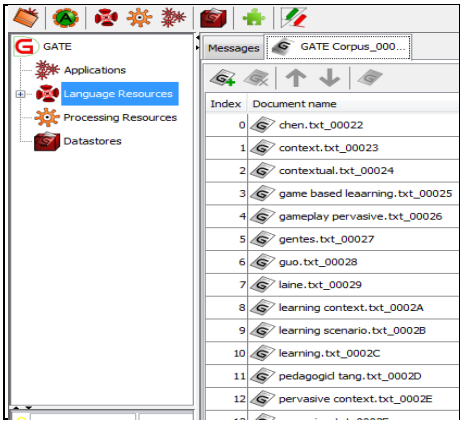


Figure 1. PGBLSs knowledge corpus

4.2. Requirements analysis

Some requirements are critical for the success of the system. Hence, requirements should be analyzed so that the ones that are most likely to achieve customer satisfaction can be selected for implementation. PGBLSs development organizations often must deal with requirements that tend to evolve quickly. Rapid changes in competitive threats, player preferences and development technology make pre-specified requirements inappropriate. Agile methods that seek to address the challenges in such dynamic contexts have gained much interest among practitioners and researchers. Table 1 outlines a number of different analysis techniques. We, then, categorized the requirement analysis techniques according to a number of criteria such as ease of use, required completion time, reliability of results, etc. Those ranks accorded to the various techniques are based on a literature study [9] [10] [11] [12].

Table 1. Comparison of different analysis techniques

	Rank according				
Techniques	Ease of use	Total Time Taken	Scalability	Accuracy	Total Number of Comparisons
Numerical Assignment Technique (NAT)	6	6	5	6	1
Analytical Hierarchic Process (AHP)	5	5	6	5	3
Value Oriented Analysis (VOP)	2	1	1	2	1
Cumulative Voting (CV)	4	3	4	3	1
Planning Game (PG)	1	2	3	4	1

Outcome of the table says that VOP is supposed to be the best method for prioritizing software requirements. It is an easy method, it gives one of the most accurate results, and it is rather comfortable to handle even if there are many more requirements. In most questions' PG was located in the middle, neither the best nor the worst techniques. The worst candidate is NAT. However, this order of the requirement analysis techniques obtained is not a global one as rankings can be reordered if criterion weights are assigned differently. Nevertheless, the technique and formulae used here to compare among different analysis techniques can be used in any scenario with appropriate criterion weights suitable for that scenario. In general, requirements can be analyzed taking many different aspects into account. An aspect is a property or attribute of a project and its requirements that can be used to prioritize requirements. Common aspects are importance, penalty, cost, time, and risk [6]. Often, the aspects interact and changes in one aspect could result in an impact on another aspect [7]. However, in the field of PGBLSs, requirements are changing following the highly dynamic environments. In the user context, users can specify their preferences along with their context. For example, a player may specify that whenever she/he looking around in the museum and trying to locate exhibits (Museum Scrabble game), she/he would like that the query processor takes into account the chosen topic and the available hints. Besides, Game Theory [38] is a mathematical tool that describes and analyzes behaviours in strategic situations. It is usually used to predict the outcome of complex interactions among rational entities. We propose a game theory based approach to resolve Users Requirements conflicts in the context of PGBLSs. Table 2 illustrates a manual analysis of three different requirements with Game Theory concepts.

Table 2. Manual analysis of PGBLSs requirements with Game Theory concepts

Requirements list definition	Elements of Game Theory				Assumptions of Game Theory	
	Players	**Strategies**	**Information**	**payoffs**	**Rationality**	**Common knowledge**
Learning requirement Learners perform activities to create an outcome using an environment in which there are learning objects and services. (requirement conforms IMS LD standard)	Learners	Learning activities	A complete description of the possible activities, the outcomes for each activity and the available objects and services in the environment.	Learning outcomes	Calculate which activities will maximize their learning outcomes.	Each learner/user/player knows the set of learner/user/player, strategies and payoffs from all possible combinations of strategies: call this information 'X'. Common knowledge means that each learner/user/player knows that all learner/user/player know X, that all learner/user/player know that all learner/user/player know X, that all learner/user/player know that all learner/user/player know that all learner/user/player know X, and so on…
Pervasiveness requirement Users need to expand the contractual magic circle of the system socially, spatially or temporally.	Users	Social strategies, spatial strategies, temporal strategies	A complete description of the social, spatial and temporal aspects.	Services outcomes	Calculate which strategies will maximize their services outcomes.	
Game requirement Players, need a set of strategies available to them, and specification of players' payoffs for each combination of such strategies (possible outcomes of the game)	Players	Options specific to the game	A complete description of the information available to players at each decision made.	Entertainment outcomes	Calculate which options will maximize their entertainment outcomes.	

