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Knowledge Management of Games for Decision Making

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Abstract. Games for decision making have developed into a powerful tool for corporations. Irrespective of their size, corporations have been increasingly using these games in order to evaluate and ascertain impactful business decisions and strategies. Despite their proven added value to the decision making process, there is still lack of research on whether, and if so how, these games can be used by researchers and practitioners to build evidents on systems' behavior, as part of a larger scheme. To this effect, this paper proposes a framework to determine the different artifacts of games that should be logged and stored for future use.

Keywords: Knowledge management system · Games · Simulations
Knowledge Elicitation · Game design · Debriefing

1 Introduction

All knowledge is not created equally [5]. The same applies to the knowledge gained from serious games. Serious games are a subgroup of simulations and are also known as simulators, human-in-the-loop, participatory simulations, or just games. Serious games have become a popular and effective tool for purposes like learning, training, and decision making [4]. As a result, research on serious games has dramatically increased over the last decade. A quick search of the term "serious games" in two of the most popular search engines for academic research, Google Scholar and Scopus, returned 17.900 and 4.418 results respectively for papers published between 2007 and 2016, but only 2.060 and 49 results for all the years up to 2007. These results might be skewed due to the adaptation of search engines in the past decade; yet, the differences are too large to ignore. Despite this boost in popularity and research, researchers have not as of today focused on how knowledge acquired through serious games can be retained and reused.

It has been observed that game artifacts reused in decision making processes often intertwine with artifacts reused in game development. The former are used in order to avoid iterations of the same games and apply, instead, prior knowledge to a current problem, whereas the latter are used in order to develop similar

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games in a faster and more cost-effective way, e.g. by reusing chunks of code. The present study, as suggested by the title, focuses on games for decision making (hereinafter referred to as games) and more specifically, on the respective artifacts that are used for knowledge reuse.

Knowledge management and reuse is not, and should not be, of academic interest only. The effectiveness of a corporation depends heavily on how it manages and reuses knowledge [11], or in layman terms, how in the first place it obtains and thereafter maintains the so-called "Know-how". As a corporation acquires and builds up on knowledge obtained through games, it improves its know-how, and thus sustains or even increases its competitive advantage [5].

In this paper, the first step towards the formalization of knowledge management and reuse of games is described. The different constituents of games are identified and ways to log and store them are proposed.

In Sect. 2, a representative sample of the body of work on knowledge management and reuse is identified and the lessons learned are discussed. In Sect. 4, the lessons learned in Sect. 2 are applied into games and a framework for formalizing knowledge management and reuse of games is proposed. In Sect. 5, the particularities of the proposed framework are analyzed and any potential threats towards its validity are identified. Finally, in Sect. 6, the future potential extensions of the framework are presented and final remarks are made.

2 Background Work

In this section, literature on knowledge management and reuse is reviewed. [8] first suggested that, even thought it may be complex, the collection of empirical data from game sessions can create a body of knowledge that can facilitate the researchers' understanding of systems' behavior.

Based on the literature reviewed and to the best of our knowledge, a methodology on management and reuse of knowledge derived from games has not yet been proposed. Hence, the aim of this section is first to present the state of the art in the field of knowledge management and reuse in general, and then to extract the techniques that can be applied into the games' field.

In principle, knowledge management and reuse requires some sort of documentation. [11] expands on the matter by making a distinction between documentation based on the author and the intended audience of these documents. He points three important factors that influence the successful management and reuse of knowledge, namely: (a) the costs involved, (b) the incentives knowledge producers have to contribute to a knowledge management system (hereinafter referred to as KMS) that can be used by others, and (c) the need to transform knowledge so that it is appropriate for use by others.

[20] propose a multi-theoretical model with the aim to tackle the problem of knowledge contribution and reuse. Their model, which is an extension of [9]'s model, addresses both the knowledge contribution to a KMS and the knowledge reuse. They further identify several factors that lead to increased contribution and reuse of knowledge, which include, inter alia, the reciprocal nature of contribution and the increased team performance. Further to the above, they assert

that reuse of knowledge is highly influenced by the ease with which someone can access the available knowledge, the trust towards the primary source of the knowledge, and undoubtedly the usefulness of this knowledge. Finally, the authors find a strong positive correlation between reuse and contribution.

