Evaluating the Usability of Interactive Digital Television Applications

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***Abstract*—Applications for Interactive Digital Television (IDTV) are becoming increasingly popular. Users no longer interact only with software applications on computers or smartphones, but also through a television set. Therefore, developers must address efficiency and effectiveness aspects when creating those applications to provide the user with a satisfying interaction experience. Thus, this paper proposes an Application Usability Model for IDTV based on two approaches: the quality of the software product and the quality in the use of the software product. Additionally, the model mainly draws upon the ISO/IEC 25010 standard in which a set of usability characteristics are defined. These characteristics have been divided into subcharacteristics of the IDTV to quantify each of their attributes according to several metrics, and with the obtained values, identify the usability problems that might exist in software applications. For instance, to have a better idea of how the evaluation should be performed, two examples are presented that employ the proposed usability model on applications designed for IDTV from different domains.**

Keywords—Evaluation, Usability, Interactive Digital Television, Feature, Metric.

I. INTRODUCTION

Television is seen as a means to communicate, inform, entertain, and educate [1]. This device can be found in most homes around the world, implying interactions with all kinds of users [2]. The transition from analog television to digital television (DTV) has been made in many countries because, unlike analog TV, DTV increases the number of channels available, improves the quality of audio and video, and allows the incorporation of interactive applications [1]–[4]

Hence, interactive digital television (IDTV) enables a dialogue between the user and the device—i.e., it is the active participation of the user with the content broadcast [2]. Thus, a stream of multimedia content could be established to grow as the interaction between viewers and television applications occurs [2],[5]. Also, IDTV allows interaction with different platforms such as communication systems, mobile devices, among others, which makes it more accessible [1].

On the one hand, an IDTV application provides three types of services: i) information services that are related to the broadcasted programs, ii) broadcast programming services, and iii) transactional services that involve sending and receiving information [6]. These services require high-quality interactions between the IDTV applications and the user to meet the requirements and needs of the latter.

On the other hand, the employment of usability criteria for developing interactive applications is required to improve the user experience [4]. Currently, there are few tools that provide support for usability assessment; however, the objective is not only to identify the existent usability problems but also to search for ways to prevent and solve those problems, especially during user tests [7]. Thus, during the development of interactive applications, it is essential to use diverse models, techniques, and principles focused on users of IDTV [8]. Some aspects must be considered here, in particular, the available devices that the viewer has to interact with the applications (e.g., remote control, second-screen devices). Likewise, it is important to acknowledge users with limited or no experience in the handling of new technologies. Those users might perceive them as difficult to use and assume that the operation of an IDTV application is different from that of a computer or mobile device application [8].

Henceforth, it becomes crucial to create a model that allows software developers to evaluate the usability of their IDTV applications to ensure that users get the best interaction experience in terms of satisfaction, efficiency, and effectiveness. As a response to the identified need, this work proposes a usability model based on the ISO/IEC 25010 standard [9].

The proposed model considers two approaches: i) *the model of product quality*, which refers to the "ability of software to be understood, learned, used, and attractive to the user, under specific conditions of use" [10] and ii) *the model of quality in the use of the product* that refers to the "effectiveness, efficiency, and satisfaction with which a product allows specific objectives to be reached by specific users in a context of specific use" [11].

Besides, this model considers and defines a set of characteristics, subcharacteristics, attributes, and metrics that support the generation of measurable values. Those values provide insights to address the quality quantitatively and to identify existent problems, always regarding usability, of the different applications and their components. Consequently, this model can guide the development process, so it concentrates on providing meaningful and relevant experiences to users and improving those that have already been implemented.

Finally, this article has the following structure: Section 2 presents related work regarding usability evaluation methods for IDTV applications. Section 3 describes the proposed usability model and each of its parameters. Section 4 details application examples of the usability evaluation model.

Finally, Section 5 draws some conclusions and discusses future work.

II. Related Work

There have been several studies over the years [12]–[15] that apply various techniques for evaluating usability. A description of the existent work is presented below.

On the one hand, [12] introduces a proposal based on a previous Usability Evaluation Method (UEM) that integrates collaborative processes, which according to the authors, allow obtaining results richer in content than traditional UEMs. They propose three different evaluation variations, which depend on two factors: the objectives of the evaluation and the desired results. The variations are: i) global evaluation that analyzes an IDTV application in a whole way using heuristic evaluations, constructive interactions, and interrogation methods; ii) specific evaluation where specific functionalities of the IDTV application are analyzed through heuristic evaluations, formal experiments, and interrogation methods; and iii) complete evaluation which involves a more in-depth analysis than the previous ones, making use of each of their techniques.

