Metrics for Assessing Gamers' Satisfaction: Exploring the Graphics Factor

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***Abstract*—Requirements' engineering (elicitation and documentation) is considered to be one of the most crucial phases of the software development process. More specifically, many products fail to reach the market or to capture a respectable share of it, due to problems derived during requirements engineering. In any game the main requirement is expected to be entertainment: i.e., guaranteeing that the user has fun while playing the game. The experience of the user, while playing any game, is highly correlated to non-functional requirements, such as game speed, game graphics and scenario. However, in the majority of the cases such non-functional requirements are vague, since there are no success indicators (metrics) or target values that can (to some extent) guarantee user satisfaction. In this paper, we propose a process that can be used for enhancing game requirements' engineering, by specifying non-functional requirements along with metrics, based on user satisfaction factors. The employed user satisfaction factors, are reused from previous work (i.e., a survey with regular gamers), whereas in this work we identify game characteristics that are relevant to a specific user satisfaction factor (namely: graphics) and we propose and validate metrics for their automated quantification from game code and artifacts.**

Keywords—Games, metrics, user satisfaction

I. Introduction

Playing video games is a form of entertainment that continuously gains popularity during the last decades, as captured by both the revenues of the corresponding industry[1], as well as surveys on the most popular means of entertainment among the youth[2]. As a product that aims primarily at entertainment, the key characteristic of a successful game is user satisfaction: the user must want to play a game again after quitting it (*replayability*), must be *immersed* in the game while playing it, etc. [1]. To this end, various studies (see Section II.A) have explored the factors that affect the satisfaction that a user gets from playing a game (termed as ***user satisfaction factors***). The analysis of user satisfaction factors (similarly to any kind of quality assurance process) cannot be an afterthought for game development, since such factors are usually related to early-stage game design decisions, such as scenario design, characters design, graphics, etc.

In almost every software development lifecycle model, the analysis stage is connected to requirements engineering. Specifically for game development, Callele et al. [2] stated that requirements engineering is a crucial step for ensuring the success of the game; constituting it an interesting and relevant research field. On the one hand, despite the fact that the functional requirements of a game are very important [3], they only set a baseline for success; on the other hand, even more important is the ability of the game to create emotions to the player (non-functional requirements) [4]: the user is expected to feel several emotions during game play similar to those while watching a movie [5]. Achieving this, leads to an engagement between the player and the game, and is important for ensuring user satisfaction from gaming.

However, in software development (including game development), the conformance of the product to non-functional (or quality) requirements is a wicked problem [6]. The main problem while performing non-functional quality control is the abstractness in specifying quality requirements. According to Sommerville [7], quality plans must clearly specify the targeted property (***quality attribute***), a straightforward success indicator (***quality metric***), and a target value that when reached indicates meeting the requirement (***metric score***). With the aim of systematizing the non-functional quality control of games, we propose the enhancement of game requirements engineering process, by championing the consideration of non-functional requirements that are related to user satisfaction, as part of the game analysis phase. In particular, we propose a metric suite that is capable of assessing user satisfaction from game code and other artifacts.

Regarding the selection of the assessed user satisfaction factors, in this paper we focus on ***game graphics*** (details on this decision are provided in Section II.A). This paper is the third one of a series of studies that aim at proposing metrics for assessing gamers' satisfaction. The first paper, of the series [1] introduced metrics that assess the quality of game scenarios; whereas the second [8] introduced metrics for game graphics. The main difference of this work, compared to the prior work on metrics for graphics assessment is the evaluation. In particular, the metric suite introduced by Ampatzoglou et al. [8] was evaluated based on still images, a decision that introduced a construct validity threat, in the sense that games involve interactive (not still) graphics. To alleviate this problem, this study is a replication (using the same metrics), that enables us to draw safer conclusions that are closer to the context of game development.

