Applying a Serious Game Quality Model

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Abstract. This paper has the following goals: (1) To introduce a preliminary version of a Serious Game Quality Model (QSGame-Model), (2) To present an example of the application of this model and (3) To outline the future empirical studies that we plan to perform in order to refine and validate the model.

Keywords: QSGame-Model · Quality model · Serious Game · Survey · Experiment

1 Introduction

A Serious Game (SG) is a game whose main purpose goes beyond than mere entertainment [1]. Although these games are widely used in education, they can also be applied to areas as varied as defense, scientific exploration, health care, emergency management, city planning, engineering, religion, and politics. SGs are a rapidly-emerging area of opportunity, as well as being a growing market [2] and can be a means of achieving important objectives from both personal and institutional points of view; all these aspects make them vitally important. The social impact of SGs is very high, due to the fact that the number of SGs users is growing day-by-day. We thus believe that the quality of SGs is a high priority, and consider it is our duty as researchers and practitioners to ensure this quality. That concern led us to establish our research objective, which was to propose and validate a quality model adapted specifically to SGs. We started by carrying out a systematic mapping study (SMS), aiming to discover the current state-of-the-art on research into SG Quality [3]. This literature review manifested that researchers are concerned about SG quality, but there is no consensus on what the most relevant quality characteristics SGs are desired to fulfill. For that reason we have proposed a preliminary version of a product quality model for SGs, called QSGame-Model [4], a version which is based mainly on the current standard on software product quality, the ISO/IEC 25010 [5]. In [4], we presented the complete process of the construction of the QSGame-Model, but we did not give any example of its application. The main goal of this paper is to illustrate the use of the QSGame-Model for evaluating a SG. This application example will very useful for professionals in software quality and in SGs development, giving an illustration that makes the quality model easier to understand. The remainder of this document is organized as follows. Section 2 gives a brief introduction to the QSGame-Model.

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Section 3 describes an example of how to evaluate the quality of SGs using the QSGame-Model, and Sect. 4 presents general ideas for the future empirical studies we are planning to perform in order to refine and validate the model. Finally, our main conclusions and ideas for future work will be set out in Sect. 5.

2 The QSGame-Model

The QSGame-Model presented in [4] was based on the generic ISO/IEC 25010 [5] standard and was adapted to the SG domain. This standard establishes high-level quality concepts, which must be adapted or extended if they are to be useful in specific domains. We decided to adapt our model using the top-down methodology proposed by Franch and Carvallo [6]. The detailed steps followed to define QSGame-Model can be found in [4].

Results of the state-of-the-art on SG quality [3] showed us the elements addressed by research in this field. Based on these results, we considered the incorporation of specific SG attributes applied to SG which are not defined in the standard product quality model [5].

We incorporated different attributes to the Functional Suitability sub-characteristics: Functional completeness, Functional correctness and Functional appropriateness; and to the Usability sub-characteristics: Appropriateness recognizability, Learnability, Operability, User interface aesthetics, and Accessibility. The incorporation of attributes in these two characteristics came about because we believe they are directly associated with the elements that facilitate the flow experience [7] (objectives and clear rules, feedback, balance between challenges and skills and concentration). In addition, these two characteristics were those addressed most by research according to the SMS on SG quality [3] findings. By way of example, Fig. 1 shows the sub-characteristics and attributes of Functional Suitability, while the measures for each attribute are presented in the following section. The complete description of the QSGame-Model can be accessed at http://alarcos.esi.uclm.es/SeriousGamesProductQualityModel/.

3 Applying the QSGame-Model

In this section we will present an example of the evaluation of the Functional Suitability characteristic of a prototype of an SG, called "Ceebot-A demo 1.17" [8]. The Functional Suitability characteristic is defined as the *Degree to which an SG provides functions that meet stated and implied needs when used under specified conditions.* Ceebot is an SG (Fig. 1) whose main objective is for users to learn Programming while having fun. Ceeboot-A demo requires the player to cover two main topics (Fundamentals and Continuation) by carrying out the functions shown in Table 1. For each of the functions, the game provides all the instructions needed for completion.

We will now go on to describe each of the measures that have been proposed to evaluate each of the attributes of the Functional Suitability sub-characteristics,

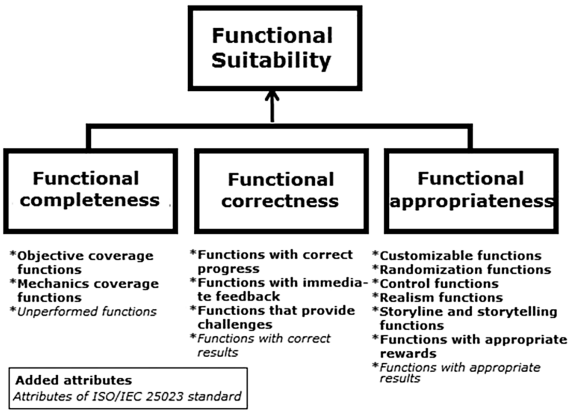

Fig. 1. Functional suitability: sub-characteristics and attributes

Table 1. CBoot-A functions.