On the other hand, [13] proposes an evaluation of IDTV applications based on specific tasks that are broken down into generic tasks that must be executed by a user. The objective is to measure the effectiveness, efficiency, and Satisfaction of the level of usability of an application in relation to the definition of specific tasks. Usability testing can be done on menu layouts, multiple video screens, content display areas, pagination, and scrolling, among others.

Additionally, in [14] the authors seek to examine universal access to IDTV applications by evaluating how accessible, usable, and compelling IDTV application user interfaces are within the television experience. They use a collection of constructs and quantitative measurement instruments obtained by combining research on affective Human-Computer Interaction (HCI) and media studies, considering: unique characteristics of the television environment, the television audience, and the context of use. However, this evaluation focuses on the user interfaces obtaining general quantitative results of effectiveness and the affective capacity of the interface.

Furthermore, to evaluate the usability of IDTV applications, [15] presents a set of heuristics divided into three groups: design and aesthetics, flexibility and navigation, and errors. To analyze each heuristic, it is necessary to fill out a template specifying information related to the heuristic, such as identification, name and definition, examples, benefits, and problems. The evaluators assess the interface through the proposed heuristics; for this, it is necessary to establish usability problems, assign points to each problem according to its severity from 0 (less frequent) to 4 (more recurrent), add the results, and classify the problems according to their criticality.

The proposals mentioned above are different from the one presented in this work because they do not require the active collaboration of the user through experiments and methods of interrogation or they concentrate on general aspects of the interfaces.

Contrarily, the model presented in this work obtains quantitative results of specific characteristics and attributes of both the quality of and the quality in the use of IDTV applications. Those parameters are based on the ISO/IEC 25010 standard, which has not been used before and provides a clear picture of what will be evaluated. The evaluation helps to determine whether an application is usable or not. Moreover, both the developers and the users themselves can perform the evaluation.

III. Usability Model for IDTV Applications

In this section, the usability model for IDTV applications is presented along with a brief description of the subcharacteristics, attributes, and metrics. For reasons of space, only the most relevant attributes of each sub-characteristic are described. The complete model is available at https://afly.co/sgl3

This model is an adaptation of the model presented in [16]; the model covers usability concepts, attributes, and metrics applied to the field of Mashups. Besides, it contains six subcharacteristics of the ISO/IEC 25010 standard. The definitions have been modified to apply them to the field of Digital Television.

Regarding the quality of the product, each of the subcharacteristics come from five of the six recommended features for usability in the ISO/IEC 25010 standard [9]: *intelligibility*, *learning*, *operability*, *error handling*, and *aesthetics*. The remaining feature is *accessibility*, and it was not considered because it focuses on the ability of users with certain limitations to perform IDTV application tasks [9]. Conversely, the proposed method focuses on the typical user—i.e., a user who does not have either motor or cognitive impairments and who does not have difficulties in using technology.

About the quality in the use of the product, it is necessary to add a *satisfaction* characteristic. It evaluates the quality according to the level at which the application complies with the user's expectations. Thus, the final six characteristics and their subcharacteristics are depicted in Figure 1.

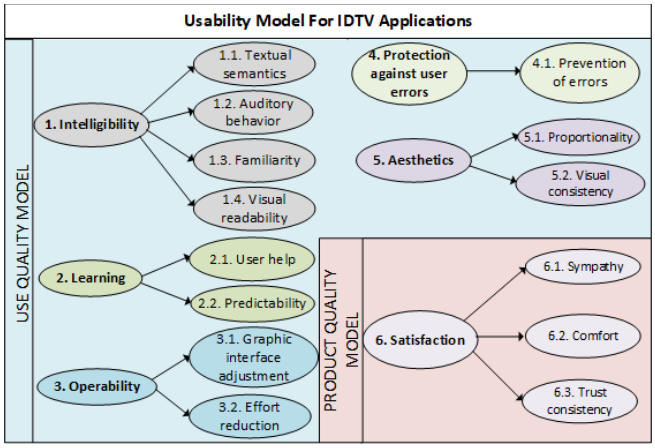

Figure 1. Characteristics and subcharacteristics of the model for evaluating the usability of IDTV applications

A. Intelligibility

Intelligibility allows the user to understand if the application is adequate to meet their needs [9]. Its subcharacteristics and some attributes are detailed below and listed in TABLE I.

i) *Textual semantics* represents the level of understanding of the displayed text.

ii) *Auditory behavior* is the presentation of images synchronized with sound.

iii) *Familiarity* is the interaction of the user with the graphic interface and its elements. It contains the following attributes: internationalization and component popularity.

iv) *Visual readability* refers to the visual aspects that make an application suitable for the user. It contains the following attributes: density of the displayed information, the layout of components on the screen, and the size of the components.

