A Systematic Review of Geolocated Pervasive Games: A Perspective from Game Development Methodologies, Software Metrics and Linked Open Data

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Abstract. Pervasive games are a new way of social interaction through new technologies such as sensors, software applications and network communication that can be found in mobile devices. Those games allow us to do daily activities in a natural way and arise as a new option of entertainment. For that reason, we decided to do a systematic literature review to identify the methods and metrics used in the development of pervasive games and how they relate to Linked Open Data (LOD). This review presents findings to confirm the need of methodologies to develop applications related to games and entertainment of pervasive nature, and incorporate all its characteristics, which make them different from traditional software.

Keywords: Pervasive games · Game development · Semantic web · Game metrics · Systematic review

1 Introduction

The majority of mobile devices nowadays harness location and orientation-sensing capabilities [1, 2] such as GPS (Global Positioning System), compass and accelerometer to provide information about the current context of players and deliver a gaming experience [3]. This is how mobile devices have become in fundamental part of our lives, allowing that much of the activities we carry out every day are sensible to the context where we do them. Due to the wide availability of personal communication devices, there is an increase in the demand for mobile services based on location [4]. We use mobile devices to work, communicate with family and friends and even for entertainment through games. It allows that each context takes advantage of communication networks. Focused in entertainment, it is feasible to think of applications that contain

A. Marcus and W. Wang (Eds.): DUXU 2017, Part II, LNCS 10289, pp. 335–346, 2017.
DOI: 10.1007/978-3-319-58637-3_27

virtual worlds inviting users to be part of them. That is how people make an absolute immersion, and when that happens there is a disconnection of the real world. That is why computer games and related technologies are being used in research of applications with different aims, like teaching, health and tourism, and not totally centered on entertainment [5].

This document considers a pervasive digital game as a game in which the player's experience is extended to the real world. That is possible through the use of device's sensors [6]. These games are a recent form of entertainment that brings the game experience out of the device and into the physical world, integrating both virtual and physical realms [7]. In addition, it introduces a new game experience that is possible to play wherever and whenever the user wants, this combines virtual and real objects, places and people, and even the gaming time with real events. Pervasive games break the boundaries of the circle that is around classic games [8].

In the following section, we present a contextualization of research topics. Section 3 describes the planning of the systematic literature review. In Sect. 4 are shown the data extraction activities from relevant papers that were found in Sect. 3. In Sect. 5 we present the analysis of search execution and their outcomes, relations and figures. Finally, in the Sect. 6 we discuss about conclusions and future work.

2 Background

2.1 Pervasive Games

Pervasive games represent a radically new game form that transfers gaming experiences out into the physical world, weaving ICTs into the fabric of players' real environments [9]. Many different forms of gaming have been grouped under the concept, including the massively collaborative troubleshooting games (The A.I. Game), the location-based mobile games (Botfighters), the games augmenting the reality with ludic content (Visby Under) and the games staged with a combination of virtual and physical elements [8]. Currently mobile devices are the main elements to achieve pervasive games objectives, because these are linked directly and naturally. Mobile devices are currently the main driver to fulfil the promises of pervasive game playing because they are naturally networked, full of sensors, widespread, and easily accessible [7]. Due to the necessity for a corresponding infrastructure, short-range proximity sensors are not ideal for implementing pervasive games; thus GPS and Wi-Fi form the basis of most recent location-aware games [10]. Emerging pervasive games use sensors, graphics and networking technologies to provide immersive game experiences integrated with the real world [11].

These games may involve one or more players who may be distributed or co-located, and where game play can take place in the broad variety of locations and contexts where one might expect such mobile devices to be used [12]. Games have not received the full attention of the requirements engineering community. This scenario is becoming more critical as we move towards newer forms of games, such as pervasive games [7].

2.2 Software and Game Development Methodologies

Especially, in recent years, the use of mobile applications has increased dramatically along with the concept of 'smart' phone [13], these applications allow the continuous communication and information exchange between mobile devices through wireless technologies, that interaction can be detailed on Fig. 1.

