Software architectures supporting Human-Computer Interaction analysis: A Literature Review

Juan Cruz-Benito, Roberto Therón, Francisco J. García-Peñalvo

Department of Computers and Automatics, GRIAL Research Group,
University of Salamanca, Salamanca, Spain.
{juancb, theron, fgarcia}@usal.es

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Introduction

Human-Computer Interaction is a research area in continuous development, and increasingly important in the current times regarding the arising of topics like Big Data, User Experience (UX), etc. and the strong scope that puts the Business world in the monetization of online systems through improving the HCI related areas and by the creation of a data-driven culture that enables decision-making processes were the users' interaction is the key point and the users are the main actor.

Introduction

The systems that retrieve and analyze information from the users' interaction with software systems are currently a trend topic.

Introduction

The application of complex systems and software architectures is currently special interesting in areas related to HCI like

- Measuring UX metrics,
- Performing data analytics about users interaction
- Enabling decision making supported by data visualizations and visual analytics
- Internet of Things (IoT)
- Learning Analytics
- Sales revenue analytics
- Data-driven marketing
- Etc.

Introduction

This Literature Review (LR) is about software architectures that support the Human-Computer Interaction (HCI) analysis, emphasizing on discovering how these software architectures work with different kind of HCI analysis approaches (devices and environments where the interaction analysis is performed, etc.), how are designed (using software engineering) and to find out if there is a niche in the reviewed literature related to the application of software architectures that support HCI analysis regarding to eLearning environments.

Theoretical background

The Software Architectures are not a new thing in Computer Sciences. From the 90's the work and research about this topic has been a constant

Theoretical background

But, even assuming that the concept is not new, what is a Software Architecture? How can be defined a Software Architecture?

Theoretical background

A Software Architecture is "[...] the set of significant decisions about the organization of a software system, the selection of the structural elements and their interfaces by which the system is composed, together with their behavior as specified in the collaborations among those elements, the composition of these structural and behavioral elements into progressively larger subsystems, and the architectural style that guides this organization -these elements and their interfaces, their collaborations, and their composition- …"

Kruchten (1998)

Bass, Clements and Kazman (2012)

Theoretical background

A simpler definition about Software Architecture:

Theoretical background

"The Software Architecture of a system is the set of structures needed to reason about the system, which comprise the software elements, relations among them, and properties of both"

Bass, Clements, Kazman (2012)

Theoretical background

Other definitions important for this SLR

Theoretical background

Usability is “the extent to which a product can be used by specified users to achieve specified goals with effectiveness, efficiency and satisfaction in a specified context of use” (ISO 9241–11)

Dix (2009)

Theoretical background

Observation and Empirical Data where can be featured the main the methods to evaluate and observe the HCI, the *laboratory experiments* and *field studies*. The *laboratory experiments* are where users perform a task or interact under controlled conditions, and the *field studies* are those performed where users are use technology without controlled conditions (in the workplace, outside, in their homes, etc.)

Dix (2009)

Literature Review: Research Questions

- Question 1: What is the current state of the art of software architectures in the field of HCI analysis?

- Question 2: Are there trends or mechanisms in software engineering that cover the field of software architectures supporting HCI analysis?

- Question 3: Are there a specific trend in the software architectures designed to support HCI analysis related specifically to its application in eLearning?

Literature Review: Metodology

This Systematic Literature review tries to answer the three questions based on the content indexed in the Web of Science and SCOPUS databases.

Literature Review: Metodology

Terms used to perform the literature review (the search was not restricted by time periods):

- In the Web of Science: *TS=("software architecture" AND (HCI OR "Human- Computer Interaction") AND analy*)*
- In Scopus: *TITLE-ABS-KEY ("software architecture" AND (HCI OR "Human- Computer Interaction") AND analysis)*