Function name	Function objective
1. Move	Just move forwards
2. The straight line	Draw a perfect straight line
3. First turn	Draw a large "L"
4. Massacre 1	Destroy three targets with a short program
5. Massacre 2	Use a loop to blow up six targets

providing results of their evaluation (see Tables 2, 3 and 4). Each measure includes the measure name, measure description, measurement function, the value obtained and the comments that are needed to clarify some aspect of the values obtained.

The Functional Completeness sub-characteristic is defined as the *Degree to which the set of SG functions covers all the specified tasks and user objectives.*

The Functional Correctness sub-characteristic is defined as the Degree *to which an SG provides the correct results with the needed degree of precision.*

Functional Appropriateness sub-characteristic is defined as *Degree to which the SG functions facilitate the accomplishment of specified SG tasks and objectives.*

The results obtained from the evaluation of all the quality attributes of the Functional Suitability characteristic revealed that Ceebot-A is of good quality with respect to this characteristic, except for the following measures (Fig. 2):

- Mechanics coverage: The value obtained in the evaluation was 0.6, because 2 of the functions do not provide rewards when the player achieves the function objective (Table 2). To improve this result to its maximum value of 1, these two functions should provide rewards when the player achieves the goal.
- Functional Randomization and Functional Control: The value of 0 obtained in those measures shows that none of the functions has actions or tasks that occur in random order, and that the game does not allow the user to choose different controls for operating the game (Table 3). These results could be improved to reach the value of

Table 2. Functional completeness sub-characteristic.

Measure name	Measure description	Measurement function	Measure value/Comment
Objective coverage	How complete is the implementation according to established objectives in requirement specifications?	X = 1 − A / B A = number of functions missing B = number of total functions specified X [0,1]; the closer to 1 the better A missing function is detected when the SG does not have the ability to perform a function related to an established objective on requirements.	A = 0; B = 5 X = 1 − 0 / 5 = **1** Although requirement specification is needed to evaluate this measurement, in this evaluation example we are assuming all objectives established were implemented.
Mechanics coverage	How complete is the implementation of game mechanics in SG functions so that each function objective established provides a challenge, and each challenge is expected to offer a reward?	X = 1 − A / B A = number of functions missing B = number of total functions specified X [0,1]; the closer to 1 the better A missing function is detected when the SG does not have the ability to perform a function with mechanics.	A = 2; B = 5 X = 1− 2 / 5 = **0,6** Functions "Move" (1) and "The straight line" (2) do not provide rewards (2 of 5).

1 if, in the first case, the 5 functions had tasks that occur in random order, or if, in the second case, the game allowed the user to choose different controls to operate it.

- Appropriateness Rewards: The value of 0.4 obtained shows that just 2 of the 5 functions offer appropriate rewards (Table 3). This value could be improved to reach a value of 1 if the 5 functions provided appropriate rewards.

4 Outline of the Future Refinement and Validation of the QSGame-Model

Our future work will focus mainly on the refinement and validation of QSGame-Model. To do this, we have first constructed a survey that we plan to distribute to the largest possible number of experts in SG development and teaching, to ask them about the relevance and understandability of each of the quality attributes defined in the QSGame-Model. Table 5 shows an example of a question on the survey; it corresponds to Objective Coverage Function, an attribute of the Functional completeness sub-characteristic. To contextualize the survey responses, we have included a block of

Table 3. Functional correctness sub-characteristic.

Measure name	Measure description	Measurement function	Measure value/Comment
Functional progress	To what extent do functions provide a correct and accurate score in order to signal the player's progress or advancement in the game?	X = A / B A = number of functions which provide correct and accurate score to signal progress B = number of total functions of SG X [0,1]; the closer to 1 the better	A = 5; B = 5 X = 5 / 5 = **1** 5 out of 5 functions provide correct progress.
Functional immediate feedback	To what extent do functions provide the player with immediate feedback in response to incorrect action?	X = A / B A = number of functions which offer immediate feedback to the player in response to incorrect action B = number of total functions of SG X [0,1]; the closer to 1 the better	A = 5; B = 5 X = 5 / 5 = **1** 5 out of 5 functions offer immediate feedback to the player in response to incorrect action.
Functional challenge provided	To what extent do functions allow the SG user to set levels of difficulty in challenges that adapt to their particular skills?	X = A / B A = number of functions allow the SG user to set levels of difficulty in challenges that adapt their skills B = number of total functions of SG X [0,1]; the closer to 1 the better	A = 5; B = 5 X = 5 / 5 = **1** Although the CeeBot-A demo version does not allow the reuse of the option of establishing levels of difficulty in challenges, we are assuming this would be possible; the game has the option of setting those levels.

questions regarding demographic information about the respondents, such as their gender, education level, country in which they work, experience in video game and SG development, etc.