- The *layout of components on the screen* attribute reflects the viewer's satisfaction concerning the location of the components on the screen.
- The *size of the components* attribute refers to the fact that the displayed objects do not cause an overloaded presentation that hinders visual understanding. The associated metric refers to the ratio of the number of components with the appropriate size among the total number of components.

TABLE I. SUBCHARACTERISTICS AND ATTRIBUTES OF INTELLIGIBILITY

Subcharacteristics	Attribute	Meaning
1.1 Textual semantics	1.1.1 Understanding textual information	Is the textual information presented coherently and is it easy to find in the message that is desired to transmit?
1.2 Auditory behavior	1.2.1 Sound and images synchronization	Are the audio and video images synchronized (no lag)?
1.3 Familiarity	1.3.1 Internationalization	Are the available actions to navigate the application similar to the ones commonly used?
	1.3.2 Component Popularity	Are the components presented easily recognized because they have been accepted and commonly used?
1.4 Visual readability	1.4.1 Density of the displayed information	Is the amount of information presented on the screen adequate?
	1.4.2 Layout of components on the screen	Are the components easy to find and recognize?
	1.4.3 Size of the components	Is the size of the components suitable for a viewing?

B. Learning

This characteristic allows the user to easily learn the content of the application [9]. It has two subcharacteristics, which are shown in TABLE II and described below.

i) *User Help* represents the ability of the application to provide help to the user.

- The *help on how to use the buttons* attribute refers to the information of the functionalities associated with each button so that users always have in mind what they can do. The associated metric corresponds to the ratio of the number of buttons that have a description of the activities they perform among the total number of buttons available in the application.
- The attribute *expressiveness of the labels associated with the media* refers to a label that defines the functionality of the associated medium to allow consistent navigation and rapid learning by the user [17]. The associated metric consists of the relationship between the number of descriptive labels associated with the media and the total number of labels associated with the media.

ii) *Predictability* represents the expression level of the graphical interface to define the actions of each component.

- The attribute *predictability of component actions* refers to the ease of determining what action is executed if a component shown on the TV screen is used. Its metric is associated with the relationship between the number of components with foreseeable actions and the total number of components.

TABLE II. SUBCHARACTERISTICS AND ATTRIBUTES OF LEARNING

Subcharacteristics	Attribute	Meaning
2.1 User help	2.1.1 Help on how to use the buttons	Is there information provided to the users about the actions to be executed when using a button? (Red, yellow, green button)
	2.1.2 Information on activities to be performed	Is there information provided about the activities necessary to perform a task?
	2.2.1 Expressiveness of the labels associated with the media	Is it easy to foresee that a concept is associated with a label of an element of the interface?
2.2 Predictability	2.2.2 Predictability of component actions	Is it easy to predict the action a component performs?
	2.2.3 Determination of possible permitted actions	Is it easy to determine the actions allowed by the application?

C. Operability

It refers to how easy it is for the user to operate, manage, and control the application [9]. TABLE III presents the subcharacteristics and attributes related to this characteristic, and their descriptions are also detailed as follows.

TABLE III. SUBCHARACTERISTICS AND ATTRIBUTES OF OPERABILITY

Subcharacteristics	Attribute	Meaning
3.1 Graphic interface adjustment	3.1.1 Auto-adjustment of the interface to various screens	Can the graphic interface be auto-adjusted to screens of different sizes without damaging the visualization of its components?
3.2 Effort reduction	3.2.1 Minimum actions	Are there mechanisms that allow carrying out a task where the user performs few actions?

i) *Graphic interface adjustment* is an automatic interface adjustment to any screen size or device.

ii) *Effort reduction* checks that the effort made by the user to complete a task is the minimum possible.

- The *minimum actions* attribute is referred to as everything that facilitates the use of the application, allowing to quickly execute specific

actions—i.e., managing shortcuts, so the user operates the application more efficiently [17]. The associated metric refers to the relationship between the number of actions required to complete a task using shortcuts with the number of actions without shortcuts.