[1] http://www.gamesindustry.biz/articles/2015-04-22-gaming-will-hit-usd91-5-billion-this-year-newzoo

[2] https://www.science20.com/content/video_games_are_bigger_than_movies_and_music_combined_and_surveys_show_that_gap_may_widen

The rest of the paper is organized as follows: In Section II, we present related work on: (a) the identification of user satisfaction factors (see Section II.A), and (b) how they can be assessed (see Section II.B). Section III presents the reused metrics suite; and Section IV the study replication protocol. Section V presents and discusses the results of the study; and Section VI concludes the paper, by discussing implications; and presenting limitations and future work opportunities.

II. RELATED WORK

A. Identifying User Satisfaction Factors

In this section, we present the studies, which led us to the selection of the user satisfaction factors to explore in this series of studies (so far)—namely: Scenario and Graphics—while proposing metric suites. The first study that was conducted by Ham et al. [9], suggested that game satisfaction factors differ among game genres. Ham et al. [9] considered seven factors (namely: *Scenario*, *Graphics*, *Sound*, *Game Speed*, *Game Control*, *Character* and *Community*), which have been ranked based on their importance. The most important factors have proven to be *Graphics*, *Game Control* and *Character*, while *Community* and *Sound* have appeared to be less important. The average importance of each factor among games genres is depicted in Table I. The importance of *Graphics* has been further highlighted by Young [10], suggesting that more than the half of survey participants support that graphics influence their decision of playing a game.

TABLE I. USER SATISFACTION FACTORS [9]

Id	*Factor*	*Importance*
1	Character	20,0 %
2	Graphics	17,6 %
3	Game Control	16,7 %
4	Game Speed	13,7 %
5	Scenario	11,1 %
6	Sound	10,8 %
7	Community	10,1 %

The results of Ham et al. [9] have been updated by Paschali et al. [11] in a more recent survey, which suggested that *Scenario*, *Character* and *Sound* are the most important factors that influence user satisfaction. Nevertheless, the importance of the *Graphics* factor is highlighted by the authors, who note that graphics are of primary importance to Sports, Role-Playing, and Strategy games. Based on the above, as part of this series of studies, we have prioritized towards *Scenarios* and *Graphics*. The importance of these factors has also been highlighted by other studies. For instance, Lee [12] identified *visual representation*, *content*, and *interaction* as the most important satisfaction factors for online games. Additionally, Ari et al. [13] suggested that there is a statistically significant relationship between *visual appeal* and pleasure: meaning that the gamers' pleasure increases when the visual and aesthetic design is more attractive.

B. Assessing User Satisfaction

In the literature, one can identify two "*schools*" for assessing gamers' satisfaction: (a) heuristics [14][15][16][17]; and (b) metrics [1][8][18][19]. Since this study is related to metrics assessment we focus only on the latter category.

Multiplayer online games have now become popular with millions of gamers across the globe, capturing the attention of both researchers and practitioners. Unfortunately, online games still have to deal with the limitations imposed by some unresolved issues. Interactivity, consistency, fairness, and scalability are the major requirements that need to be addressed efficiently in order to provide an appealing product to a huge number of potential customers worldwide. To answer this demand, Ferretti et al. [18] performed a survey exploring a holistic approach that can exploit the semantics of the game to satisfy the aforementioned requirements. They provide extensive and comparative results that demonstrate how the proposed scheme copes efficiently with an elevated level of game traffic. Wattimena et al. [19] describe the development of an end-to-end quality measurement method that allows quantifying the perceived quality of Interactive Gaming, with an emphasis on the so-called First-Person Shooter (FPS) game Quake IV. The paper included a number of subjective experiments to quantify the impact of network parameters on the perceived quality of this recent FPS game. These experiments were only for the game Quake IV and it was important to validate the proposed quality model for other games also.

By focusing on the series of studies that this work belongs to, Ampatzoglou et al. [8], identified a variety of measurable technical characteristics of 3D software that estimate user satisfaction, based on the graphical representation of the game. The evaluation of the metrics has been conducted through a pilot experiment, with still images. The results suggested that some technical characteristics, such as textures, are more important than the details of the 3D mesh, i.e., number of polygons. Finally, Paschali et al. [1] proposed a model that identifies and quantifies user's satisfaction factors in order to evaluate the quality of game scenarios. The seven factors are level of narrative, re-playability, interactivity, characters' interaction, content, achieved curiosity and desirability. According to the results, re-playability, interactivity, characters' interaction and achieved curiosity are these factors that are strongly correlated.

