

SimpleAR: Augmented Reality high-level content design framework using visual programming

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Abstract—This research work proposes a new augmented reality high-level content design framework, this is, a tool to create augmented reality applications aimed at staff with basic or no programming knowledge. The proposed framework summarizes the experience gathered from a systematic mapping study carried out on similar frameworks. Our proposal has a flexible approach regarding its ability to be adapted to any augmented reality programming framework. We demonstrate its viability with an implementation of our framework with Vuforia for the creation of marker-based augmented reality applications. The results of usability tests based on ISO 9241-11 show that our proposal is effective because all users were able to complete all tasks, it is efficient because users were able to create augmented reality applications in less than 5 minutes and it satisfies the user by qualifying as “Highly acceptable” according to the average score of the System Usability Scale questionnaire.

Index Terms—augmented reality, usability, authoring tool

I. INTRODUCTION

Augmented reality authoring tools have made it possible the growth of use and development of augmented reality (AR) in several areas (education, maintenance/assembly, video-games, etc.). According to their level of abstraction of the authoring tools, [1] has classified these in programming frameworks and content-design frameworks. Using an AR programming framework requires advanced programming knowledge, as an example, we have Vuforia, ARCore, ARToolkit and Wikitude SDK. On the other hand, AR content design frameworks do not require any special skills beyond basic computer skills and can be classified as low or high level (HCDF). A HCDF usually includes a visual editor which makes easier to create AR applications.

Current HCDFs are made over a single AR programming framework, which can only be expanded by the HCDF developers as described in section II. Our proposed HCDF allows being expanded following the same AR concepts proposed in section IV. This would, in turn, make easier for end-users to be adapted to the creation of different types of AR applications (using natural markers, fiducial markers, surface-based, etc.).

This research proposes a new web-based HCDF for AR mobile applications, which is flexible and usable. We consider that it is flexible because it can be adapted to any AR programming framework by encapsulating basic functions such as obtaining 3D models or by triggering actions through events, and we

consider that it is usable because end users are able to easily build AR mobile applications.

The rest of the paper is organized as follows: section II gives an overview of related works, section III and section IV describe in detail the initial considerations and the architecture of the proposed framework, section V shows the features of the implementation made with Vuforia, section VI describes the methodology to perform the usability evaluation, section VII gives the results obtained following the methodology of the previous section and finally the section VIII concludes the investigation and proposes future work.

II. RELATED WORK

Several HCDFs have been proposed for the easy creation of AR applications. Most of them are oriented to a specific domain such as education [2]–[5] and maintenance [6]–[9]. They are implemented over AR programming frameworks such as Vuforia and ARToolkit and they use a user interface not based on visual programming. Meanwhile, visual programming is being widely used in other areas such as the creation of video-games or computer programming teaching. For example, [10] allows children to create AR applications on the Scratch platform and demonstrates that users without AR skills or experience (children between 8 to 12 years old) can create complex AR applications such as games that involve physical interactions.

Our work major contributions are focused on:

- Demonstrating the viability of the visual programming approach applied in the creation of AR applications.
- Proposing a HCDF adaptable to any AR framework, this is, it can use any AR tracking method such as fiducial markers, natural markers, by location, by surface detection, etc.
- Demonstrating the application of the standard ISO 9241-11 [11] in the usability assessment.

III. PRELIMINARY CONSIDERATIONS

We must consider the following conditions before developing the HCDF

A. Features of our HCDF proposal

The basic features of our HCDF are justified and listed below:

- 1) Programming framework: Our HCDF can abstract any programming framework through a standard interface. This work has been implemented with Vuforia, but it can be extended to any other AR programming framework.
- 2) AR tracking method: It depends on the AR programming framework. Since we are using Vuforia, our work can support tracking natural markers.
- 3) Interface projection platform and development platform: The development platform is the web and the interface projection platform is a mobile device.
- 4) User interface: Our HCDF has a 2D user interface.
- 5) General dataflow model: According to the classification of [12], our HCDF is classified as Model 2: Stand-Alone + PI. This model was chosen because it is the most used and it is portable to any device.
- 6) Field of application: Our HCDF targets users with basic computer skills. By using our HCDF they can develop an AR application in any domain, so the field of application is generic.