By looking into management consulting firms, [7] distinguish two types of knowledge management and reuse - what they basically call *Codification* and *Personalization*. *Codification* stores and makes available for reuse any acquired knowledge, which is in reality isolated from its source. On the other hand, *Personalization* is the exchange of knowledge that has been acquired in the past through one-to-one conversations and brainstorming sessions; it is a way to promote discussion and exchange of ideas and knowledge between people in a more personal manner.

On a different level, [10] argue that when actually implementing a KMS, one shall prefer the use of Wikis to the traditional and conversational KMSs. Their study shows that Wikis, unlike the two other methods, address four of the most important challenges in knowledge management:

- The bottleneck of expertise, which refers to the limited number of experts that can contribute to a KMS [19].
- The lack of incentives, which refers to the lack of motivation from the experts in sharing their knowledge, either due to lack of rewards for sharing or due to the experts' tendency in maintaining expertise for themselves only, which in turn explains their unwillingness to share [15].
- Knowledge contextuality, which refers to the context required for the use of knowledge beyond narrow and well-structured tasks [6].
- The maintenance bottleneck, which refers to problems arising from maintaining a KMS against the backdrop of a system expansion, and especially, the possibility of knowledge sharing being impeded, or even ceased, due to the time required to just maintain the ever increasing knowledge [2].

While there is a lack of literature in the area of knowledge management and reuse of games, existing literature in the general areas of knowledge acquisition, contribution, management and reuse create a pathway towards knowledge management and reuse in games. The literature reviewed in this section shows that there are three distinct layers of knowledge management and reuse, while each of these layers influences one another in a sequential order. The first layer is the intended audience of this knowledge and their incentives. The second layer is the method pertaining to the management and reuse of knowledge, which is heavily influenced by the type of knowledge and the intended audience, in the sense that people who inquire on an expert's opinion but do not want to acquire his knowledge (expertise-seeking novices [11]) will most likely prefer to consult an expert in a one-to-one conversation (*Personalization*), whereas people that want to learn from past projects and apply this knowledge in the future (secondary knowledge miners [11]) will most probably prefer a documented and detailed record of these past projects (*Codification*). Finally, the third layer is the actual implementation of a KMS, which again is influenced by the knowledge management and reuse method, in the sense that a *Personalization* knowledge exchange method requires a simplistic system that can connect the interested party directly with an expert. On the other hand, a *Codification* knowledge exchange method requires a more complex and perhaps hybrid solution that can capture and store all the different elements of games for future use.

In the next section, the motivation for building a KMS for games is described; the analysis also provides an indirect answer to why a KMS for games can be an impactful contribution.

3 Motivation

Despite the fact that games have proven to be cost effective in multiple occasions, they still involve a substantial financial cost [13]. Depending on several factors, like the degree of realism or the intended audience, the cost of developing a game may vary significantly. For instance, board games are considered to be a low-cost solution, whereas high-fidelity military simulators usually bear a significant cost.

In addition to development costs, there are costs associated with game sessions which, more often than not, are not trivial. A game session might require expensive hardware, an appropriate space to take place, and most importantly participants, who are compensated for participating in the game.

Moreover, time is required to process the game outcomes and come with the best possible business decision. This additional time does not only increase the accrued costs but also delays decisions that sometimes are time-sensitive.

All of the above combined with the lack of a methodology for managing and reusing knowledge acquired through games, lead companies, researchers, and game practitioners to "reinvent the wheel" by conducting consecutive and (almost) identical game sessions, accompanied by data analysis.

The motivation for this study is therefore triggered by our strong belief that the acquisition, management and reuse of knowledge requires a methodology that will maximize the game outcomes concurrently with the minimization of the associating costs and risks.

4 Game Information

In this section, a framework for managing and reusing knowledge acquired from games is proposed. This framework aims at decomposing games into their core constituents, so as to give insight on the kind of knowledge a game produces and the way this knowledge can be stored and reused in the future.