III. QUANTIFYING USER SATISFACTION

In this section, we present the metric suite that we reused for assessing gamers' satisfaction from technical characteristics of 3D scenes. Such predictors can be used at an early game analysis phase as success indicators for non-functional requirements, which will guarantee certain user satisfaction levels. In this paper, the considered metrics deal only with the graphical representation of the scene and not the theme or the movement speed. The metrics are based on the process for building realistic 3D scenes, described by Omernick [19].

The metrics that we use in this study are based on Ampatzoglou et al. [8]:

- Each 3D scene contains a ***Number of Entities*** (NE). These are 3D objects (aka meshes), textures, materials and lighting. The number of the aforementioned elements, in each 3D scene is captured by the metric NE.

$$NE = \#Textures + \#Materials + \#Lights + \#Meshes \quad (1)$$

- Meshes are a set of polygons that represent the appearance, shape and volume. The smaller the polygon size, the more detail and precision the object represents. The ***Average Size of Triangles*** (ST) metric is calculated as the average size of polygons for all objects in a 3D scene.

$$ST = \frac{\sum_{i=0}^{\#meshes} \frac{avg(triangle\_size\_of\_mesh[i])}{size\_of\_mesh[i]}}{\#meshes} \quad (2)$$

- Textures are images that are used to add more details in the visualization of 3D objects. The more and detailed (in term of resolution) textures employed while "*painting*" a 3D scene, the more realistic the final outcome will become. The ***Texture Size*** (TS) metric is calculated by averaging the number of pixels of texture images, divided by the resolution of a baseline 512x512 texture image.

$$TS = \frac{\sum_{i=0}^{\#textures} \frac{texture[i]\_width \cdot texture[i]\_height}{size\_of\_mesh[i]}}{\#textures \cdot 512 \cdot 512} \quad (3)$$

- Apart from textures, the realism of an object can be improved by ***Advanced Texturing Effects*** (TE), such as: bump mapping, specularity and opacity. TE is calculated as the fraction of 3D objects that use at least one advanced texturing effect, over the total number of 3D objects in the scene.

$$TE = \frac{\#meshes\_with\_advanced\_texturing}{\#meshes} \quad (4)$$

- On top of textures, or for visualizing simpler 3D objects, the artistic teams of games use materials that are responsible for calculating the reflection of light. Thus, each mesh in the scene must correspond to at least one material. The ***Number of Materials*** (NM) metric captures the percentage of objects, which have been linked to materials.

$$NM = \frac{\#materials}{\#meshes} \quad (5)$$

- Apart from objects and textures, a 3D scene uses several environmental effects for improving the aesthetics and realism of the product, such as: lights, fog, shadows, etc. As far as the lighting is concerned, the ***Number of Lights*** (NL) metric captures the lights that have been attached to the 3D scene. We note that a scene might have multiple and different (e.g., directional, omni, etc.) lighting sources. On top of that the ***Environmental Effects*** (EE) metric is responsible for determining whether global illumination, fog and shadow effects are considered, while rendering the 3D scene. When considered, the parameter contributes one point to the score of the EE.

$$NL = \#Lights \quad (6)$$

$$EE = Global\ Illumination + Fog + Shadows \quad (7)$$

- Finally, the two game resolution metrics (***width*** and ***height***) capture the size of the rendering of the 3D scene. Similarly to TS, in order to avoid large metric values, we normalize RW and RH against a baseline rendering size.