B. Target user

Taking into account the three main dimensions of [13] on which users' experience differs, we defined our target user in the following range of skills:

- 1) Experience with the system:
 - a) The user has never used a similar HCDF
 - b) The user has never used our HCDF
- 2) Experience with computers in general
 - a) The user has basic IT skills
 - b) The user has basic programming knowledge
- 3) Experience with the domain:
 - a) The user is not familiar with the AUGMENTED REALITY concept
 - b) The user is familiar with the NATURAL MARKER concept, understands what AUGMENTED REALITY means, and knows how to create and edit 3D models

IV. SYSTEM OVERVIEW

Our proposed HCDF, which is known as **SimpleAR**, raises the following new concepts for the creation of AR applications:

- Resource: A resource is a representation of each item that can be used in the AR application and it is used to create the components. Examples of resources are natural markers, fiducial markers, 3D objects, images, videos, audios, etc.
- Component: A component represents entities that use AR tracking methods and their input data are resources. Examples of components are “Augment a resource on a marker”, “Augment a resource on a surface”, etc.
- Component configuration: Each component can be customized with events and actions.

According to Figure 1, SimpleAR is composed of two sub-applications: SimpleAR Editor, to edit applications through a

web browser and SimpleAR Viewer, to view the application created on an Android mobile device. Both communicate through the Firebase real-time database, the editor writes data and the viewer is responsible for reading the project information. Both extract information of the 3D models from Google Poly, the editor only gets an image of the 3D model preview and the viewer downloads the entire 3D model. The source code of SimpleAR is freely available in two repositories on GitHub [14], [15].

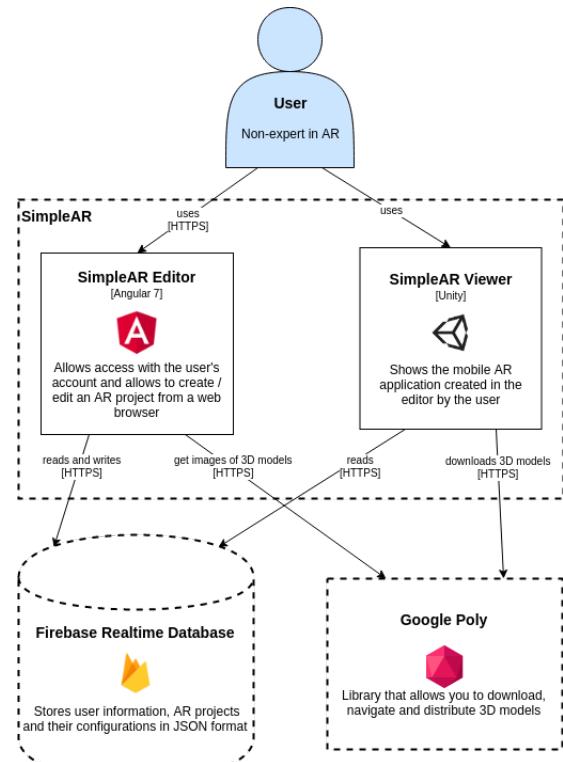


Fig. 1. System overview

A. SimpleAR Editor

SimpleAR Editor is a web application made with Angular 7 and Google Blockly (visual programming editor with blocks), we made this editor extensible to use other AR programming frameworks in addition to Vuforia.

Figure 2 shows the arrangement in 3 columns for the creations of resources, components, and their configuration. The editor is responsible for loading the resources or components required according to the selected AR programming framework, for example, if a framework such as ARCore were implemented, the marker resource is not necessary, since ARCore creates AR applications by detecting surfaces.

In this work, we implemented the resources “Marker” and “3D Model”, and the component “Augment marker”. We configured it in a way that Vuforia is enabled to use the resources and components mentioned.

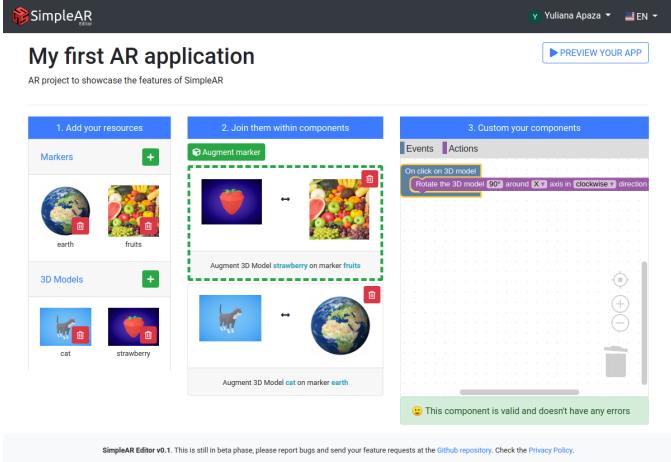


Fig. 2. User interface of SimpleAR Editor for Vuforia

B. SimpleAR Viewer

SimpleAR Viewer is a mobile application for Android made with Unity and Vuforia, it also uses the Firebase and Google Poly SDKs to make calls to their respective APIs and the ZXing library to read QR code.

