a cube model with three dimensions interrelated with the system: usability measurement, evaluation techniques and measurement of realism of the immersive experience.

Both, Bandung in [49] and Sun in [50] presents studies related with the MS development. Bandung shows a description of practices that guide a specific process for the development of solutions and emphasis is placed on the Hardware-Software design necessary for the creation of an embedded system and its graphical user interface. Sun exposes an architecture for the deployment of audio and video experiences using streaming techniques. However, neither Bandung nor Sun describes methodologies for MS development.

Related with trends about MS based in emerging technologies, the job presented by Moreno et al. [51], introduce a set of challenges of Multimedia, related with decision-making processes based on cognitive computing, suggesting a merge between Multimedia and other areas as machine learning, as a trend. In the dimension related with knowledge consumption, the concept of Mulsemedia (Multiple-Sensorial-Media) is mentioned as a key for the deployment of interactive experiences on behalf of the cognitive processes of the user, taking advantage of the multiple sensorial media offered by the System. This is consistent with the development of new haptic devices for Human-Computer Multisensory Interaction, allowing the multiple sensorial media integration in the emerging Mulsemedia Systems (MSS) [52], based in a system architecture like MPEG-V [53], for the interoperability between virtual and real worlds, enabled through the use of sensors and actuators and supporting a Sensorial Effects Description Language (SEDL), based on XML.

The third challenge, is focused in capturing the intention of the user as decision maker, involving knowledge fields and technologies based on Internet of the Things (IoT) and Cyber Physical Systems (CPS), where the SLR has lead us to authors like Kaeri et al. [54], recognizing advances in a novel trend related with the Internet of Multimedia Things (IoMT) architectures, supporting remote collaboration with video stream and storage services, involving basic IoT elements and devices such as sensors, cameras, microphones and multimedia communication lines.

The works presented by Duchon [55], Liu [56] and Akpınar in [57], are examples about the merge of areas as multimedia with the CPS and IoT respectively, bringing in the first reference, the Cyber-Physical Multimedia System (CPMMS) term, related with a solution using sensorial-auditory perceptions, for auditory experiences between users which are located in different geographical regions, feeling a proximity perception. The second reference, related with the development of an adaptive multimedia recommender system, using feedback control frameworks in CPSs, and the last one, related with a multimedia collaborative environment represented by a table, where both: virtual objects and functional representations of real objects can be shared remotely. All these works are foundations from which the IoMT paradigm is emerging.

The trends in Multimedia, evidences a transition from traditional Multimedia to Multisensory Multimedia such as described by Sulema [58], opening new possibilities for exploiting other human senses, such as olfactory, thermoception and kinesthetic, among others. The author describes a set of hardware devices that have been used for Multisensory MS development. These devices allow the information capture and the deployment of system's sensorial effects directed towards the User Experience.

Ghinea et al. [59], exposes an analysis about the importance of making progress in the Quality of Experience (QoE), particularly on the development of mathematical models that allow the user to obtain more realistic experiences during the deployment of the mulsemedia interactive experience offered by the system. This is corroborated in recent publications dealing with different approaches and designs to improve the QoE, mainly in experiences integrating auditory, visual and olfactory perceptions, as the works showed by Murray et al. in [60] and Monks et al. in [61], where in the last one, the model is used for integration with a 3D-based video experience. In these studies, the proposed mathematical models are linear, in contrast with the work of Jalal and Murroni [62], which proposes a non-linear pattern for QoE evaluation in the MSS, obtaining a better precision and performance, in relation with the traditional linear models.

Only Sousa et al. in [63] deals with a model based in Model Driven Architecture (MDA) for MSS development, integrating software, media and sensory effects, centered on solutions based on digital TV. The model describes a set of layers adapted from MDA: the computation independent model (CIM) for the requirements specification of the application through artifacts from the sensory multimedia and software development area, a platform-independent model (PIM) receiving the artifacts generated by the CIM and performs the design activity supported by the Multimedia Modeling Language (MML) offering a set of views: (i) the scene model and the (ii) presentation model, responsibility of the media team. The (iii) structural model and the (iv) interaction model, responsibility of the software team. Finally, the platform-

specific models (PSM) makes the transformation to one specific mulsemedia digital TV application model.