Once the QSGame-Model has been refined, we will conduct experiments to obtain empirical evidence on its usefulness, i.e., to obtain empirical evidence that will allow us to ascertain whether the presence of the model allows SG developers to build better quality SGs. We will therefore have obtained a quality model for SG that has been agreed on by experts and which is also useful for SG developers.

Table 4. Functional appropriateness sub-characteristic.

Measure name	Measure description	Measurement function	Measure value/Comment
Functional customization	Does the SG allow the user to establish particular preferences, e.g. to be identified as a character of a particular sex or given appearance, etc.?	X = yes or not If the game allows the user to establish particular preferences, X value will be "1"; otherwise X value will be "0" X [0 or 1]; 1 is better	X = **1**
Functional randomization	What proportion of the implemented functions has actions or tasks produced in random order?	X = A / B A = number of implemented functions which have actions or tasks produced in random order B = number of total functions of SG X [0,1]; the closer to 1 the better	A = 0; B = 5 X = 0 / 5 = **0** 0 out of 5 implemented functions have actions or tasks produced in random order.
Functional control	Do the game functions allow the user to choose different controls for operating the game?	X = yes or no If the game allows the user to choose different controls for operating the game, X value will be "1", otherwise X value will be "0" X [0 or 1]; 1 is better	X = **0**
Functional realism	What amount of the implemented functions allows that virtual world to be as close as possible to the real world?	X = A / B A = number of implemented functions which allows the virtual world to be as close as possible to the real world. B = number of total functions of SG X [0,1]; the closer to 1 the better	A = 5; B = 5 X = 5 / 5 = **1** 5 out of 5 implemented functions allow the virtual world to be as close as possible to the real world.
Functional storyline and storytelling	What amount of the implemented functions has tasks	X = A / B A = number of implemented	A = 5; B = 5 X = 5 / 5 = 1

(*Continued*)

Table 4. (*Continued*)

Measure name	Measure description	Measurement function	Measure value/Comment
	and activities relevant to the storyline and storytelling being conducted throughout the game?	functions which has tasks and activities relevant to the storyline and storytelling B = number of total functions of SG X [0,1]; the closer to 1 the better	5 out of 5 implemented functions have tasks and activities relevant to the storyline and storytelling.
Appropriateness of reward	What proportion of the implemented functions offered appropriate rewards, in relation to the challenge achieved?	X = A / B A = number of the implemented functions which offer appropriate rewards B = number of total functions of SG X [0,1]; the closer to 1 the better	A = 2; B = 5 X = 2 / 5 = **0,4** Function "Massacre 1" (4) and "Massacre 2" (5) provide appropriate rewards (2 of 5).

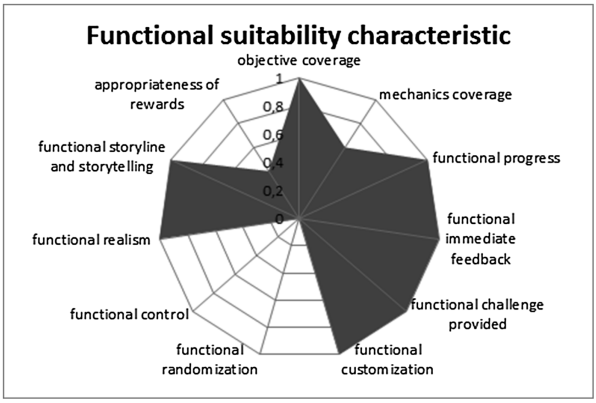

Fig. 2. Functional suitability characteristic: evaluation results.

Table 5. Example question on the survey of objective coverage function on functional completeness sub-characteristic.

Num	Question description		
1.	The Serious Game should have all the functions that are necessary to attain the objectives established in the requirements specification.		
	¿Do you understand this definition clearly? **Yes No**		
	¿How important do you consider the quality attribute that has been defined?		
	It is not important	**It is quite important**	**It is very important**
	Observations:		

5 Conclusions and Future Work

The main contribution of this paper is to present an example of the application of a product quality model specifically for SGs (QSGame-Model), which we proposed in [4]. We have in particular evaluated the Functional Suitability of an SG for learning Programming, called SG Ceebot-A [8] and we have also provided some suggestions for the improvement of the game. In addition, we have outlined the refinement and validation activities we are planning to perform in the near future. Our final goal is to obtain an SG quality model that has been agreed on by experts and which will be useful in practice, thus contributing to the building of higher quality SGs by SG developers.

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