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The restaurant and view of Skövdes´ Boulogner park in three different techniques.

1910 - Ludvig Ericson. Black-White (large format negative)

2015 – Torbjörn Svensson, Digital color photography (Nikon D700)

2014 – Max Mellhage, computer visualization of Boulogner park (Unreal Engine)
+ hand cursor by Torbjörn Svensson

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# Towards a Construction and Validation of a Serious Game Product Quality Model

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***Abstract*— A Serious Game (SG) is a game for purposes other than mere entertainment. SGs are currently in widespread use and their popularity has begun to increase steadily. The number of users of these systems is also growing day-by-day, signifying that their social impact is very high; it is precisely for this reason that SG quality evaluation is of the utmost importance. The principal objective of our long-term research, initiated one year and a half ago, is therefore to define and validate a quality model adapted specifically to SGs that has been agreed on by experts and is useful in practice, in order to allow SG designers and developers to ensure, evaluate and improve the quality of the SGs they build from the early stages of its development. The main goal of this paper is to present the construction processes of a preliminary version of the SG Quality Model (QSGame-Model) adapted from the ISO/IEC 25010 standard, which is a product quality model that can be applied to any kind of SG and will be validated in the near future.**

***Keywords— Serious Game; Quality Model; ISO/IEC 25010***

## I. INTRODUCTION

Serious Games (SGs) are games for purposes other than mere entertainment, which means that they have a serious purpose not only as regards education but also training, advertising or simulation [1]. SGs use have many benefits, some of the main ones being the following: 1) SGs allow learners to experience situations that it would otherwise be impossible to come across in real life owing to aspects related to costs, resources, time, security, etc. [1]; 2) There is evidence that SGs support the acquisition of knowledge, that they are more effective than traditional instructional methods as regards training cognitive skills, and that they are promising as regards their use in the learning of fine-grid motor skills that require excellent hand-eye coordination [2]; 3) SGs enable the employment potential of staff to be enhanced, while simultaneously improving their technical capabilities. They also make it possible to catch up with and keep abreast of technological development, in addition to fostering local development and strengthening regional cohesion [3].

SGs are a fast-emerging area of opportunity, in addition to being a rapidly-growing market [4]. In 2012, worldwide revenues for game-based learning (a type of SG) alone amounted to 1.5 billion dollars. With a global growth rate of 8 % a year, it is forecasted that by 2017 worldwide revenue will reach 2.3 billion dollars [5].

SGs are vitally important at present, as they may be a means to achieve relevant goals from both a personal and an institutional point of view. They may be used in fields as diverse as defense, education, scientific exploration, health care, emergency management, city planning, engineering, religion, and politics. What is more, the number of users of these systems is growing each day, signifying that their social impact is very high. It is for this reason that the quality of SGs is so critical; they are not just another variety of software (in which it is already assumed that quality is important), but may have a major impact on many areas of society and on a huge amount of users; it is therefore our duty as researchers and computer professionals to ensure their quality. The principal objective of our long-term research, initiated one year and a half ago, is therefore to define and validate a quality model adapted specifically to SGs that has been agreed on by experts and is useful in practice, in order to allow SG designers and developers to evaluate and improve the quality of the SGs they build. We planned to achieve this main goal by following the research plan shown in Fig. 1.

As a first Step of this research plan, we conducted a systematic mapping study (SMS) in order to discover the current state-of-the-art on research into SG Quality [6] following the guidelines proposed by [7]. An SMS is a well-known research methodology designed to provide a wide

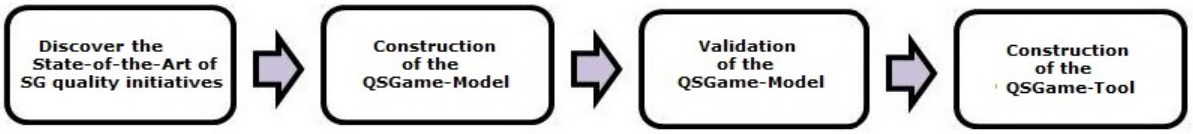


Fig. 1. Research plan

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overview of a particular research topic in a systematic and rigorous manner [7] [8] [9]. The main characteristics of the SMS performed are shown in TABLE I.