Literature Review: Metodology

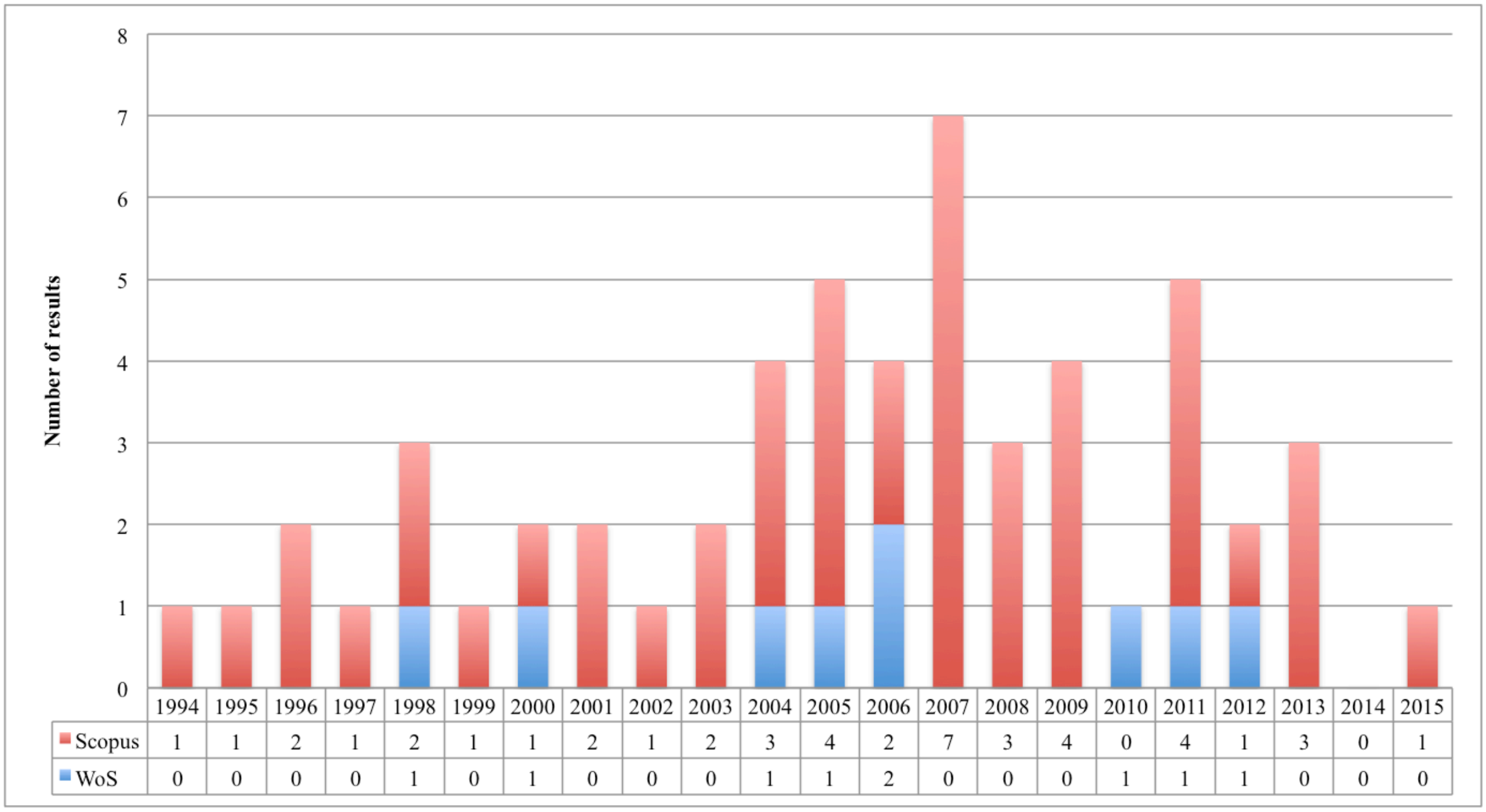
Full details of results and the literature review process performed (filtering, selection/rejection decisions, etc):
https://goo.gl/Mq0nmd

Literature Review: Results

Results of the search query:

- 8 documents in the Web of Science
- 63 documents in Scopus (finally 55 valid results, excluding coincidences with Web of Science)

Literature Review: Results



	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015
Scopus	1	1	2	1	2	1	1	2	1	2	3	4	2	7	3	4	0	4	1	3	0	1
WoS	0	0	0	0	1	0	1	0	0	0	1	1	2	0	0	0	1	1	1	0	0	0

Results of the queries - distribution over the time (results excluding coincidences among both databases

Literature Review: Results

After the selection of the papers regarding their titles, abstracts or full text, 16 papers result to be the most relevant for the defined Literature Review purposes.