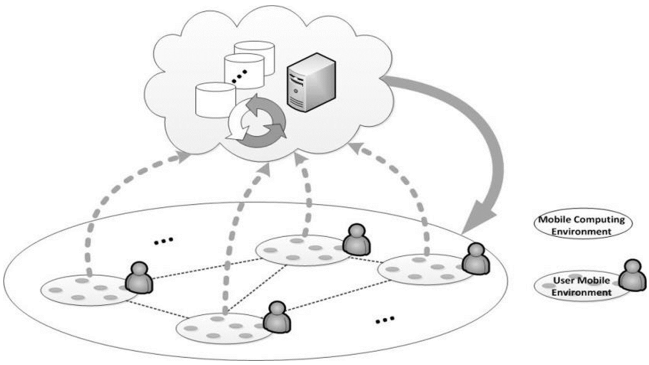

Fig. 1. Movement on mobile computing environment [13]. Figure shows the interaction between users and devices through internet connection.

Most software development organizations make use of a standard set of practices when developing software [14]. Although, Software developers rarely adopt systems and software development methods outright, but rather filter and combine elements from these methods to fit their needs [15]. For pervasive games based on location it is not different, they are implemented using traditional methodologies of software development. In addition, developers do not consider the HCI (Human-Computer Interaction) concepts, which neither are contemplated by those methodologies. Is important to take them into account because the user's requirements and their needs must be explored to improve them applying HCI techniques [16].

2.3 Game Metrics

Game metrics are interpretable measures of something related to games. More specifically, they are quantitative measures of attributes of objects. A common source of game metrics is telemetry data of player behavior [17]. There are three types of metrics used by Game User Researchers: User Metrics (metrics related to people playing the game), Performance Metrics (metrics related to the performance of software or hardware of the game) and Process Metrics (metrics related to the process of developing the game) [18]. When the game is measured, aspects of the game itself must be included, but there is something that is more important: the player experience. For this topic, metrics known as "playability metrics" appear [19] that allow to measure the fun created by a game in a player.

2.4 Linked Open Data

Model Driven Software Development (MDSD) & Domain Specific Modeling (DSM) are means to overcome software development challenges [20]. Semantic web allows knowledge representation through elements and conceptual relationships (modeling).

Knowledge generated recently is available in Linked Open Data (LOD) standards which allow to have free access to such knowledge. In addition, LOD connects local information with other data sources through key terms. The main reason why semantic web and web 3.0 are important to improve human performance is known as cognitive overload [21].

3 Systematic Review

A systematic literature review is a method to analyze, evaluate and interpret all relevant studies to a particular research question, or specific area, or phenomenon of interest [22]. This type of process had their origin in medicine, due to continuous advance of such area, it is necessary to address a research towards a not researched specific topic. There are some proposals to apply these protocols in software engineering. Kitchenham and Charters [23] propose a set of phases to do it. In this document is used those phases, the process is shown next.

3.1 Literature Review Need

A consequence of the current wide adoption of mobile computing is the emergence of mobile and pervasive gaming [12]. It is necessary to get information about pervasive game, software development methodologies – The emergence of pervasive technologies has led to an increased interest in both the design and the development of pervasive games [24] –, game metrics – qualitative and quantitative metrics [18] –, and location techniques through mobile devices.

3.2 Research Questions

The main objective of this systematic literature review was to get most important scientist data to identify current status of pervasive game development. In consequence, it was necessary to research about methodologies to develop that kind of games. In addition, we searched frequently used metrics to evaluate performance, usability, process resources, etc. Finally, we found semantic web applications that produce a better design and implementation of pervasive games.

- **RQ1:** ¿Are there specific methodologies to develop pervasive games based on location?
- **RQ2:** ¿Which metrics are most used to evaluate a software development methodology and their products?
- **RQ3:** ¿Are there ontologies to store data produced by pervasive games based on location?

Continuing with the methodology phases given by [23] and conduct this review, we considered to apply PICOC [24] to define main concepts. Table 1 shows these concepts.

Table 1. Definition of concepts using PICOC.

Criterion	Description
Population	Researchers, students and game developers.
Intervention	Game development methodologies supported by linked open data and their metrics.
Comparison	Other methodologies used to develop games.
Outcome	List of methodologies, metrics and semantic resources to game implementation.
Context	Academic level, research level and industrial level.