The results of this SMS indicate that researchers are principally concerned with demonstrating or confirming whether an SG has accomplished the purpose for which it was created, along with being capable of providing enjoyment and entertainment in the game. However, we were unable to find an agreed on quality model that considers all the characteristics, sub-characteristics, attributes and measures that are applicable to any kind of SG.

Based on the SMS findings, in a second Step, we proposed an SG product Quality Model (QSGame-Model) by adapting and extending the current standard on software product quality the ISO/IEC 25010 standard [10]. QSGame-Model considers attributes that can facilitate the player's flow experience and can contribute to achieving the serious purpose of the game. In addition, we believe these attributes have an influence when the game is in use, thus allowing a better player experience [11]. The QSGame-Model is a model for product quality, and we believe that it will be useful for designing SGs that satisfy desirable requirements that contribute to achieving better SG usability and playability. The QSGame-Model was built using the methodology proposed by Franch and Carvallo [12] which drives the construction of domain-specific quality models. The main goal of the third step is the empirical validation of the QSGame-Model with the objective of attaining two main goals: 1) to contrast the opinions about the model's relevance and comprehension of the model provided by experts, which will allow us to refine it and 2) to validate the usefulness of the model in practice. Finally, in the last step, once the quality model has been validated it will be automated by means of the QSGame-tool.

The main goal of the current paper is to present the construction process of a preliminary version of the QSGame-Model that will be validated in the near future.

The remainder of this document is organized as follows. Section II briefly introduces the ISO/IEC 25010 standard and presents the related work. Section III thoroughly describes the steps followed to build the QSGame-Model. An outline of the validation that we plan to perform in the near future is described in Section IV. Finally, our main conclusions and ideas for future work will be presented in Section V.

TABLE I. MAIN CHARACTERISTICS OF THE SMS ON SG QUALITY

| SMS characteristic | Description |
|---|---|
| Objective | To collect the existing literature on SG quality in a systematic and rigorous manner. |
| Inclusion criteria | • Papers that present any kind of research as regards evaluating/assessing/measuring/ testing the quality of SGs.<br>• Journals, conferences and workshop papers.<br>• Papers written in English.<br>• Papers published until April 2013 (inclusive). |
| Search sources | SCOPUS, Science@Direct, Wiley InterScience, IEEE Digital Library, ACM Digital Library, Springer |
| Number of papers analyzed | 112 |

## II. RELATED WORK

The quality model we are proposing in this work has been developed by taking the ISO/IEC 25010 [10] standard as a starting point and adapting it to the domain of SGs. This section presents an overview of the ISO/IEC 25010 [10] standard, and research works in which quality models based on the extension and adaptation of standards to specific domains have been proposed.

Software quality is defined as the "degree to which a software product satisfies stated and implied needs when used under specified conditions" [10]. Evaluating the quality of software has been tackled for several years and is done using the standards related to software quality as a basis. The reasons for using a standard are: 1) to avoid conflicts and inconsistencies as regards the vocabulary used; and 2) to start with a widely accepted set of quality characteristics that has been agreed on by consensus. The main purpose of the ISO/IEC 25010 standard is to specify and assess the quality of software products [10]. The ISO/IEC 25010 quality model is composed of the Product Quality Model and the Quality in Use Model. Both models are useful as regards evaluating the quality of a software product which is determined from two perspectives: Product Quality, by measuring internal properties (such as software specification, architectural design, among others), or by measuring external properties (typically by measuring the behavior of the code when executed); and Quality in Use by measuring quality in use properties (when the product is in real or simulated use). The Product Quality Model classifies product quality properties in eight characteristics and thirty one quality sub-characteristics (Fig. 2); while the Quality in Use Model describes five quality and nine sub-characteristics, [10]. The main idea behind this standard is the definition of a quality model and its use as a framework for software evaluation. A quality model is defined by means of the general characteristics of software, which are further refined into sub-characteristics, which are in turn decomposed into attributes, thus yielding a multilevel hierarchy. The bottom of the hierarchy contains measurable software attributes whose values are computed by using a particular measure. These measures must be thoroughly and precisely defined within the quality model. The output of a quality evaluation of a software product is therefore a set of measurement values that have to be interpreted in order to provide developers and designers with feedback regarding the quality of the software products.