D. Protection against user errors

This characteristic refers to the ability of the product to prevent users from making mistakes [17]. TABLE IV (a) shows the subcharacteristics and attributes related to it.

The subcharacteristic *prevention of errors* has the *restriction of non-necessary functions of the remote-control* attribute. It is necessary to bear in mind that having a small and limited number of functionalities available to interact with the application improves usability because the user does not have to remember the operation of each button of the remote control.

TABLE IV. SUBCHARACTERISTICS AND ATTRIBUTES OF PROTECTION AGAINST USER ERRORS AND AESTHETICS

Subcharacteristics	Attribute	Meaning
(a) Protection against user errors		
4.1 Prevention of errors	4.1.1 Validation of data entry	How much data entered into the application has any errors?
	4.1.2 Restriction of non-necessary functions of the remote control	Is there a small and limited number of functionalities available to interact with the application?
(b) Aesthetics		
5.1 Proportionality	5.1.1 Ratio of size between elements and screen size	Is the area occupied by a component correctly related to the total area of the application on the screen?
5.2 Visual consistency	5.2.1 Coherence in the grouping of components	Are the components grouped according to the purpose they must fulfill?
	5.2.2 Uniformity of colors	Are the background colors used consistently in all sections of the application?
	5.2.3 Contrast colors	Is the level of brightness and colors of the components ad-equate?

E. Aesthetics

The aesthetics characteristic refers to the ability of the user interface to please and satisfy the viewer—i.e., the user's perception of the application interface [9]. TABLE IV (b) details the sub characteristics and attributes related to it, and a brief description of some of them is presented below.

i) *Proportionality* represents the proper fit and size of items with screen size.

ii) *Visual consistency* refers to the consistent classification and grouping of visual components, colors, and contrast.

- The attribute *coherence in the grouping of components* refers to the fact that the components must be grouped in contiguous zones of the screen according to the actions they execute (for example, those components with similar activities or those whose execution precedes the execution of another component). The associated metric corresponds to the relationship between the number of coherently grouped components and the total number of components.

All metrics for these five characteristics are calculated by using a Likert scale with a range of 0 to 1 to indicate the level of compliance. A value of 0 represents a more significant usability problem, while a value of 1 indicates there is no problem.

F. Satisfaction

As mentioned before, this characteristic is also necessary to establish a quality model to evaluate the quality in the use of the applications for IDTV, considering the devices through which the user can interact with said applications. It measures the degree to which users feel satisfied with the experience of interacting with the application in a context of specific use [9]. TABLE V presents subcharacteristics and attributes of this characteristic.

TABLE V. SUBCHARACTERISTICS AND ATTRIBUTES OF SATISFACTION

Subcharacteristics	Attribute	Meaning
6.1 Sympathy	6.1.1 Compliance on the behavior of the application	Does the user feel comfortable with the tasks that are allowed to perform in the IDTV application?
6.2 Comfort	6.2.1 Navigability between available functions	What is the level of compliance achieved when using the available navigation method to move from one functionality to another?
	6.2.2 Text input modes	How much time does it take for a user to enter text into the application?
6.3 Trust consistency	6.3.1 Consistency of the result	Are the results presented adequately?
	6.3.2 Results waiting time	How long must a user wait for the results to be presented after having executed an action?

i) *Sympathy* represents the level of *compliance on the behavior of the application*, measured with the Likert scale with values of 0, which means nothing, and 5, which means that it is wholly expected.

ii) *Comfort* has two attributes that are: *the navigability between available functions*, it is the comfort level in the navigation of the application, and the *text input modes* (text input through a keyboard, mobile device, remote control), which is the average time taken by the user to enter text.

iii) The subcharacteristic *trust consistency* refers to the level of presentation of results; it has two attributes that are: *consistency of the result*, and *results waiting time*.

- The *consistency of the result* attribute represents the level of consistency. The associated metric is a Likert scale from 0 to 5, where 0 means no consistent and 5 means completely consistent.
- The *results waiting time* attribute refers to the waiting time between the execution of an action and the presentation of results. The associated metric states that it will have a value of 0 if the response time is greater than or equal to 10 seconds, it is 0.2 if the response time is between 5 and 10 seconds, 0.4 if it is between 2 and 5, it will be 0.8 if the response time is between 0 and 1, and lastly, it will be 1 if it is less than or equal to 0.