The studied trends suggest an important evolution around the multimedia and its merge with new systems and emerging technologies, giving a reason to lead efforts in this SLR, towards the research about the evolution and changes of multimedia foundations, mainly those related with the MS and its relationship and differences with the IS and MMS. We found few evidence in the consulted databases about recently MS foundations, involving the relationship and differences between them, the IS and MMS. However, we found recent studies about MMS fundamentals in the work of Wechsung [64], with no evidence of its relationship and difference with the MS and IS, except by the Oviatt definition cited by Wechsung for MMS, involving the MS term. As Wechsung, the work of Caschera et al. [65] offers an analysis about the MMS development and focused in the evolution of the methodologies applied between 2005 and 2015, showing a solid background about its foundations and trends.

4.1 Findings Regarding About Research Questions

RQ1. ¿What methodologies or frameworks have been used or are susceptible to being adapted for the development of Multimedia Systems?

The 28% of the all selected documents in the SLR described some type of methodology for MS/IS/MMS development. The works studied in [34] through the validated experience in [36, 40] showing a life cycle process and a set of practices for MS development, [41] through the MS development for Human-In-the-Loop-Simulations, [42] with the MS development for IFE, and [63] for multiple sensorial development system based in Digital TV experience, are related or have some evidence of been used for MS development. However, in [40] there is not a validation evidence about the practices suggested for MS development.

In the other hand, the work studied in [43] describes a methodology centered in MMS development, using some case studies as validation, for a system design with multimedia content deployment; and [45], where authors exposes a methodology with 8 phases for MMS development, without evidence about validation process, but taking account an adapted model for the design of the interaction modalities of the system.

The methodology exposed in [38] for IS development, is strongly centered on mission critical systems and use the model-design approach, from the system engineering and its merge with practices from software engineering. The IS development methodology studied in [44], it's a conceptual process model, based in activity theory for merge subject-tool-object in a model; and centered in prototyping and UCD practices, without evidences about a validation process until now.

We observe the methodology studied in [34] for IS development, based on Usability, Accessibility and Software Engineer, offers flexibility to be adapted for multiple purposes, such the case studied in [35].

Finally, we found a set of generic methodologies adapted for MS development; and methodologies based in IS and MMS development that has been used for MS development. However, in both cases, we do not find a methodology specifically designed from its basis and foundations, for MS development, in contrast with the studied methodologies for IS and MMS development.

RQ2. ¿What practices and tools are the most commonly used to guide a process of development for Multimedia, Multimodal and Interactive Systems?

Almost 47% of the documents selected for review, are related with practices and tools used for MS, IS and MMS development, where cases studied in [46–49] and [50], do not specify any kind of methodology related with their practices. Software Engineering, Systems Engineering and HCI are the dominant disciplines for the model process development and practices used, using mostly, evolutive and iterative cycles. Prototyping and evaluation practices are recurrent in each of the phases of the iterative cycle being a necessary strategy to involve the user from the initial stages of the solution design. These practices are also adapted for the "V" model process, in cases where the MBD methodology is applied, as studied in [38, 41] and [42]. Only those techniques used from MBD describe processes related with both, software and hardware design.

Only in studies discussed in [38] and [47], describes a set of software tools for support different activities and processes that are involved within the IS development life cycle.

RQ3. ¿What validation processes of the methodology or framework studied has been used, as evidence of their effectiveness to drive the developing process of Multimedia, Multimodal or Interactive Systems?