$$RW = \frac{resolution\_width}{640} \quad (8)$$

$$RH = \frac{resolution\_height}{480} \quad (9)$$

IV. Replication Protocol

In this section we present our study design, which is a replica of the experiment conducted by Ampatzoglou et al [8]. The only parameter that has changed along the replication is the input that the human evaluators received. In contrast to the original study, when the evaluators received still images of different themes, in the current setup eight (8) versions of the same scene has been made available via a dedicated evaluation webpage to 40 gamers (invitations sent through email) with different age range and experience with 3D graphics. The scenes have been developed by combining 3D Studio MAX and the Unity game engine. However, the scenes have been distributed as walkthrough videos to the evaluators, so as to factor out Speed and Controls, which are different user satisfaction factors. In the webpage, each scene was accompanied by a question, asking the evaluators to rate the scene that they have just seen regarding the quality of graphics, in a range between 1 (worst) and 20 (best)[3]. After grading all videos, the webpage demonstrated to the evaluator the top-5 rated versions (from worst to best), asking them to verify, or update the ordering. In this manner we avoided invalid comparison of videos, due to over- or under-expectations of the evaluator in the first time that he/she saw the videos.

The ***data collection*** was automated, and results have been gathered in a dataset of 8 rows (one for each video) and 10 columns (as presented in Table II). The first nine (9) columns correspond to the metrics for each video, whereas the 10^{th} column to the Average Perceived Graphical Quality (PGQ). PCG is the average grade for the specific video, by all evaluators (excluding min and max assessments as outliers). The complete dataset along with the video versions used for evaluation are available in the study replication package[4].

TABLE II. Experiment Parameters

Id	***Parameters***
1	Number of Entities (NE)
2	Average Size of Triangles (ST)
3	Average Texture Size (TS)
4	Average Texture Effects (TE)
5	Number of Materials (NM)
6	Number of Lights (NL)
7	Environmental Effects (EE)
8	Average Resolution Width (RW)
9	Average Resolution Heigh (RH)
10	Average Perceived Graphical Quality (PGQ)

The ***data analysis***, followed the well-known standard for software metrics evaluation (*namely*: 1061 IEEE Standard for Software Quality Metrics). From the evaluation procedure, we selected to perform *Consistency* and *Discriminative Power* analysis. On the one hand, Consistency assesses if the metric under study is consistently correlated with the quality factor, by using their ranks. The criterion is desirable to ensure that the metric under study can accurately rank, by quality, a set of products or processes. The criterion is quantified by using the coefficient of rank correlation [20]. On the other hand, *Discriminative Power* assesses if the metric under study is capable of separating groups of high-quality and low-quality components. Although the criterion is proposed to be quantified through a contingency table, we visualize it through boxplots [20].

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3 "*How satisfied you would be, by the level of graphics, after playing a game with the given scene? NOTE: The video corresponds to in-game graphics and not introductory or cut-scene videos*"

4 https://users.uom.gr/~a.ampatzoglou/aux_material/ase4games.rar

V. RESULTS

This experiment aims at assessing the quality of graphics (from the viewpoint of gamers' satisfaction), based on metrics. To assess Consistency, we performed Spearman Rank correlation, as presented in Table III. In Table III we denote statistical significance at two levels 0.10 (one star) and 0.05 (two stars). We note that due to the small size of the dataset, we relaxed the threshold for significant correlation from 0.05 to 0.10 and 0.01 to 0.05 respectively [22].

TABLE III. CORRELATION ANALYSIS

Independent Variable	***Correl. Coeff.***	***sig***
Number of Entities (NE)	0.807**	0.008
Average Size of Triangles (ST)	-0.575*	0.068
Average Texture Size (TS)	0.590*	0.062
Average Texture Effects (TE)	0.458	0.127
Number of Materials (NM)	-0.590*	0.062
Number of Lights (NL)	0.509*	0.099
Environmental Effects (EE)	-0.327	0.214
Average Resolution Width (RW)	0.446	0.134
Average Resolution Height (RH)	0.446	0.134

Based on the analysis, ***Number of Entities***, ***Size of Triangles***, ***Texture Size***, ***Number of Materials*** and ***Number of Lights*** have a statistically significant correlation to gamers' satisfaction from the graphics quality of the 3D scene. *Number of Entities* has proven to be a key-factor on how appealing a 3D scene is for the gamer. This finding is expected in the sense that: (a) this metric is a collective one pertaining to objects, lights, textures, and materials; and (b) intuitively a 3D scene with more objects is able to provide a more detailed visualization of the world. The *Size of Triangles* metric is negatively correlated to perceived graphical quality, since the smaller and more triangles comprise a 3D mesh, the "*curvier*" and more realistic it can "*feel*" to the gamer (by default most real-world object are comprised of curves rather than lines). Despite the fact that modern 3D modelers assist polygon reduction to boost performance, the optimizer (or the artist) is identifying a threshold under which polygons become too large and the object too coarse-grained.