The analysis table shows that Game theory seems a good starting point for analyzing strategic interactions in PGBLSs. Throughout this analysis, feasible conflicts in PGBLSs would appear because end users seek to maximize gains and minimize losses. From the outcome point of view, the payoff depends on the choices of all players and it distinguishes many activities choices as non cooperative (have less priority) and others activities choices are non cooperative (more priority). However, as the context of PGBLSs changes needed information changes or new information appeared.

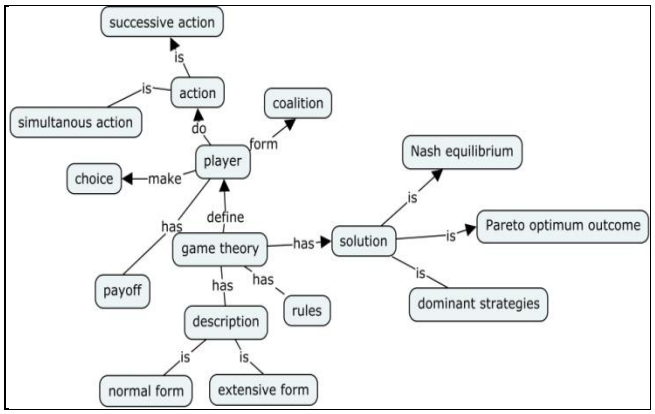
Game theory is rich of concepts to sets out, first, broad patterns of resource allocation (activity assignements). Then, it shows how conflict arises from the allocations. Finally, it highlights potential solutions to those conflicts.

Among those concepts, we can list "The Pareto-optimal outcome of the game which is the outcome as a result of cooperation amongst the players involved. While the Nash Equilibrium is the outcome of a game whereby given the options of another player, no player can do any better (improve his payoff) by changing his strategy. Nash stability is about what is good for an individual without considering what is good for the whole system while Pareto-optimality is about what is good for the system without considering the interests of the individuals within the system" [39]. The Dominant strategy equilibrium of a game is a strategy which any agent in the game would use regardless of what strategies the other agent uses. All these outcomes of the game are called 'Solution concepts' which lead to the best strategies of every agent or player (the more important strategies).

The process of analysis should be automated because game theory is difficult to be processed automatically when users are not Game Theory skilled.

In fact, Game Theory concepts are expressed in a natural pseudo language based on mathematics and could not be used in an automatic processing. This requires a formalism that must be flexible and adaptable to the dynamic aspect of the context.

For that aim, we propose a Semantic Web technology based solution. More specifically our proposal, in this paper, will focus on a unified semantic modeling for both Game Theory and Requirements (more detailed in section 4.3). Consequently, we have proposed in [40] a consistent and comprehensive domain ontology of game theory (GTO). Figure 2 shows an excerpt of the GTO.



.

Figure 2. An extract of the proposed PGBLSs ontology of requirements

The Game theory ontology (GTO) will be used for PGBLSs needs analysis in order to allow learning/gaming objectives achievement. In fact, the role of GTO in the process of designing PGBLSs is to help the designer to automatically analyze his/her strategic situation by game theory. Our proposed automatic analysis process is more explained by the next activity diagram.

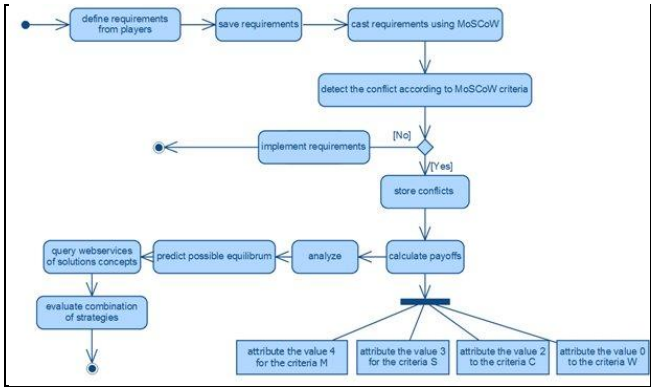


Figure 4. The activity diagram of the automatic analysis process

The Analyst must be able to save details of user requirements gathered from different requirements elicitation techniques in an ontology of PGBLSs requirements (result of specification phase). Where a requirements conflicts is identified and verified, the Analyst must be able to store details of this conflict.