4.1 Requirements

The development of a serious game starts by first eliciting the requirements. In regard to games, there are two sources from where requirements should be elicited, namely, the client and the real system the game imitates. The latter might be obsolete in case of open games, where there are (almost) no rules or restrictions.

In order for one to keep track of the progress and make sure that all the features are implemented as planned, eliciting and documenting the game requirements remains equally important throughout the development of the game. Although requirements are usually considered to be relevant only for the game they are elicited for, according to [21], requirements engineering is also concerned with the evolution of the relationships among the several factors of a system across software families. As such, requirements immediately become a tool for knowledge reuse, as they provide common ground for comparing different systems and pointing similarities. These similarities can be used either to improve future game development, as a domain specific knowledge [3], or in order to avoid building new games and reuse the outcome of previously created games to analyze a current issue.

4.2 Game Design Document

There have been several approaches towards the adaptation of game design documents from entertaining games to serious games as well as approaches towards structuring serious games in a model-driven way [16–18]. Regardless of the approach one chooses to adopt, there are certain game elements that need to be taken into account, as follows:

- Rules, which reveal information about the real system and the fidelity level of the game.
- Scenario, which shows the particular challenges and tasks of the game as well as its relevant setup details.
- Stakeholders/Actors, who are actively engaged with the game, such as participants, facilitator(s), game designer(s), and any other interested party.
- Purpose, which is the reason the client wants to build the game, e.g. for assisting decision makers.

The above indicated information shall be documented. On this basis, a comparison between a previously created game and a potential new game can determine whether the new game is actually required or not. In case the similarities between the two games are enough for the results of the old game to be used in the current occasion, the new game is obsolete.

4.3 Validation and Verification

Game validation deals with the assessment of behavioral or representational accuracy of the game and addresses the question of whether we are creating the "right game" [1]. On the other hand, game verification deals with the assessment of transformational accuracy of the game and addresses the question of whether we are creating the game in the right way [1].

Despite the fact that Validation & Verification (V&V) usually require formal methods and quantitative data, they are almost always subjective. Moreover, games cannot be absolutely validated [12] and verified, and successful V&V can only be claimed for an instantiation of a game (a specific game session) and for a specific use (purpose). Therefore, meticulously documenting every detail associated with V&V is of paramount importance; it can also reveal a twofold benefit to potential reusers: (i) they can ascertain, with rather minimal effort, whether the results of the game can be used for their intended purpose, and (ii) they can, again with much less effort than without the V&V details, perform their own V&V study and hence, use the game for slightly or completely different purposes.

A V&V study incorporates two types of data; (i) metadata associated with the V&V study, and (ii) information describing the V&V process along with raw data and final results.

The metadata that should be stored are:

- The date, time, & location (if relevant) of the V&V study.
- The version of the game, in case there are multiple versions available.
- The purpose for which the game has been used.

With regards to the actual V&V process, the information that should be stored is:

- The methods used for the V&V study and the justification on preferring these methods for the different phases of the game, like game requirements, game design, and game results [1].
- All the input and output data, both quantitative and qualitative ones, that were used during the V&V study (See how to store quantitative and qualitative data below in Sect. 4.4).

4.4 Game Sessions

A game session can also be seen as a game instantiation. In object oriented programming terms, the game can be seen as a class with the rules and general guidelines of how the game works, whereas the game session can be seen as an object of this class. A game is usually designed once (involving several iterations) but can be played multiple times with a similar or a completely different setup. In other words, a game session is the application of a game with a specific scenario, stakeholders, and purpose. Therefore, this characterization helps to understand how an actual KMS can be built to support a game.

Every game is different, hence it requires a different approach with regards to how the knowledge produced on it can be acquired and stored. Nevertheless, all games have the same main pillars; metadata, input and output data (quantitative & qualitative), and debriefing.

The metadata that should be stored are:

- The time, date, & location (if relevant) the game session took place.
- Detailed information regarding all stakeholders (participants, facilitator(s), and any other interested party.
  - Professional & educational background.

  - Age, sex, and any other relevant information.
- The annotations to all the data (quantitative & qualitative), which can be in the form of textual description, path to figures and audiovisual material on a server etc.