3.3 Search Terms

With PICOC analysis, arise a set of general concepts. These concepts are defined as related terms between them. Next list shows terms:

- Pervasive games
- Geolocation games
- Ontology pervasive games
- Pervasive games methodology
- Software methodology metrics
- Software development
- Software design

3.4 Search Process

Based on search terms and their synonymous, the complete query string was generated, which was complemented with logic operators. We considered published papers, whose publication date was since 2012. This string was executed, and only 3 papers were obtained. For that reason, we decided to split the first query string in three main topics (Pervasive games based on location, software development methodologies and software metrics, and Linked Open Data in games). When we did that on 25th August, 2016, we got the following results:

- **Pervasive games based on location**

  (((geolocation) **OR** pervasive) **AND** gam*)

- **Software and games development methodologies and software metrics**

  (((((game) **OR** software) **AND** methodology) **AND** metrics) **AND** (((software) **OR** game) **AND** ((((((development) **OR** implementation) **OR** construction) **OR** design) **OR** planning) **OR** methodology)))

- **Linked open data in games**

((((((“semantic web”) **OR** ontology) **OR** “semantic repository”) **OR** “linked open data”) **AND** game*))

In addition, for best results, we applied filters. Those filters were defined as inclusion criteria and exclusion criteria. The next sections show a list of each criterion type.

3.5 Inclusion Criteria

1. Paper published between 2012 and current date.
2. Paper published as result of conferences, congress or journals.
3. Paper written in English.
4. Paper included into databases shown on Table 2.
5. Paper associated with these topics: HCI, Computer, Informatics Engineering and related.

Table 2. Used databases. Specific data of each database where were executed the query strings.

Name	URL	Acronym
Springer link	http://www.springer.com/	Springer
Scopus	https://www.scopus.com/	Scopus
IEEE xplore digital library	http://ieeexplore.ieee.org/	IEEE Xplore
ACM digital library	http://dl.acm.org/	ACM
Web of science	https://webofknowledge.com/	Web of Science

3.6 Exclusion Criteria

1. Paper only with content table or resume.
2. Paper not related to a research.
3. Paper not related to software or game development, LOD or software metrics.
4. Paper which does not fulfill at least one of inclusion criterions.

3.7 Extracting Information

Process of systematic literature review used different databases, some free access and other private access. Table 2 shows each database information.

Table 3. Results of queries. Matrix of results for each databases and query strings.

String database	Pervasive games	Methodologies and metrics	Linked open data	Total
IEEE xplore	90	30	50	170
ACM	126	47	19	192
Springer	170	383	120	673
Scopus	65	68	45	178
Web of science	41	68	16	125
Total				1338

Through the search executed for each database on Table 2, the results shown on Table 3 were obtained. Graphic representation is on Fig. 2. To reduce the number of results, the inclusion and exclusion criteria were applied.

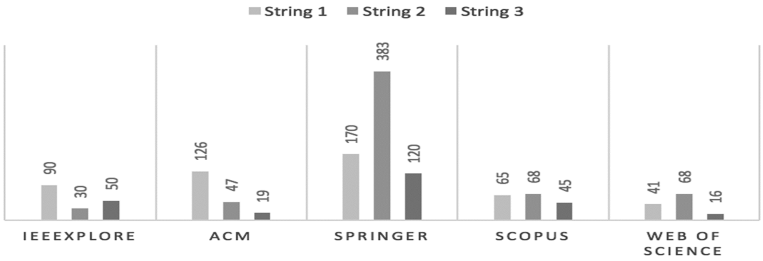

Fig. 2. Database results by string query. For each database three query strings were executed, which showed related papers. String 1: pervasive games based on location, String 2: game/software development methodologies and game/software metrics, String 3: LOD related to games.

4 Data Analysis and Results

4.1 Additional Filters

According to Table 3, where total results are presented, we analyzed each paper evaluating its title and abstract. We read all titles, checking that each one had relation with the topic research. All results are presented in Table 4.

Table 4. Title and abstract analysis results. This table shows accepted and rejected papers, in addition are presented duplicated papers.

Databases	Total	D[a]	%D	A[b]	%A	R[c]	%R
IEEE xplore	170	16	9.4	39	22.9	131	77.1
ACM	192	0	0	19	9.9	173	90.1
Springer	673	12	1.8	15	2.2	663	97.8
Scopus	178	30	16.8	26	14.6	152	85.4
Web of science	125	14	11.2	11	8.8	114	91.2
Total	1.338	72	5.4	110	7,8	1228	92.2

[a]Duplicated: When a paper was included in result list more than once.