The ISO/IEC 25010 quality standard is generic; the characteristics defined by it are relevant to all software products and are not exclusively related to code or executable software, but also to analysis and design artefacts. Owing to this generic nature, the standard fixes some high-level quality concepts which can be tailored to specific domains [12].

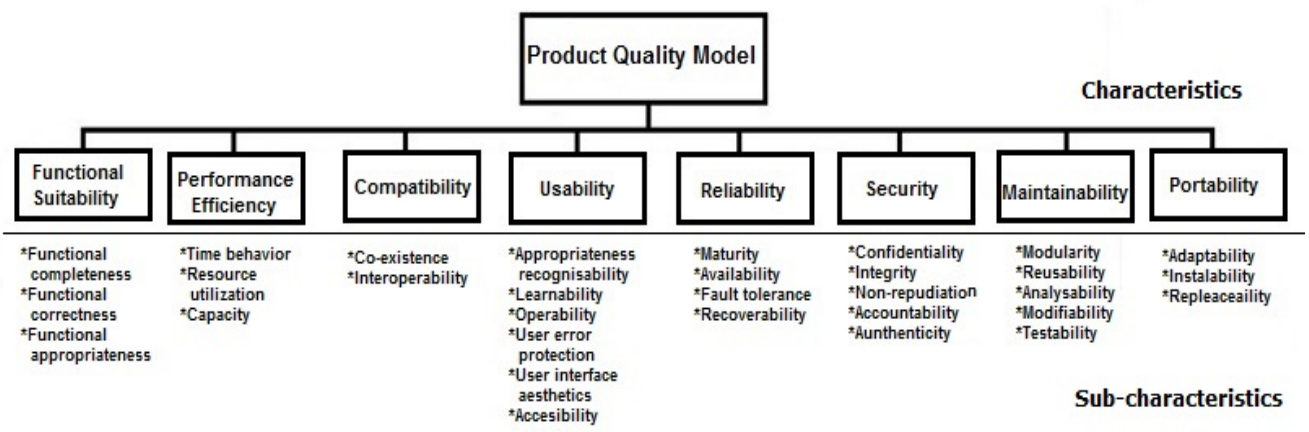


Fig. 2. Product Quality Model of ISO/IEC 25010

Several models have been developed by taking this standard as a starting point and adapting it to specific domains. Some examples are:

1. Radulovic, García-Castro, and Gómez-Pérez [13] presented a product quality model for semantic technologies called SemQuaRE. This quality model is based on the SQuaRE standard and describes a set of quality characteristics specific to semantic technologies and the quality measures that can be used for their measurement.
2. Herrera, Moraga, Caballero, and Calero [14] adapted a quality in use model to assess the level of quality in use of Web portals. The quality model used the ISO/IEC 25010 standard as a base. Some of the sub-characteristics defined in the standard were adapted to the contexts of web portals and other sub-characteristics were not included because they could be considered as not being sufficiently relevant for web portal usage.
3. González, Montero, Padilla, and Gutiérrez [15] presented a quality in use model with which to evaluate the player experience during the use of video games. This quality model is based on the ISO/IEC 9126-4 standard [16] and characterizes the player's experience through the definition of factors and measures.
4. Carvallo, Franch, and Quer [17] built a product quality model based on the ISO/IEC 9126-1 [18] quality standard and adapted it to a particular COTS domain: that of mail servers. This model can be used in two different contexts related to COTS procurement: precise formulation of quality requirements and description of COTS.