These papers selected papers were published among 1998-2013

(Details of these papers are available in https://goo.gl/Mq0nmd).

Literature Review: Results

RQ1: What is the current state of the art of software architectures in the field of HCI analysis?

Regarding this question, all the papers [23-38] fulfilled a minimal answer, because each one of them provides its point of view of the current state of the art. For example, many of them provide application approaches, explaining the devices and physical contexts that could appear in the HCI analysis, among the different devices and contexts, appear in the review the personal computers, wearables, mobile/smartphones, servers, domotics or robots. On the other hand, there papers that focus its content to certain aspects related to software architectures and HCI analysis process.

Literature Review: Results

RQ1: What is the current state of the art of software architectures in the field of HCI analysis?

Regarding the HCI aspects and the context application of the analysis, there is a broad range: there are papers that present contents on:

- HCI analysis regarding astronauts training [23]
- Humanoid robots that analyze HCI and react to users and environment [33-34]
- HCI analysis observing the body and physical reactions of users and not only analyzing the behavior in front the software [29, 36]
- HCI related to hardware[23, 25, 29, 32-34, 36]
- Software elements involved in HCI analysis[24-28, 30-32, 35, 37-38]
- Also there is a trend among the results in software architectures that support HCI analysis to improve the *usability* of the software/hardware systems [24-25, 30, 38]

Literature Review: Results

RQ2: Are there trends or mechanisms in software engineering that cover the field of software architectures supporting HCI analysis?

The common issues that cover these papers (more related to the software engineering) are related to:

- Software patterns to model properly the behavior and functionality of the software components [24-28, 30, 32, 35]
- The correct description of the software architecture system through using UML (Unified Modeling Language) or ADL (Architecture Description Language) [24-28, 30, 32, 35].
- Also there are references to some trends in software engineering and related areas that can be relevant for the topic apart of those previously described, like the requirements engineering, or even in other papers not selected finally for the final Literature Review, topics like information fusion, visualization of HCI interaction, etc.

Literature Review: Results

RQ2: Are there trends or mechanisms in software engineering that cover the field of software architectures supporting HCI analysis?

Singularly in those paper more focused on software engineering, there is a lack of description about how these components that collaborate to achieve the common goal of the software architecture communicate between them: there are only 3 papers that explain it ([23, 28-29]).

Also authors find lacks in descripting the technologies used in those papers that present practical test of the architectures, as well as a serious lack describing or using standards in the software architectures description or designing.

Literature Review: Results

RQ3: Are there a specific trend in the software architectures designed to support HCI analysis related specifically to its application in eLearning?

The unique paper resultant of the search performed in the Literature Review scope that answer this question (at least in a partial way) was the paper [32] written by Doswell in 2006. In this paper, Doswell present a software architecture that includes communication with wearable and mobile devices in order to measure the HCI regarding to eLearning processes and how it could be used in the future to find out engagement, etc. however, the paper do not deepen in features like standards (in any aspect) or in formal specifications.

There is another paper [33], written by Kato *et al.* in 2004, that points out implicitly a possible use of humanoid robots in physical learning processes, but only as an possibility of use, with no concretion.

Literature Review: Results

RQ3: Are there a specific trend in the software architectures designed to support HCI analysis related specifically to its application in eLearning?

Despite of these considerations pointed out previously, authors consider that there are many key points, features and approaches presented in the papers that could serve to develop software architectures that help learning processes through the analysis of HCI in the context of students' interaction with eLearning systems and contents.

Analysis and discussion: Category classification

In order to summarize the main features retrieved from the software architecture, HCI analysis processes and eLearning properties of each paper retrieved during the Literature Review, authors have built a category classification (available online in https://goo.gl/3TJvbY) with the common properties observed (24):

1. Physical context / devices (included in the analysis)
   (a) Personal computers
   (b) Wearables
   (c) Mobile/smartphones
   (d) Servers
   (e) Domotics
   (f) Robots

Analysis and discussion: Category classification

2. Software Engineering specifications

(a) Components' communication: details on how the software architecture components communicate among them, etc. (strategies, format, standards).
(b) Information collectors: details on how the system collects the information about HCI processes.
(c) Architecture diagrams (ADL, UML, etc.)
(d) Design details (patterns, use cases, etc.)
(e) Technologies, languages: description about the software/ hardware properties, the technologies, frameworks or languages used.
(f) Standards: is the architecture presented based on standards?