In the next step, the GBL scenarios designer wants to predict possible equilibrium of the game. He/she should, in this step, query the GTO for identifying the kind of algorithms to execute for equilibrium prediction. The Analyst cast requirements for what they think should be the payoffs for each requirement. The requirements are analyzed using the MoSCoW criteria (Must, Should, Could, Would) to describe the importance of each requirement to the increase of learning outcome. Aggregate sum of their votes are calculated to get the actual payoffs for the game.
When context change, The Analyst, instead of evaluating all possible combinations of players strategies, he only concentrate on Nash equilibrium.

4.3. Requirements specification

In this phase, we suggest an ontology of requirements representing the requirements, the relations between them and the relationships with the system. Figure 3 illustrates the idea of the proposed ontology.

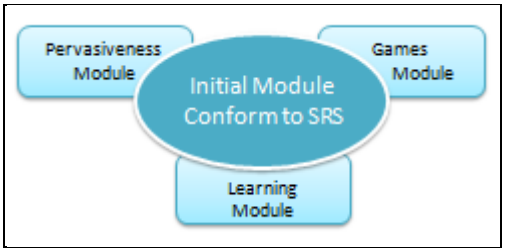


Figure 3. The proposed modules for the ontology of requirements

There are a number of methods and methodologies one can employ to develop their own ontology in a given domain. Among those methods [41] we find CyKB, Uschold and King's method, Grüninger and Fox's method, etc.. In this paper, we have adopted Noy & McGuinness's method to build our ontology of requirements. Noy & McGuinness's seven steps method requires one to [42]: 1. Determine the domain, scope and purpose of the ontology; 2. Consider reusing existing ontologies; 3. Enumerate important terms in the ontology; 4. Define the classes and the class hierarchy; 5. Define the properties of the classes – slots; 6. Define the facets of the slots; and finally 7. Create the instances classifications.

a. The scope, the domain and the purpose of the PGBLSs requirements ontology

The ontology covers the PGBLSs domain in its high level aspects (features and functionalities) as well as its organizational ones (learning strategies, gameplay scenario, and pervasive services).
The main objective of the target ontology is to provide a generic model containing knowledge about the core concepts related to PGBLSs (players, entities, requirements,

etc.). This ontology will be a support for the definition of PGBLSs requirements.
The ontology will be a meta-view for the different PGBLSs knowledge in the literature. It should harmonize the PGBLSs terminology spread in these researches and help requirements engineers in their development task.

b. Reuse of existing ontologies

The acquisition of the PGBLSs requirements knowledge started from standards (e.g. IEEE Guide for Developing System Requirements Specifications). Other knowledge acquisition sources were the different ontologies and researches that exist in the literature [43][44][45]. Moreover, ontology reuse will present an ontology modular's development as illustrated in Figure 3.

c. The concepts

Based on the knowledge elicitation step, we have made concepts and relationships between them in a conceptual model. The concepts and the relationships of the PGBLSs requirements ontology proposed in this paper were chosen according to the number of repetition of concepts in the various researches related to PGBLS domain.
The concepts were organized around three main aspects which are game aspect, pervasiveness aspect and learning aspect. Various concepts are described briefly, in the following.

SRS module: this module includes the concepts related to the Software Requirements Specification [46]
Reference: List any other documents or Web addresses to which this SRS refers. These may include user interface style guides, contracts, standards, system requirements specifications, use case documents, or a vision and scope document.
Function: Summarize the major functions the product must perform or must let the user perform.
System feature: The functional requirements for the product by system features

Pervasiveness module: this module includes the concepts related to the pervasive aspects.
Environment: Captures the entities that surround the user. Attributes, services, temperature, noise, networks, etc.
Social context: Describes social aspects of the user context. Attributes – information about friends, relatives, role in society. For example, social context at home is different from social context at work.
Spatio-temporal context: Describes aspects related to the time and space. Attributes - time, location, speed, direction, etc.
Information: Global and personal information, software, databases.