These examples have been taken into account for the construction of QSGame-Model, which is the product quality model proposed for SG Quality presented in this paper.

## III. Proposal of the QSGame-Model

We have defined a product quality model that is specific to SGs, and which is denominated as QSGame-Model. Fig. 3 shows QSGame-Model. The squares with a white background in this figure represent the characteristics or sub-characteristics, to which no changes were made, i.e., they are the same as those in the standard. Squares with a dark background represent the sub-characteristics to which modifications were made. These modifications are related to the attributes and measures that were added to QSGames-Model. Top-down approaches are frequently used to adapt quality models to a specific domain [14][15][17][19]. These approaches start from general characteristics to concrete measures. To adapt our model we consider it appropriate to use the top-down approach methodology proposed by Frach and Carvallo [12]. The methodology proposes six sequential steps but they can also be intertwined or repeated. As a preliminary Step in the methodology, the domain of interest has to be examined and described. We then followed the six Steps shown below in order to identify the quality characteristics, sub-characteristics and attributes, according to the model:

1. Determining quality sub-characteristics. This step deals with the decomposition of characteristics into the sub-characteristics that appear in the standard (add new sub-characteristics specific to the domain, refine the definition of existing ones, or even eliminate some). Taking the top of the hierarchy from the ISO/IEC 25010 standard as a starting point, we adopted the sub-characteristics and made minor modifications to them. The principal changes consisted of adapting all the definitions of the sub-characteristics to the context of SGs; in some cases, we adapted some sub-characteristics and made only minimal changes to them, such as the sub-characteristic learnability. In the ISO/IEC 25010 standard [10], learnability is defined as " the degree to which a product or system can be used by specified users to achieve specified goals of learning to use the product or system with effectiveness, efficiency, freedom from risk and satisfaction in a specified context of use", while our

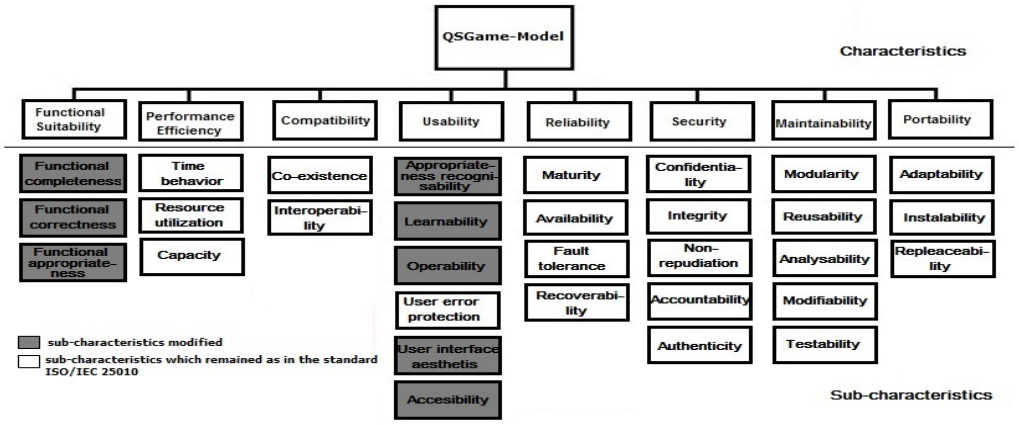


Fig. 3. QSGame-Model

definition is "the degree to which an SG and its mechanics are easy to understand and master by SG users, with effectiveness, efficiency, efficiency and satisfaction in an SG context". We redefined this sub-characteristic in order to consider the learning of the game mechanics as a part of the SG learning process.

2. Defining a hierarchy of sub-characteristics. It is possible to decompose sub-characteristics with regard to certain factors, thus yielding a hierarchy. We adopted all the sub-characteristics that are defined on the second level of the hierarchy as defined in the ISO/IEC 25010 standard.