The works involving the use or adaptation of the MPIu+a methodology, are validated through the application of case studies, mainly for Web-based applications solutions, without any other evidence about validations related with hardware-software systems, which would imply validation processes designing other kind of interfaces. The studies based on MBD makes its validations, in cases related with the aeronautical industry mainly. In [42], the validation offers more detailed evidence about its obtained results in the process development, but not describes teams or UCD practices involved along the process. The study cases exposed in [38] and [41], are supported by an industry antecedents in the aerospace and aeronautical industry mainly, but documents not describes a specific validation process.

RQ4. ¿What are the trends related with the development of Multimedia Systems based on emerging technologies?

From discussed studies in [55, 56] and [57] developing multimedia experiences based in IoT and CPS principles and cited by some authors as CPMMS, we found the basis for evolve towards a novel paradigm where the smart and heterogeneous multimedia things, can interact with another things in a network, named as IoMT.

The trends in MS development evidences an evolving merge with machine learning and its influence in emerging services as the IoMT, or for the QoE optimization related with the multimedia experience, not just for multiple-sensorial media experiences and new interaction possibilities for the user, as we can see in [59], but also, for improve the QoE of IoMT services for networks users.

The MSS open new possibilities beyond those offered by traditional MS limited in visual and auditory perception, offering new experiences involving sensory perceptions, such as kinesthetic, olfactory and thermoception, among others. However, the development of algorithms for improve the QoE is one of the current challenges for both: the MSS development and IoMT service networks.

RQ5. ¿What studies have taken place regarding the characterization, relationship and differences between the concepts of Multimedia, Multimodal and Interactive Systems?

In contrast with the studies related about the MMS fundamentals in [64] and [65], there are few recent studies related with methodologies and trends involving fundamentals about MS, not just as a basis that we consider relevant for establishing the scope and boundaries from a well-defined methodology for MS development, but also, about the new possibilities that can offer for the User Experience, trends as multiple sensorial media design and the growing multimedia services omnipresence, thanks to emerging paradigms as the IoMT.

5 Conclusions and Future Work

There has been produced a SLR, with a set of papers chosen in a wide window of time publication (2004 and early quarter of 2018); taking into account a diversity of concepts about fundamentals, methodologies, frameworks and trends, related with the MS development process.

It covered 1506 studies and found 32 relevant documents for the SLR that have been selected following the exclusion and inclusion criteria and a set of search protocols for each database, related with the research questions. Of these 32 documents, 12 deals with aspects directly related with methodologies or frameworks for MS, IS and MMS development; and 1 about MSS development. However, only 3 are focused specifically on practices and a methodologies related with MS development.

In none of the methodologies or framework studied we observed practices for choose the media contents more suitable for the user needs and expectations, or practices and process related with a specific process for the design of the multimedia experience to be supported through the MS. Neither practices nor process design were recognized, for the design of interfaces or interaction techniques more suitable, according to the type of multimedia content that want to be deployed.

Only the study presented by de Sousa in [63], deals with a process design from the adapted MDA, for the development of multiple sensorial media experiences systems. However, this approximation is restricted for multimedia experiences based in interactive digital TV experiences. Also, for wind, vibration and light sensorial experience design restricted to a software system design, without taking account, practices and process related with hardware design for objects and devices as sensors or actuators, according to user needs and expectations.

On the other hand and related with emerging trends as the IoMT, we identify that are not covered by any scope of the studied methodologies and frameworks for MS development, being an opportunity for the development of new methodologies, that innovate the design process of these systems, with novel practices and tools, dealing with trends as IoMT, or mulsemedia experiences and machine learning for MS development.

However, we observe “hundreds” of new MS developed by the industry making the multimedia an omnipresent resource for the people, using different devices and peripherals. This would suggest an increasing of “in-house” practices, as part of the

"know-how" and value strategy of the involved companies, to ensure its competitiveness and productivity. Maybe, a new and recent survey following a similar methodology as worked by Lang and Barry in [3], could offer a better clarity about the current trends and behaviors of the multimedia industry.

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