Games module: this module includes the concepts related to the game development field.
Action: Describes what the player is doing. Attributes – goals, tasks and actions.
Emotional requirements: The fun and enjoyment part.
Game mechanics: such as basic rules , themes, characters, environment and story are finalized.

Learning module: this module includes the concepts related to the learning systems development field.
Consistent learner information: Learner information shall be consistent throughout the platform.
Groups and roles: It shall be possible for users be allocated to one or more groups and assigned roles.
Load content objects: It shall be possible to load, store and make sharable content objects available to users. Run-time interactions with content objects should be supported. This includes being able to load bundled resources (content packages) and unpack them.

d. The relationships

High-level relationships between those concepts were defined. They were categorized into four kinds: Functional, Inverse Functional, Symmetric, SubClassOf and Transitive.
Relationship is functional if, for a given individual it can be in relation with individual, it can be in relation (through such property) with only another individual. For example, Aline (player1) hascompetitor Bob (player2). Inverse Functional relationship is the inverse of functional relationship. Symmetric relationship can be briefly described as "Aline hascompetitor Bob" allows to infer also "Bob hascompetitor Aline". Transitive relationship means that if Aline hascompetitor Bob and Bob hascompetitor Amelie, then we can infer that Aline hascompetitor Amelie. SubClassOf implies a superclass-subclass hierarchy.

e. The axioms

In addition to concepts and relationships, an ontology contains axioms and attributes. Formal axioms are assertions accepted as true about abstractions of a field. The axioms allow us to define the meaning of concepts, put restrictions on the values of attributes, examine the conformity of specified information, or derive new concepts [47].
Table 3 illustrates some axioms with their descriptions and the related concepts.

Table 3. Part of the Table of axioms

Description	Expression	Concepts
A world can be either real or virtual.	∀ x: world ⇒ realworld (x) ∨ virtualworld (x)	World Realworld virtualworld
players belong to different groups are competitors.	player(?x) ∧ has_group(?x, ?y) ∧ has_group(?x, ?z) ∧ differentFrom(?y, ?z) → competitor_of(?y, ?z)	player

4.4. Requirements validation

The validation is the confirmation of the quality of requirements and their compliance with the needs and desires of stakeholders. The requirements are tested using a prototype. Indeed, a validation of the quality attributes of those requirements (completeness, validity, usability) must be conducted.

The completeness criterion is achieved by mapping the ontology of requirements and other Ontologies of requirements related to PGBLSs from literature in order to detect the level of covering knowledge comparing to other research.

The validity criterion is evaluated by requests of RO using its terminology and its capacity to answer. Table 4 summarizes some of these questions.

Table 4. Informal and formal questions to the requirements ontology

Queries	Part of result
What are the locations available for playing the game? --- Location (?L) → sqwrl: select (?L)	Location x Location y
What are the impacts of such an action on the learning outcome? --- Implies (outcome, ? I) → sqwrl: select (?I)	Enhancing-impact
What are the exhibits to be collected in the museum X? What is the location of each exhibit? --- Has_item(Museum X,?a) ∧ Has_Location(?a, ?l) → sqwrl:select(?a, ?l)	Exhibit x Exhibit z Located in the Hall H1 Located in the Hall H4

Finally, the usability criterion is validated by using the RO in a real project. Currently, we aim to test the integration of ontologies in the process of defining PGBLSs requirements.

We focus on a case study in order to validate the feasibility of our proposed approach.

5 Conclusion

We presented in this paper our vision regarding an explicit classification of PGBLSs requirements following the three dimensions which are pervasiveness, games and learning systems. The main idea of our approach is an ontology of requirements following the requirements engineering process. The guidelines of the ontology of requirements help developers to capture user requirements, to facilitate the updating of dynamic requirements due changing context and allow reuse of the ontology when the learning environment varies.

Following that, an ontology of requirements is developed, focusing on different kinds of context changes. We aim, in the future work, that our proposal could be used as a foundation for the relating domains.

References

[1] Montola, M., Stenros, J., and Waern, A. Pervasive Games: Theory and Design. Experiences on the Boundary Between Life and Play. Morgan Kaufmann, Amsterdam et al., (2009).