3. Decomposing sub-characteristics into attributes. Since quality sub-characteristics provide a comprehensible abstract view of the quality model, it is necessary to decompose these abstract concepts into more concrete ones (attributes). An attribute keeps track of a particular observable feature of the software in the domain. Based on the elements of the SGs considered by researchers according to the state-of-the-art on SG quality [6], our main contribution is the addition of specific SG attributes which are not considered in the standard product quality model [10]. We believe that these added attributes could facilitate the player's flow experience [20] while simultaneously contributing to achieving the serious purpose of the game. We also believe that added product attributes, have an influence when the game is in use, thus allowing e a better player experience [11] (that is, quality in use). We considered the addition of several attributes to the Functional Suitability sub-characteristics: Functional completeness, Functional correctness and Functional appropriateness (See Fig. 4); and to the Usability sub-characteristics: Appropriateness recognizability, Learnability, Operability, User interface aesthetics, and Accessibility. We added attributes only in these two characteristics because we believe the elements that facilitate the flow experience (objectives and clear rules, feedback, balance between challenges and skills and concentration) are directly related to them. Furthermore, the results of the SMS on SG quality [6], showed that these two characteristics of the product quality model were those most frequently addressed by researchers. We did not make any significant changes to the rest of the sub-characteristics from the product quality model standard: Performance efficiency, Compatibility, Reliability, Security, Maintainability, and Portability sub-characteristics. As an example, TABLE II describes the attributes added to the Functional appropriateness sub-characteristic, which is a sub-characteristic of the Functional Suitability characteristic.

4. Decomposing derived attributes into basic ones. When an attribute cannot be directly measurable (derived attribute), it should be decomposed until it is completely expressed in terms of basic attributes. Some attributes of the QSGame-Model have been divided into basic attributes. One example of this is the attribute "likeability appearance" of the user interface, which refers to the qualities that a likeable user interface should have. These qualities are, among others, balance, symmetry, regularity, etc.

5. Stating relationships between quality characteristics, sub-characteristics and attributes. If a more exhaustive model is to be obtained, it is important to explicitly state the relationships between quality characteristics,

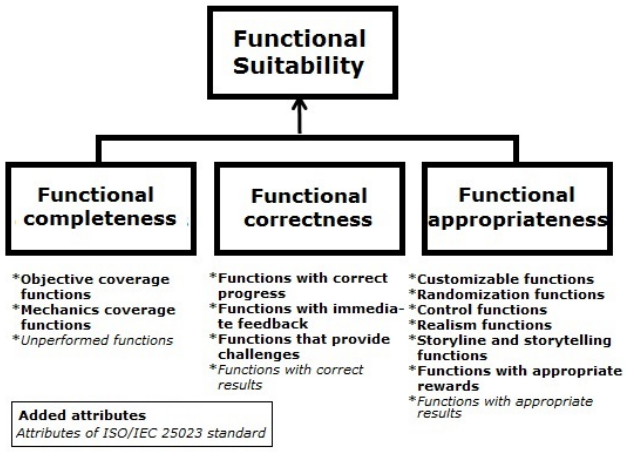


Fig. 4. Functional suitability: sub-characteristics and attributes

TABLE II. ATTRIBUTES ADDED TO FUNCTIONAL APPROPRIATENESS SUB-CHARACTERISTIC.

| **Functional appropriateness**<br>Degree to which the SG functions facilitate the accomplishment of specified SG tasks and objectives. | |
|---|---|
| **Attribute name** | **Attribute description** |
| **Customizable functions** | Functions that allow the user to establish particular preferences, e.g. identified as a character of a particular sex or given looks, etc.? |
| **Randomization functions** | Functions that have actions or tasks produced in a random order. |
| **Control functions** | Functions that allow the user to choose different controls in order to operate the game. |
| **Realism functions** | Functions that allow virtual worlds to be closer to the real world. |
| **Storyline and storytelling functions** | Functions that have tasks and activities that are relevant to the storyline and storytelling being conducted throughout the game. |
| **Functions with appropriate rewards** | Functions that offer appropriate rewards, in relation to the challenge achieved. |

sub-characteristics and attributes (which we shall refer to as quality entities). Given two quality entities A and B, the types of relationships are:

- Collaboration (+). Growing A implies growing B.
- Damage (-). Growing A implies decreasing B.
- Dependency (D). Some values of A require that B must fulfill certain conditions.