The *Texture Size* metric is positively correlated to PGQ, which is expected in the sense that the better the resolution of images, the more realistic the 3D object becomes. Interestingly, this metric is not so strongly correlated to PGQ as NE. The reason for this is not the fact that very high-resolution images cost in game speed (this cannot be captured by our experiment, since it is a different factor), but to the fact that from some point and on the details offered by a very large texture cannot be seen in small, distant, or fast-moving objects. In light of these findings, we provide evidence that game developers must select the resolution of textures, based on various parameters (size of object, distance, speed, anticipated user devices, etc.) to save game speed. A rather unexpected result was that *Number of Materials* is negatively correlated to perceived graphical quality: intuitively we would expect that the use of materials would improve realism. However, it seems that an excessive use of materials does not only make the rendering more resource hungry, but also it does not improve gamers' engagement. An alternative to this could be the use of multiple textures for effects (TE has a positive correlation to PGQ—see next paragraph). Finally, the result on the strong correlation between *Number of Lights* and PGQ is considered intuitive, in the sense that the use of more lighting sources enables the realistic rendering of the scene, enabling effects such as shadows and reflections to promote the aesthetics of the scene.

By comparing the results of the replication and the original study [8], we observe that all metrics that are highlighted as statistically significantly correlated to gamers' experience in this study, have also been identified as important in the first study with still images. The main difference from the original study is the fact that our replication has not pointed to ***Texture Effects*** as a major parameter for achieving gamers' satisfaction. A possible interpretation for this observation is the fact that in still images, it is easier for the "*eye*" of the evaluator to "*catch the detail*" of texturing, which might slip his/her attention when seeing moving 3D objects.