There is a general interface called FrameworkController which defines all events, actions, resources, and components, and also takes care of pre-loading 3D models and markers. VuforiaController implements only those parts that this AR framework supports such as the “Augment marker” component. This general interface can be extended and we can create another implementation for another AR programming framework which would handle only the components, resources and settings that can support. Figure 3 shows the AR application created by the user after scanning the QR code corresponding to their project.



Fig. 3. User interface of SimpleAR Viewer

V. FEATURES

SimpleAR has the following features:

A. Resource creation

Figure 4 shows the creation of a marker (earth) and a 3D model (cat), each resource needs a name so that it is easy for the user to remember.

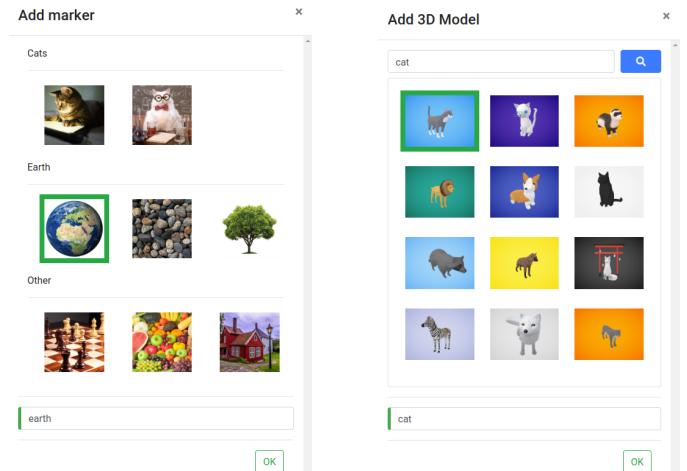


Fig. 4. User interface to create resources of type (a) Marker and (b) 3D model

B. Component creation

Figure 5 shows the creation of a component of type “Augment marker” which will augment the previously created 3D model over the selected marker of Figure 4.

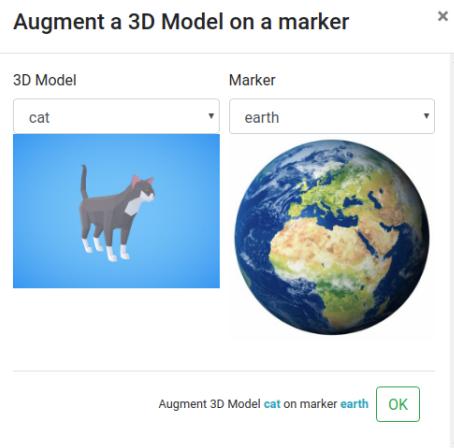


Fig. 5. User interface to create a component of type “Augment marker”

C. Component configuration

Figure 6 shows the configuration for the component of Figure 5. After touching the 3D model, it will follow a rotation of 30° and a translation.

The results are detailed in Figure 7 after making a touch event. We can make some interesting actions as shown in Figure 8, the 3D model (cat) circles around the earth marker.

VI. USABILITY EVALUATION

We carried out tests to verify the functionality and viability of our HCDF in the target users. The usability of the system is measured according to the standard ISO 9241-11 [11].

Each usability assessment session has three phases:

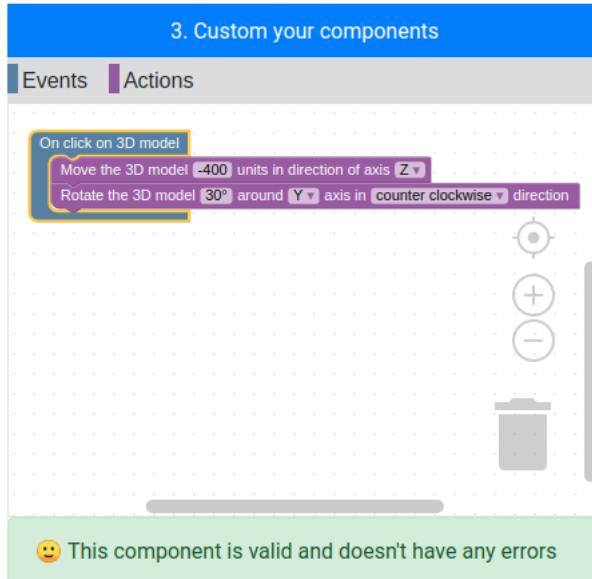


Fig. 6. User interface using Blockly to configure a component

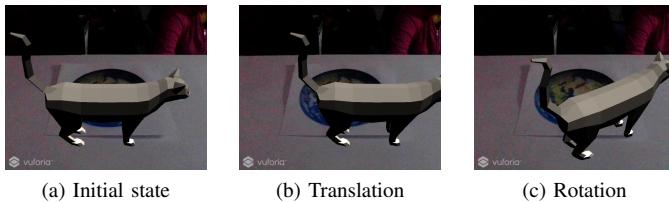


Fig. 7. Actions triggered by the touch event according to the configuration. (a) The component gets started, (b) then the 3D model is translated (c) and finish with a rotation