TABLE III (whose design was taken from [17]) shows an excerpt of the relationships established. Attributes in rows contribute to attributes in columns. For example, as more functions are implemented by considering *Mechanics coverage* (i.e., each objective established provides a challenge, and each challenge achieved offers a reward), there will be more functions with clear game mechanics. On the other hand, functions that allow players to set challenges (*Functions that provide challenges*), depend on whether the functions in the game have established *clear game mechanics*.

6. Determining measures for attributes.

We defined measures for each of the attributes that are directly measurable. The measurement description and the measurement function are included for each measure. TABLE IV shows only those measures that were added to the Functional appropriateness sub-characteristic for reasons of space. For each of the measures added or modified, we defined their name, a description of them, and the sources from which these measures were obtained. These sources are the primary studies of the SMS on SG quality [6] and/or [11]. For example, for the functional correctness sub-characteristic, an added measure is functional progress. This measure was added because in SGs it is important to show the player accurate results of his progress during the game. For reasons of space constraints, we cannot include the complete model in this paper, but the complete names of the measures (added or modified), the description of the measures and the sources from which they were obtained is accessible at http://alarcos.esi.uclm.es/SeriousGamesProductQualityModel/.

Most attributes of the QSGame-Model proposed can be evaluated with integer or floating values of a particular unit (for example the ratio of functions which provide a correct score to signal progress or advancement in the game); and very few of the attributes can be represented using logical single values such as yes or no (for example functional customization measure if the SG allows the user to establish particular preferences).

It is important to mention that when using a quality model it is not always necessary to evaluate all the quality characteristics of the model. What we evaluate will depend, among other things, on the type of application, the application needs that are to be covered, the quality requirements, etc. This means that we shall propose the quality models mentioned, consisting of characteristics, sub-characteristics, attributes and measures. When using them, the evaluators must determine what the most relevant quality characteristics requiring assessment are. The evaluators could use the quality

TABLE III. EXCERPT OF ATTRIBUTES RELATIONSHIPS

| **CHARACTERISTIC** | | | **Usability** | |
|---|---|---|---|---|
| **Functional Suitability** | **SUB-CHARACTERISTICS** | | **Learnability** | **Operability** |
| | | **Attributes** | Functions with clear game mechanics | Functions with real controls |
| | **Completeness** | Objective coverage functions | + | |
| | | Mechanics coverage functions | + | |
| | **Correctness** | Functions that provide challenges | D | |
| | **Appropriateness** | Realism functions | | + |

TABLE IV. MEASURES ADDED TO THE ATTRIBUTES OF THE FUNCTIONAL APPROPRIATENESS SUB-CHARACTERISTIC.