Analysis and discussion: Category classification

3. Human-Computer Interaction specifications

(a) Measurement process description
(b) React to users' interaction: is the HCI analysis intended to allow the software architecture reacts to the interaction?
(c) Centered on usability: is the HCI analysis presented centered mainly on usability?
(d) HCI – software elements: is the HCI analysis based on interaction with software elements?
(e) HCI – hardware elements: is the HCI analysis based on interaction with hardware elements?
(f) Laboratory experiments: is the HCI analysis performed in a laboratory experiment?
(g) Field study: is the HCI analysis performed in a field study?
(h) Standards: uses standards in the HCI analysis?

Analysis and discussion: Category classification

4. Learning

(a) Purpose of analysis: the paper describes the learning purpose/ goals/intentions of the HCI analysis?

(b) Standards: are involved eLearning standards in HCI analysis or in the software architecture?

(c) Potential users: it describes the potential users/beneficiaries of the HCI analysis related to eLearning?

(d) Mobile learning: is the eLearning application of the HCI analysis related to mobile learning?

Analysis and discussion: Category classification

Categories	Physical context / devices						Software Engineering specifications						Human-Computer Interaction specifications								Learning			
Features	Personal Computers	Wearables	Mobile/ smartphones	Servers	Domotics	Robots	Components' communication	Information collectors	Architecture diagrams (ADL, UML, etc.)	Design details (patterns, use cases, etc.)	Technologies, languages	Standards	Measurement process description	React to users' interaction	Centered on usability	HCI - software elements	HCI - hardware elements	Laboratory experiment	Field study	Standards	Purpose of analysis	Standards	Potential users	Mobile learning
An Information System Prototype for Analysis of Astronaut/Computer Interaction During Simulated EVA	I	E	U	I	U	U	E	I	U	U	E	U	E	U	I	I	E	E	I	U	U	U	U	U
Experiences with Software Architecture Analysis of Usability	E	U	E	E	U	U	I	I	E	E	I	I	E	I	E	E	U	I	I	U	U	U	U	U
Exploring the benefits of the combination of a software architecture analysis and a usability evaluation of a mobile application	E	U	E	I	U	U	I	I	E	E	U	I	E	I	E	E	E	I	E	E	U	U	U	U
Bridging patterns: An approach to bridge gaps between SE and HCI	E	U	I	U	U	U	I	I	E	E	I	I	E	I	I	E	I	U	I	U	U	U	U	U
A unified architecture to develop interactive knowledge based systems	E	U	U	U	U	U	I	I	E	E	E	U	E	U	U	E	U	U	U	U	U	U	U	U
Mockup-based Navigational Diagram for the Development of Interactive Web Applications	E	U	U	U	U	U	E	E	E	E	E	I	E	I	U	E	U	I	U	U	U	U	U	U
An Integration Framework for Motion and Visually Impaired Virtual Humans in Interactive Immersive Environments	U	U	U	I	E	U	E	E	E	E	E	I	E	I	I	I	E	I	U	U	U	U	U	U
Towards improving user interfaces: a proposal for integrating functionality and usability since early phases	I	U	U	U	U	U	I	I	E	E	U	E	E	I	E	E	U	E	U	E	U	U	U	U
A case study of post-deployment user feedback triage	I	U	U	I	U	U	U	I	U	U	E	U	I	U	U	E	U	U	U	U	U	U	U	U
Context-aware mobile augmented reality architecture for lifelong learning	I	E	E	I	U	U	I	I	E	E	E	U	I	I	I	E	E	I	U	U	E	U	E	E
Development of a communication robot ifbot	U	U	U	U	U	E	U	E	E	U	I	U	E	E	U	U	E	E	I	U	U	U	I	U
Autonomous Behavior Control Architecture of Entertainment Humanoid Robot SDR-4X	E	U	U	I	U	E	U	I	E	I	U	U	I	E	U	U	E	E	I	U	U	U	U	U
Usability and software architecture	U	U	U	U	U	U	I	I	E	E	U	I	I	E	I	E	U	E	I	U	U	U	U	U
An architecture for automatic gesture analysis	I	U	U	I	U	E	U	I	U	U	U	U	E	I	U	U	E	E	U	U	U	U	U	U
Inconsistency Management for Multiple-View Software Development Environments	E	U	U	U	U	U	U	U	I	E	E	U	U	U	U	E	U	E	U	U	U	U	U	U
Linking usability to software architecture patterns through general scenarios	I	U	U	I	U	U	U	I	E	E	U	U	I	E	E	E	U	E	I	U	U	U	U	U