IV. Application of the Usability Model

Two IDTV applications have been randomly selected, by two of the authors who are experienced software developers, for testing. They applied the proposed usability model to validate and ensure the feasibility of this study. The first application, called *El Clima*, shows the current state of the weather for a city or place selected by the user. The second application, called *QuizTV* [18], is a platform that allows users to log in using a username and password. This game consists of answering several questions on different topics (games, series, among others); it stores the score obtained in each category. For the implementation and execution of these applications, a virtual Set-Top-Box was used, which comes pre-installed with the Ginga environment and can be run as a virtual machine according to the recommendations given in [18].

To evaluate these IDTV applications, the following steps have been applied:

i) *To select* subcharacteristics, attributes, and metrics of interest from the IDTV application usability evaluation model.

ii) *To apply* the metrics in the IDTV applications to obtain the values that quantify the selected attributes and subcharacteristics.

iii) *To establish* the threshold values for the metrics. These threshold values represent the degree of usability of the application; they will allow the developer to detect problems that may exist and to classify them according to their level of criticality. Additionally, a weight must be assigned to each problem level to rank its impact on the evaluation. TABLE VI presents the classification of the problems given the threshold intervals defined for this evaluation. It is important to emphasize that the levels and weights can change according to the selected attributes, the defined threshold values, and the use case. So, it is recommended to check the complete model introduced in Section III of this work.

TABLE VI. Threshold Values and Weights of Problem Levels

Problem Level	Threshold Intervals	Weight
Major	0 - 0.39	1
Medium	0.4 - 0.69	0.6
Minor	0.7 – 0.94	0.3
Non-existent	0.95- 1	0

iv) *To prepare* a report containing a summary of the measurements, the descriptions of all the detected usability problems, and the suggestions to solve these problems.

v) To *calculate* the usability error indicator (I_U), which measures the percentage of usability problems found in the application. The lower the value, the fewer usability problems the application has.

$$I_U = \frac{\sum_i (P_i \times w_i)}{N} x100\% \qquad (1)$$

In (1), *i* represents the level of the usability problem, *Pi* is the number of attributes with usability problems of level *i*, *w* is the weight assigned to each problem level, and *N* is the total number of attributes applied to evaluate the application.

Ought to space constraints, only four attributes will be applied to evaluate the usability of these two applications. The evaluation of each application is presented below.

A. Evaluation of the weather application

The usability evaluation of the application for weather visualization is performed using four attributes with their respective metrics. The objective is to generate a brief usability report. The selected subcharacteristics and attributes are the size of the components (1.4.3), help on how to use the buttons (2.1.1), navigability between available functions (6.2.1), and results waiting time (6.3.2).

Figure 2. Layout of the El Clima application for IDTV

Size of the components: Figure 2 shows the main interface of the application, it has 20 graphic components, ten components have an average size in relation to the size of the area that the entire screen occupies, two components occupy approximately half of the screen, and eight components are minimal. Then, the value obtained for this attribute in (2) represents a medium usability problem based on Table VI.

$$SOC = \frac{10}{20} = 0.5 \qquad (2)$$

Help on how to use the buttons: The result obtained in (3) means that the application has a major usability problem because out of the eight buttons available in the application, only two are associated with a description of the actions performed.

$$HBU = \frac{2}{8} = 0.25 \qquad (3)$$

Navigability between available functions: this metric is calculated by using a Likert scale with a range of 0 to 1 to indicate the level of conformity with the available navigation method, where 0 is the lowest level and 1 the highest. For the weather application, the assigned value is 0.8, which represents a minor usability problem (see TABLE VI).

Results waiting time: it is perceived that when applying for the weather of a city, the application takes 3 seconds to display the result, for which a value of 0.4 is assigned as explained in Section III subsection F. This value represents a medium accessibility problem.

TABLE VII shows a summary of the usability report containing information on the attributes and metrics evaluated as well as the results.

TABLE VII. SUMMARY OF USABILITY REPORT FOR THE EL CLIMA APPLICATION

Attribute	Metric Value	Problem Level
Size of the components	0.5	Medium
Help on buttons use	0.25	Major
Navigability between available functions	0.8	Minor
Results waiting time	0.4	Medium

Finally, the usability error indicator is calculated as defined in (1).

$$I_U = \frac{(1\times1)+(2\times0.6)+(1\times0.3)}{4} x100\% = 62.5\% \qquad (4)$$

Equation (4) indicates that although some usability considerations have been taken into account (e.g., the application is perceived as easy to navigate), other crucial usability aspects may not have been considered during the design and development of the application.