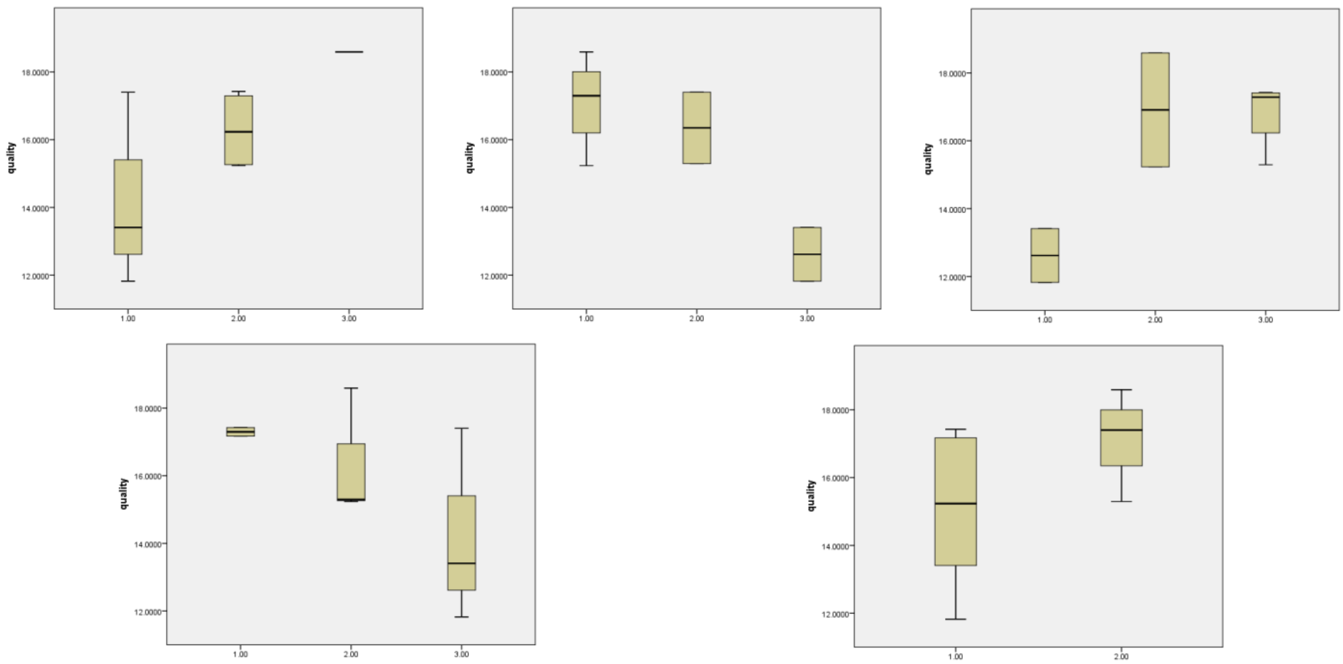

Fig. 1. Boxplots for: (a) Number of Entities, (b) Size of Triangles, (c) Texture Size, (d) Number of Materials, (e) Number of Lights

To graphically explore the Discriminative Power of metrics, in Figures 1(a)-(e) we present boxplots displaying how the perceived quality of graphics is affected by the scores of the 5 aforementioned statistically significant metrics. We remind that in order for a parameter (metric) to be able to visually discriminate among high- and low-quality products (3D scenes in our case), there must be no overlap among the corresponding boxes. Based on the results, absolute discrimination (among all classes of the category) is achieved only from the Number of Entities metric. The rest metric can only differentiate among two of them. For instance, when Size of Triangles is HIGH the PGQ deteriorates, whereas the difference between LOW and MEDIUM size of triangles, does hurt the perceived graphical quality in a substantial way.

VI. Conclusions – Limitations – Future Work

In this paper, we champion the inclusion of code and other artifact metrics in the game analysis phase, so as to control the gamers' experience, based on several user satisfaction factors. In this work, we focus on game graphics as a user satisfaction factor and evaluate nine (9) graphics metrics to predict the perceived graphical quality of a 3D scene. The results of the study suggested that five (5) metrics are strongly correlated to user satisfaction. Among these metrics *Number of Entities* seems to be the best predictor of user satisfaction. Additionally, the empirical evidence achieved in this study can provide some useful implication to game artists. Based on our findings, a 3D scene is perceived as of high-graphic-quality if it contains many elements to capture even small 3D objects (high-poly objects), the textures of 3D object are not necessary to be only high-resolution images, since from some point and on, the details are not "*caught by the eye*", and that combination of materials is not necessary for rendering all 3D objects.

As any other empirical study, this work suffers from various threats to validity. First, the relatively small number of videos used as subjects has not enabled us to develop subjects that differ only in one of the nine (9) examined parameters (e.g., subjects with low TS and NM could feel better even with lower TS and TE). Also, for the same reason, the threshold for statistical significance has been relaxed. To this end, a larger-scale experiment is necessary. Second, the obtained results might be differentiated if we do not isolate Game Graphics from other satisfaction factors, such as Game Speed. Using as subject real games and not pre-rendered videos would allow us to also see interactions among the game satisfaction factors. This potential constitutes an interesting future work opportunity. Additionally, given the significance of game parameters (e.g., object and camera speed) in the importance of metrics, we believe that an analysis of different game genres, might yield different results. For this reason, i.e., to boost generalizability among game genres, we have selected a neutral 3D scene for our experiment.

Finally, we need to note that this series of studies, open up an interesting route for further research and game development practice, since (apart from the empirical confirmation or rejection of rule of thumb practices) it enables the automation of quality control in early development stages. For instance, as future work of this study, we plan implementing the calculation of these metrics as plugins for open-source game engines and as a standalone tool that will parse the code of non-game-engine based games. Such sort of automation will allow the continuous monitoring of game quality; which in our understanding the domain of game development lags compared to conventional software engineering.

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