Input data usually include the game design decisions captured in the requirements and documented in the game design document, and they are common (but not exactly the same) for every instantiation of the game. Some input data might differ for each game session, where variations on the rules or the scenarios can be introduced. Input data can be both quantitative and qualitative.

In turn, output data might include quantitative data produced during the gameplay, audiovisual material captured during the game session or the debriefing, notes from the participants and/or the facilitator(s), game-specific artifacts and a textual analysis of the lessons learned from the game. Same as with input data, output data can be both quantitative and qualitative.

With regards to quantitative data:

- Raw datasets and any further quantitative analysis of these data should be stored in separate tables in a database, and any textual description or analysis should be included in the metadata.
- Figures produced from quantitative data should be stored in the server, and the path and any other information associated with them should be included in the metadata.

With regards to qualitative data:

- Audiovisual and any other relevant material should be stored in the server. Whilst the corresponding material should be annotated for ease of use in the future, these annotations should be included in the metadata.
- Any quantification of qualitative variables should be stored in a database or a server, depending on their format. Similarly to the textual description and the quantification methodology, the relevant material shall contain annotations, which shall be included in the metadata.

5 The Knowledge Management System

In Sect. 4, a decomposition of games and game design into their core elements was made. This analysis serves as a road map towards defining and eventually implementing a KMS of games.

The analysis in Sect. 4 strongly indicates that on the basis of their structure, design, and required and produced data, games are multi-dimensional entities. As such, defining and implementing a one-dimensional KMS seems limited and thus restrictive. A one-dimensional KMS is a system that does not combine different KMS solutions into one but rather includes a single-solution KMS, like a Wiki or a conversational KMS.

In this section, we propose a hybrid KMS that combines the advantages of individual solutions and is able to store and facilitate the reuse of the complex information pertaining to games.

A KMS should have a server-side (backend) and a client-side (frontend). The backend of the proposed KMS for games incorporates three main components:

- A database, which should be designed so as to accommodate wiki's entries, and the quantitative data and metadata associated with the game.
- A filesystem, used as a repository of audiovisual material, figures, and any similar content.
- Analytical tools, like R or Python, for the quantitative analysis of data.

The frontend of the proposed KMS also incorporates three main components:

- A graphical user interface (GUI) for the wiki.
- Visualization tools for creating graphs and figures from the quantitative data.
- A search engine for querying all data.

The proposed framework bears similar validity threats to those of its individual components. A KMS can only be successful if people contribute and reuse knowledge; in fact a causal relationship between knowledge contribution and reuse has been identified [11]. Therefore, one of the most important goals of such a system should be the adaptation of a methodology for eliminating, or at least mitigating, knowledge bias that derives from human subjectivity, which is an inseparable part to knowledge contributed [14].

In the same spirit, the success of a KMS depends heavily on the credibility of the primary source of information. In this respect, a person who aims at using knowledge previously acquired shall be confident of the expertise of the knowledge contributors, and thus trust their respective findings [20].

Finally, in order for a KMS to be used in practice, it needs to be properly and consistently indexed [11]. It follows that Knowledge contributors need to feel confident that the time required to contribute to a KMS is not wasted-time and that their input has high chances to be easily accessible and used.

6 Conclusion and Future Work

The reviewed literature and the analysis in this paper indicate that a KMS for games is needed. To the best of our knowledge, a methodology for doing so does not todate exist. The greatest challenges for developing such a KMS is the wide nature of game requirements (the different types of knowledge and the diverse potential user-base of the KMS) and the threats towards the validity of the framework (described in Sect. 5).

Ergo, this study constitutes the first step towards that direction, by setting forth a framework for building a KMS for games. The proposed framework aims at maximizing knowledge acquisition and reuse from games, through the incorporation of the advantages of different technologies (wikis, databases, statistical scripting languages) in a hybrid system, which is platform, programming language and content agnostic and thus, easily adaptable to fit different needs. Moreover, due to its foreseen use, the framework is more *Codification*-oriented, as opposed to *Personalization*-oriented.

In the future, the actual implementation of this framework will test and fine-tune the theoretical concept, and consequently improve the derived KMS.

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