B. *Evaluation of the QuizTV application*

In the evaluation of this application, four attributes have been selected: sound and image synchronization (1.2.1), uniformity of colors (5.2.2), consistency of the result (6.3.1), and results waiting time (6.3.2). In the end, a usability report similar to the previous case is shown.

Sound and image synchronization: the synchronization level perceived by the user metric is applied. Here the scale of Likert was used, where 0 means that there is an incorrect synchronization, and 1 means that there is a good synchronization of the sound. The assigned value is 0 because this application does not have any type of sound. It represents a major problem because it is not possible to measure the sound synchronization when presenting images or pressing an option.

U*niformity of colors*: the ratio of the number of screens with similar colors divided by the total number of screens metric is employed. As shown in Figure 3, this application contains 6 screens in a total of which 5 screens contain similar colors. Therefore, the value obtained in (5) represents a minor usability problem, according to Table VI.

$$UC = \frac{5}{6} = 0.83 \qquad (5)$$

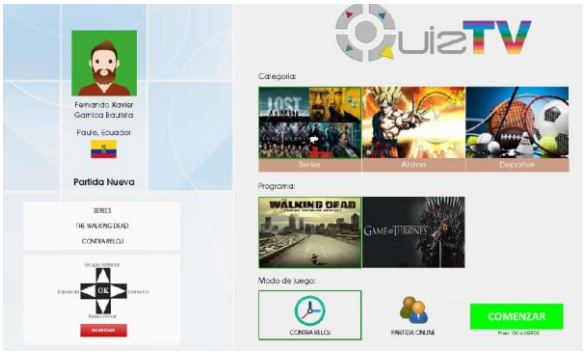

Figure 3. IDTV application called QuizTV. Fuente: [18]

Consistency of the result: during the evaluation, the results were presented consistently while answering the trivia questions; therefore, a value of 5 was assigned on the Likert scale (refer to Section III subsection F). Now, this value has been converted to 1 according to the threshold values provided in Table VI, which means that there is no usability problem in this attribute.

Results waiting time: as in the previous example, the response time is calculated. It is perceived that when the trivia is finished, the application takes 0.5 seconds to provide the results, for which a value of 0.8 is assigned as explained in Section III subsection F. This value represents a minor accessibility problem.

As in the previous evaluation, TABLE VIII shows the report of results obtained in the evaluation of the QuizTV application.

TABLE VIII. SUMMARY OF USABILITY REPORT FOR THE QUIZTV APPLICATION

Attribute	Metric Value	Problem Level
Sound and image synchronization	1	Major
Uniformity of colors	0.83	Minor
Consistency of the result	1	Non-existent
Results waiting time	0.8	Minor

Using the results of Table VIII, the usability error indicator is calculated:

$$I_U = \frac{(1\times1)+(2\times0.3)+(1\times0)}{4} x100\% = 40\% \qquad (6)$$

Equation (6) shows a reasonable percentage of problems, meaning that the application makes use of adequate colors between screens, presents reliable results, and responds in a timely manner to the viewer's requests. However, a weakness of this application is that it does not include sounds of any kind, although the use of sounds is recommended to improve the user experience.

V. CONCLUSIONS AND FUTURE WORK

This paper has presented a model for evaluating the usability of IDTV applications. It can be used for software developers or testers to assess quantitatively the usability of any applications that are deployed for IDTV. The model in question breaks down the usability characteristics proposed in the ISO/IEC 25010 standard into subcharacteristics and, at the same time, said subcharacteristics into attributes. It has also been defined as a set of metrics associated with each attribute to quantify them and therefore be able to identify usability problems, whether these are major, medium, minor, or non-existent. The model is complemented with the satisfaction characteristic, which is presented in the quality of use, which also considers the means of interaction with the application.

All the characteristics, subcharacteristics, attributes, and metrics suggested in the Application Usability Model for IDTV refer to essential elements that must be considered in applications of this field to achieve both adequate product usability and good quality in use. Finally, this model has been applied to evaluate two applications, obtaining a report in which some improvements are recommended to facilitate the interaction of the viewer with the application.

As future work, it has been considered the design and development of a method of evaluation of the usability of applications for IDTV in which the process necessary to carry out this evolution is detailed and, at the same time, give guidelines of how the evaluators should apply the Application Usability Model for IDTV, both from the perspective of the developer or of the buyer.

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