| **Functional appropriateness**<br>Degree to which the SG functions facilitate the accomplishment of specified SG tasks and objectives. | | |
|---|---|---|
| **Measure name** | **Measure description** | **Measurement function** |
| **functional customization** | Does the SG allow the user to establish particular preferences, e.g. identified as a character of a particular sex or given looks, etc.? | X = yes or not<br>If the game allows the user to establish particular preferences, X value will be "1", otherwise X value will be "0"<br>X [ 0 or 1]; 1 is better |
| **functional randomization** | What proportion of the implemented functions has actions or tasks produced in random order? | X = A / B<br>A = number of implemented functions which have actions or tasks produced in random order<br>B = number of total functions of SG<br>X [0,1]; the closer to 1 the better |
| **functional control** | Does the game functions allow the user to choose different controls for operate the game? | X = yes or no<br>If the game allows the user to choose different controls for operate the game, X value will be "1", otherwise X value will be "0"<br>X [ 0 or 1]; 1 is better |
| **functional realism** | What amount of the implemented functions allows that virtual world to be closest to the real world? | X = A / B<br>A = number of implemented functions which allows the virtual world to be closest to the real world<br>B = number of total functions of SG<br>X [0,1]; the closer to 1 the better |
| **functional storyline and storytelling** | What amount of the implemented functions has tasks and activities relevant to the storyline and storytelling being conducted throughout the game? | X = A / B<br>A = number of implemented functions which has tasks and activities relevant to the storyline and storytelling<br>B = number of total functions of SG<br>X [0,1]; the closer to 1 the better |
| **appropriateness of reward** | What proportion of the implemented functions offered appropriate rewards, in relation to the challenge achieved? | X = A / B<br>A = number of the implemented functions which offer appropriate rewards<br>B = number of total functions of SG<br>X [0,1]; the closer to 1 the better |

evaluation as a basis to provide recommendations on how to improve SG quality.

## IV. VALIDATION OF THE QSGAME-MODEL

In order to validate the quality model proposed in this research, we decided to a use a research method called "Technical Action Research (TAR)". The TAR method, proposes starting from an artifact, in our case the QSGame-Model, and then seeking ways in which to iteratively and incrementally validate the artifact in different cycles, until the artifact is used in real environments to solve real problems in industry [21].

The objective of the validation following TAR is: To obtain a specific model for SGs that has been agreed on by experts and that is simultaneously useful in practice. QSGame-Model must be useful for designers and developers from two perspectives: 1) in supporting the specification of an SG requirement, thus ensuring a higher quality SG from the early stages of its development; and 2) in evaluating the quality of an SG once it has been built, thus helping improve it if necessary.

The following subsections provide a brief introduction to the validations we plan to carry out.

### *A. Refinement of the QSGame-Model*

As mentioned previously, standard quality models such as that proposed in [10] are relevant to all software products. If the models are to be useful for specific domains they must therefore be adapted in order to address the specific characteristics of each software product. When a quality model is adapted, it will be necessary to refine the model with the objective of verifying that all the characteristics that have been included in it are valid in the specific context to which it was adapted.

In order to refine the model we planned to perform a survey carried out with a group of expert SG developers; and an example of the application of the model with a group of subjects.

#### *1) Survey with a group of expert SG developers*

We plan to carry out a survey which will be administered to a group of experts related to the SG development area. The process of applying the survey will be carried out using the principles of survey research [22]. The main objective of the survey is: to obtain feedback from SG developers regarding the understanding and the importance for them of each of the attributes of QSGame-Model. The target population of the survey will be SG and video game designers and/or developers.

We are now gathering representative contacts in order to distribute the survey.

The survey is structured in two blocks of questions:

- Background and expertise: The aim of this block of 5 closed questions is to help us contextualize the responses to the survey. The information in these questions is related to the respondent's gender and experience as a software developer in general, as a video game developer and as an SG developer.
- Assessment of the QSGame-Model attributes: This block contains 36 closed questions in which we ask the respondents how important each of the QSGame-Model attributes in the proposed model is for them; and an open question to ask about any other aspects that are important to the SG developer which have not been considered in the survey. For each closed question (36) the respondent is asked (if deemed necessary) to add a comment about the attribute defined. The response format of the closed questions has been standardized in order to reduce the time needed to fill in the survey. An excerpt of the survey is shown in Fig. 5.

The survey was designed using a cross-sectional survey design and is being applied by means of self-administered questionnaires via the Internet [22]. In Genero, Cruz-Lemus, and Piattini [21], it is mentioned that the design of cross-sectional surveys and the use of self-administered questionnaires is that which is most frequently used in the field of software engineering.