[2] ANIND K. DEY, Understanding and Using Context, Future Computing Environments Group College of Computing & GVU Center Georgia Institute of Technology, Atlanta, GA, 30332-0280, USA (2001),

[3] IEEE Computer Society "IEEE Standard Glossary of Software Engineering Terminology". IEEE Standard (1990)

[4] AFIS, Modèle de données AFIS, version 2.0, groupe de travail Méthodes et Outils, (2005)

[5] L.A. Macaulay, *Requirements Engineering*, Springer-Verlag, (1996)

[6] S.W. Ambler, Agile Modeling, John Wiley & Sons, (2001)

[7] Heba Elshandidy, Sherif Mazen, Agile and Traditional Requirements Engineering: A Survey, International Journal of Scientific & Engineering Research, Volume 4, (2013)

[8] Boehm BW, Ross R. 1989. Theory-W software project management: Principles and examples. IEEE Transactions on Software Engineering 15(7):902Ŧ916

[9] Berander P. 2004. Using students as subjects in requirements analysis. In: Proceedings of the 2004 International Symposium on Empirical Software Engineering (ISESE'04). IEEE Computer Society, Los Alamitos, pp.167Ŧ176

[10] The MoSCoW Analysis Technique LMR Technologies.2012. Agile Practices: Scrum, XP, Lean, Kanban