Table: Classification of the LR regarding the main common features observed. E – explicit feature, I – implicit feature, U – unavailable feature. Available also in https://goo.gl/3TJvbY

Analysis and discussion

Regarding the **category classification** and the results presented in the paper, it is clear that the software architectures that support HCI analysis is not the most popular subject in the Web of Science and Scopus databases.

The same search terms without “analysis” provides 38 results in the Web of Science instead of 8. Although could be possible that the term “analysis” restrict so much the search, and trying with other search terms related to the same topics could lead researchers to get better outcomes.

Analysis and discussion

Despite of the number of papers that fit outstandingly the goal planned for this Literature Review, is clear that the software architectures can have a determinant role in HCI analysis processes, due their design can improve significantly the measurement, analysis and feedback of the interaction.

Also is clear, that many approaches presented in the papers reviewed suffer a lack of rigor regarding standards, proper specifications of goals, designs and methodologies, as well as not much of them present real cases tested with real users in real contexts.

Analysis and discussion

Regarding the results, also is significant that only one paper focuses its research on software architectures and HCI analysis on the application of these approaches to the eLearning field; authors agree on this kind of software systems can help to develop new complex systems that comprise several applications and systems (conforming true learning ecosystems) where different applications, systems, devices and methods benefit learners by working together in a proper way to help and improve the learning process.

Analysis and discussion

Despite of these considerations authors believe that could exist a niche in publications regarding to software architectures, HCI processes analysis (and, of course, its application to eLearning processes); today, the research on software architectures, decentralized or complex systems and ecosystems represent the future in several fields, where there is a need of tools, systems and applications working together to achieve more complex goals than current ones.

Conclusions

In the final phase of the LR have been fully reviewed 16 software architectures proposals, analyzing if them answer one of the 3 research questions proposed

- RQ1. What is the current state of the art of software architectures in the field of HCI analysis?
- RQ2. Are there trends or mechanisms in software engi- neering that cover the field of software architectures supporting HCI analysis?
- RQ3. Are there a specific trend in the software architectures designed to support HCI analysis related specifically to its application in eLearning.

Conclusions

Authors classified SLR results according to 24 features proposed by the authors due their common use in this research area and topics. Regarding the results of the LR, there are some key points that can be featured:

- According to the results retrieved from the search in the Web of Science and Scopus database, there are not a lot of content related to the subject of this paper, or at least, not categorized in the same way paper does. This could represent an opportunity in publishing in this research area.

- Authors consider that could be a niche for publication is in the context of software architecture and HCI analysis and its application in eLearning contexts; only one paper deals with this issue of those retrieved. Despite this low number, has been observed that many of the software architectures and approaches reviewed have principles that could be applied to improve eLearning.

Conclusions

Regarding the results of the LR, some last key points can be featured:

- There are some trends in software engineering proper for this kind of software architectures, but they are not massively used in the papers reviewed.

- There is a lack on the papers about specific content on standards, communication protocols and strategies among software components, or in describing the specific technologies and technical details of those architectures presented that have been tested in real experiments. These considerations also could be applied to the HCI topics presented in the papers, authors find out that there is not enough content on how the experiments were conducted, what standards were followed, etc. and there are many issues and approaches that can be improved in further research.

Conclusions

In some cases the research that cover all of these areas is an unexplored territory, and there were retrieved some papers that begin to cover them. There is an opportunity for further research that could lead to improve the future complex systems, ecosystems and sets of varied applications that work for common goals.

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