The construction process of the survey was based on similar surveys that have been used to refine quality models proposed in domains other than SG, such as those employed in [23] and [24]. Before placing the survey on-line we plan to conduct a pilot study with experts who are professors on a "Video game development course" at our Computer Science School. The main goal of this pilot study is to know the opinion of experts about the quality model and to reduce any ambiguities.

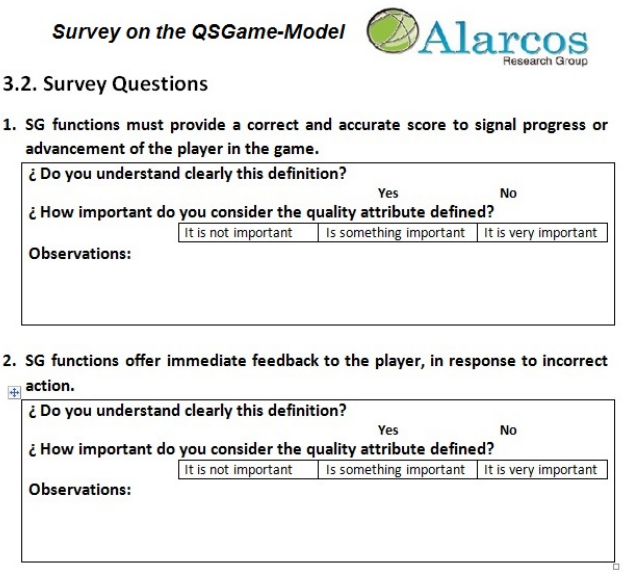


Fig. 5. Excerpt of survey on QSGame-Model

*2) An example of application of the model by a group of subjects*

Once the model has been refined on the basis of the information collected after executing the survey, we plan to provide a group of subjects with the QSGame-Model and ask them to apply it in order to evaluate the quality of an SG. This exercise will allow us to verify the accuracy of the refined QSGame-Model, i.e., whether all subjects obtain the same value for the measures and whether the subjects comprehend all the attributes and measures.

### *B. Validation of the usefulness of QSGame-Model in practice*

We plan to carry out an experiment and replications of QSGame-Model in order to gather empirical evidence about its usefulness, i.e., to assess whether the existence of a quality model permits the construction of better quality SGs. This will be done by following the guidelines provided in [25]. The main characteristics of the experiment are:

1. To ask the (carefully selected) group of subjects to develop the same SG after being provided with the requirements specification of the game.
2. The subjects will be divided into two groups; Group1 will have to develop the SG by using the quality model, while Group 2 will not have the quality model.
3. Finally the experimenters will evaluate the quality of the SG developed using the QSGame-Model defined, and statistically test whether the existence or otherwise of the quality model really allows better quality SGs to be built.

## V. Conclusions and Future Work

The results of SMS on SG quality carried out previously [6] revealed that there is no general quality model that can be applied to any kind of SG. This motivated us to focus our long-term research on the construction and validation of a product quality model that is specific to SGs.

The main contributions of this paper are:

- The QSGame-Model, which is a preliminary proposal for a product quality model for SGs, adapted from the ISO/IEC 25010 standard [10] which defines all the characteristics, sub-characteristics, attributes and measures related to SG quality. The QSGame-Model was built using the top-down methodology proposed by Franch and Carvallo [12], which has been used to build quality models that are applicable in others domains such as those of [17] and [19], among others. Based on the findings obtained by means of an SMS [6], this model considers attributes that can facilitate the player's flow experience and can contribute to achieving the serious goal of the game. In addition, we believe these attributes have an influence when the game is in use, thus permitting a better player experience [11] (that is, quality in use).

We are aware that QSGame-Model contains attributes that will not be relevant for every game, and the selection of the most appropriate along with how to score them is pending as future work.

- An outline of how we plan to validate the model in the near future, through a combination of the TAR method and experiments, with the goal of obtaining an agreed product quality Model for SGs that will be useful as regards allowing SG developers to ensure, evaluate and improve the quality of the SGs they build from the early stages of the development.

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