[b]Accepted: a paper that meets the requirements given by exclusion/inclusion criterions

[c]Rejected: a paper that does not meets the requirements given by exclusion/inclusion criterions.

In Table 4, we present percentages related with analysis results based on total papers for each database, and categorized by type (Accepted, Rejected, Duplicated). However, some papers were rejected (R) and found in different databases (D). For that reason, there is a difference between the total number of paper shown in Table 4 and total papers in Table 3.

4.2 Process Description

After applying first extra exclusion criterion (based on title), the number was reduced from 1338 to 557 papers. With second extra exclusion criterion (based on abstract), the number of papers was reduced to 115. Next, these 115 papers were read to achieve the third extra exclusion criterion (based on full text). Finally, 110 papers were selected to answer the research questions. In this phase, we were sure of relevance that each paper had with research topics. In Fig. 3 a resume of complete process on systematic literature review is shown.

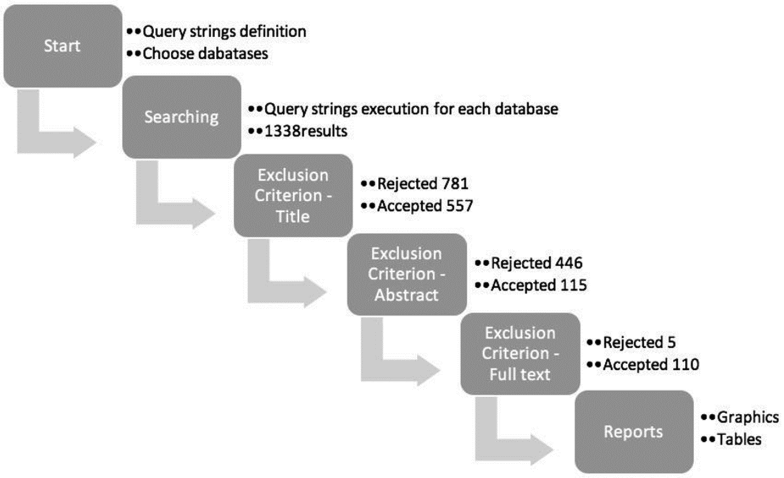

Fig. 3. Search process description and application of exclusion criterion.

With that process, we can define that numbers with most relevance are associated with accepting percentage, 7.8% is a good result, corresponding to 110 papers. Classification made subsequently is represented in Table 5. To know the complete list of paper and codes is necessary to see appendix A.

Table 5. A portion of categories of topics and papers.

Category	Subcategory	#	Studies (View appendix A)
Pervasive games	PG Meaning	37	0001, 0004, 0010, 0023, 0027, 0032, 0037, 0039, 0040, 0056, 0068, 0071, 0073, 0078, 0083, 0171, 0174, 0175, 0185, 0202, 0367, 0368, 0369, 0376, 0398, 0399, 0489, 0514, 0523, 0528, 0530, 0532, 0535, 0539, 0541, 0542, 0551
	Augmented Reality	6	0056, 0175, 0276, 0368, 0376, 0864
	PG Design	20	0001, 0004, 0010, 0027, 0071, 0078, 0180, 0185, 0226, 0276, 0368, 0369, 0489, 0514, 0523, 0528, 0530, 0535, 0842, 0861
	PG in Health	5	0004, 0027, 0190, 0402, 0839
	PG in Education	13	0073, 0127, 0147, 0188, 0348, 0530, 0532, 0535, 0539, 0633, 0641, 0868, 0893

In order to explain better the results in Fig. 4, a general description of found categories is presented. There is evidence of a little bit of work that has been done to achieve an implementation of a methodology related to pervasive games, however, there is also an important number of prototypes in that area.