[11] K. Beck, Extreme Programming explained, Reading, MA:Addison Wesley,1999

[12] J.karlsson, C.Wolin and B. Regnell, An evaluation of methods for prioritizing software requirements, information and software technology, pp 939-947,(2007)
[13] Grûber, T.: A translation approach to portable ontology specification. Knowledge Acquisition 5(2) (1993)
[14] Allemang, D., Hendler, J.A.: Semantic web for the working ontologist: Modeling in RDF, RDFS and OWL. Elsevier, Amsterdam (2008).
[15] Guarino, N., Carrara, M., and Giaretta, P. An Ontology of Meta-Level Categories. In J. Doyle, E. Sandewall and P. Torasso (eds.), Principles of Knowledge Representation and Reasoning: Proceedings of the Fourth International Conference (KR94). Morgan Kaufmann, San Mateo, CA: 270-280. (1994)
[16] Wouters, B., Deridder, D., Van Paesschen, E.: The Use of Ontologies as a Backbone for Use Case Management. In: "European Conference on Object-Oriented Programming (ECOOP 2000), Workshop : Objects and Classifications, a natural convergence", (2000)
[17] T. R. Gruber. A Translation Approach to Portable Ontologies. Knowledge Acquisition, 5(2):199–220, (1993)
[18] D. Callele, E. Neufeld and K. Schneider, "Requirements Engineering and the Creative Process in the Video Game Industry", 13th IEEE International Conference on Requirements Engineering, 2005.
[19] Carina Alves, Geber Ramalho and Alexandre Damasceno, "Challenges in Requirements Engineering for Mobile Games Development: The Meantime Case Study" 15th IEEE International Requirements Engineering Conference, 2007
[20] M. A. Teruel, E. Navarro, L. J. Víctor, F. Montero, and P. González, "An empirical evaluation of requirement engineering techniques for collaborative systems," in *Proceedings EASE 2011*, Darham, 2011, pp. 114-123.
[21] A. Cockburn, *Writing Effective Use Cases*, Addison-Wesley, 2000.
[22] A. Finkelsetin, *et al.*, "Viewpoints: A framework for integrating multiple perspectives in system development," in *International Journal of Software Engineering and Knowledge Engineering*, 1992, vol. 2, no. 1, pp. 31-57.
[23] L. M. Cysneiros and E. Yu, "Non-Functional requirements elicitation," in *Perspectives on Software Requirements*, J. C. Sampaio do Prado Leite, and J. H. Doorn, Ed., Springer, 2003, ch. 6.
[24] Google Inc., 2010. Google Docs. (April 2013). [Online]. Available at: https://docs.google.com.
[25] M. Geisser, T. Hildenbrand, F. Rothlauf, C. Atkinson, "An Evaluation Method for Requirements Engineering Approaches in Distributed Software Development Projects," Software Engineering Advances, ICSEA 2(007)
[26] W. Sitou and B. Spanfelner, Towards Requirements Engineering for Context Adaptive Systems, Technische Universitat Munchen, Department of Informatics, Boltzmannstr.3, 85748 Garching/Munich, Germany, (2007)
[27] Ahmed D. Alharthi, Maria Spichkova, Margaret Hamilton, Requirements Engineering Aspects of ELearning Systems, RMIT University, Melbourne, Australia, (2015)
[28] Verónica Castañeda, Luciana C Ballejos et Maria Laura Caliusco : Improving the quality of software requirements specifications with semantic web technologies. (2012)
[29] Decker, B., Rech, J., Ras, E., Klein, B., Hoecht, C.: Selforganized Reuse of Software Engineering Knowledge supported by Semantic Wikis. In: Proc. of Workshop on Semantic Web Enabled Software Engineering (SWESE). November, (2005)
[30] Kotonya, G. and I. Sommerville. Requirements Engineering: Processes and Techniques. John Wiley & Sons, Chichester, (1998)
[31] G. Hong, H. Trætteberg, A. I. Wang, and M. Zhu, TeMPS: A Conceptual Framework for Pervasive and Social Games, in Third IEEE Information Conference on Digital Game and Intelligent Toy Enhanced Learning Kaohsiung, Taiwan, (2010)
[32] K. Jegers, "Pervasive Game Flow: Understanding Player Enjoyment in Pervasive Gaming, ACM Computers in Entertainment, vol. 5, April (2007)
[33] A. Gentes, A. Guyot-Mbodji, and I. Demeure, Gaming on the move: urban experience as a new paradigm for mobile pervasive game design, Multimedia Systems, Vol. 16, pp. 43-55, doi:10.1007/s00530-009-0172-2 (2010)
[34] B. K. alther, Notes on the methodology of pervasive gaming in Entertainment Computing, Vol. 3711, F. Kishino, Y. Kitamura, H. Kato & N. Nagata, Eds, pp. 488-495 (2005)
[35] Quintin, J.-J., Depover, C., & Degache, C. Le rôle du scénario pédagogique dans l'analyse d'une formation à distance. Paper presented at the Actes de la conférence EIAH , Paris, INRP, 335-340.(2005)
[36] Paquette, G. Ingénierie Pédagogique. Québec: Presses de l'Univesité du Québec. (2002)
[37] Module 1: Introduction to GATE developer,University of Sheffield
[38] R. Myerson. Game Theory: Analysis of Conflict, Harvard University Press, Cambridge (1991)
[39] Madani, K. 2010. Game theory and water resources. Journal of Hydrology, 381(3), pp.225—238.
[40] Y. Mejbri, M. Khemaja, 2013. A Domain Ontology of Game Theory Applied to Game Based Learning, the European Conference on Games Based Learning
[41] O. Corcho, M. Fernandez-Lopez, and Asuncion Gomez-Perez, Methodologies, tools and languages for building ontologies. Where is their meeting point? Data & Knowledge Engineering, vol. 46, no. 1, pp. 41-64, (2003)
[42] N. F. Noy, and D. L. McGuinness, Ontology development 101: A guide to creating your first ontology, Stanford Medical Informatics (2001)
[43] E. Serral, A MDD Strategy for developing Context-Aware Pervasive Systems, Universidad Politecnica de Valencia, (2008)
[44] G. Hong, H. Trætteberg, A. I. Wang, and M. Zhu, "TeMPS: A Conceptual Framework for Pervasive and Social Games," in Third IEEE Information Conference on Digital Game and Intelligent Toy Enhanced Learning Kaohsiung, Taiwan, (2010)
[45] Laine, T.H., Islas Sedano, C., Joy, M. and Sutinen, E. Critical factors for technology integration in game-based pervasive learning spaces, IEEE Transactions on

Learning Technologies, vol 3, no 4, pp. 294 – 306. (2010)
[46] IEEE Guide for Developing System Requirements Specifications, Software Engineering Standards Committee of the IEEE Computer Society, IEEE Std 1233, 1998 Edition (1996)
[47] Staab, S., Maedche, A.: Axioms are Objects, too – Ontology Engineering beyond the Modeling of Concepts and Relations. In: Workshop on Applications of Ontologies and Problem-Solving Methods, ECAI 2000, Berlin (2000)