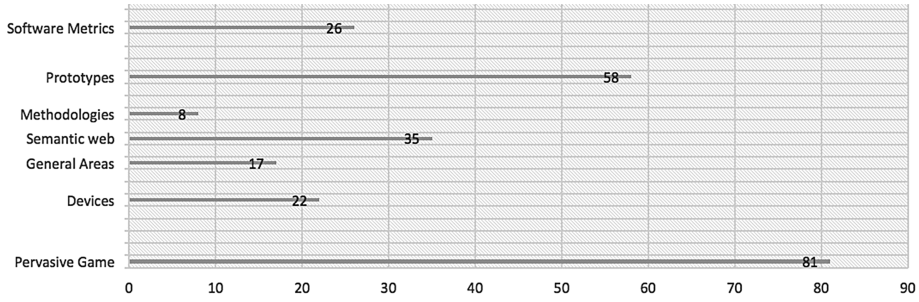

Fig. 4. Results by research topic. The 110 papers are presented grouped by category.

4.3 Results

Based on the systematic literature review and its results, the research questions are answered below.

RQ1: We found that software development methodologies used in pervasive games implementation are the same used by the development of desktop applications, information systems on web environment, among others. That is, there was not referenced a methodology or software process that considered pervasive games development. However, agile software processes adapted to game development were found, although those software processes do not contemplate features and special elements games have. In addition, we found prototypes without following a methodology, in consequence of that, these prototypes have quality troubles. Most studies using methodologies for prototype development use Scrum and Waterfall.

RQ2: Due to there are no software development methodologies focused on this kind of games, consequently, metrics used to measure functioning are the same used to measure quality, performance and resources. Design and implementation for especial features are not considered, even less, features of devices where games are executed. There are a lot of software metrics, which have been adapted according to the needs of projects. Most used metrics on games development are quality metrics as shown in Fig. 5. Based on that figure, we can conclude that there are little studies about user experience metrics. Similarly, performance metrics are not given enough importance, although, these metrics are fundamental in pervasive computing environments due to limited hardware resources on mobile devices.

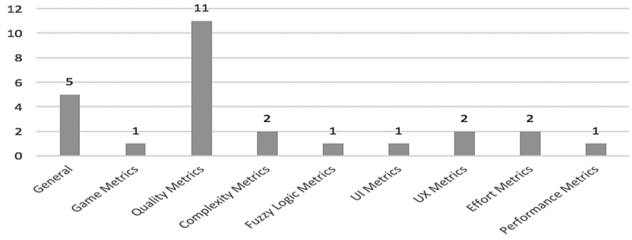

Fig. 5. Software metrics results.

RQ3: Linked open data has allowed to share results to researchers through standards fulfillment that can associate different systems. The videogames field, it is not an exception, we have found an important increase of semantic repositories in games, even more in pervasive games. This systematic literature review presents a direct relationship between these knowledge areas, having greater impact in health and education fields. In Fig. 6 we can see that 19% of game prototypes are associated with LOD.

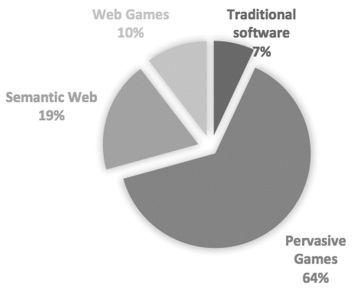

Fig. 6. Found prototypes percentages.

5 Conclusions and Future Work

The main objective of this research was to identify a specific software development methodology to create pervasive games based on location. Also, to find metrics to apply in a methodology and their products. Due to the absence of this methodology, we support the hypothesis presented in [6], where researchers mention the need to have a methodology that take into account all variables and features of pervasive games.

It is important to consider new technologies to use them as a whole, and thus, to support activities of our life such as learning, health and tourism. To achieve that, we think that using Linked Open Data standards is possible to improve those processes, due to their capabilities of semantic and cognitive power.

Mobile devices give more options to social interaction, but, in the same way they allow a total immersion in virtual worlds. According to needs of current society, where is necessary that people interact with others and mobile devices and pervasive games can help to achieve this objective through the integration of virtual and real elements.

As future work, we think that new software processes and software development methodologies that allow to consider different variables and elements own of pervasive games are necessary, specifically games based on location, using mobile devices, GPS sensor and beacons.

Also, it is necessary to define metrics to adapt them to especial needs given by games and their technological challenges. On the other hand, in order to help to give a solution in an identified problem by the systematic literature review (the meaning of pervasive games), we believe that is necessary to give a meaning to pervasive games depending of specific features, not only for each field of knowledge.

Appendix A

This information is available in: http://tinyurl.com/PG-paper-hci2017-appendix-A

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