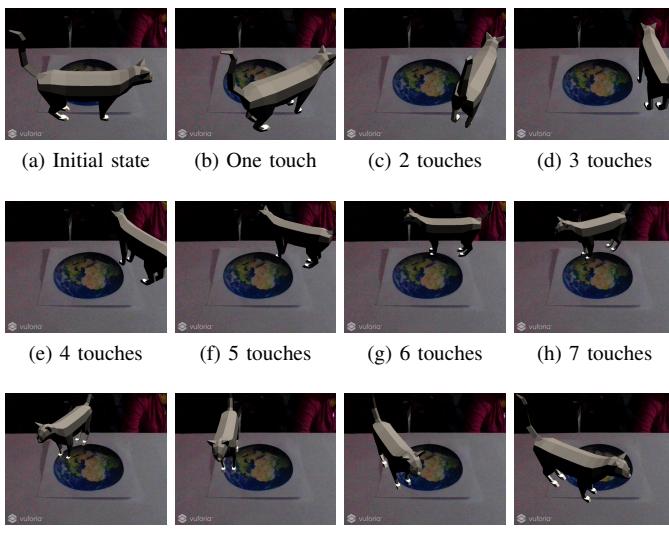


Fig. 8. Circular rotation of the 3D model after several touch events were triggered

A. Training Stage

This phase is carried out in a group, we explain the basic concepts of augmented reality, markers, and 3D models and we teach them to create a simple AR application using SimpleAR.

Next, the user is ready to start the test, previously they had to fill out the demographic form shown in Table I and the user profile validation form to know if it can qualify as our target user as described in subsection III-B, otherwise, it will not continue with the test.

According to Table II, the target user is the one who has not used this proposed HCDF to create RA applications before and has answered “Yes” in more than half of the questions in the section Computer knowledge level. On the other hand, it is not necessary for the user to have knowledge of basic AR concepts, however, this data serves to measure the user’s ease of learning of these concepts during the test.

TABLE I
DEMOGRAPHIC FORM

E-mail:
Genre:	<input type="checkbox"/> Male <input type="checkbox"/> Female
Age:

B. Evaluation Stage

This phase is carried out at an individual level, we guide the user until they have logged into the SimpleAR application. The user must perform the following 3 tasks:

- 1) Task 1 (Augment 3D models): Create an AR application which can
 - Augment a 3D model of a cat on a marker of your choice.
- 2) Task 2 (Action triggered by an event): Create an AR application which can
 - Augment a 3D model of fruit on a marker of your choice and when you touch the 3D model, it rotates 90° on any axis.
 - Augment a 3D model of an animal on a marker of your choice and when you touch the 3D model, it moves 200 units in any direction.
- 3) Task 3 (Sequential actions triggered by an event): Create an AR application which can
 - Augment a 3D model of the earth on a marker of your choice and when you touch the 3D model, it rotated 30° on the X-axis and then moves 50 units in the direction of X-axis.

The user can ask questions if they are stuck during a task, however, we are counting the number of times this is happening.

This phase is recorded in a video from the user’s screen to monitor their actions. In the end, the user must complete the usability questionnaire that includes: Single Ease Question (SEQ) [16] to measure the difficulty perceived by the user when performing each task (see Table III) and the System

TABLE II
USER PROFILE VALIDATION

Experience with similar systems	
Have you ever before used software to create augmented reality applications? Which one?	<input type="checkbox"/> Yes <input type="checkbox"/> No
.....	
Basic computer technical skills assessment	
I have frequent access to a computer and the Internet?	<input type="checkbox"/> Yes <input type="checkbox"/> No
I currently have an e-mail address	<input type="checkbox"/> Yes <input type="checkbox"/> No
I can download documents, images or other files from the Internet	<input type="checkbox"/> Yes <input type="checkbox"/> No
I can participate in an online chat or a bulletin board discussion	<input type="checkbox"/> Yes <input type="checkbox"/> No
I can turn my computer on, off and reboot	<input type="checkbox"/> Yes <input type="checkbox"/> No
I can comfortably use a mouse	<input type="checkbox"/> Yes <input type="checkbox"/> No
I can create folders on the desktop and organize files	<input type="checkbox"/> Yes <input type="checkbox"/> No
I can find lost files on my hard drive	<input type="checkbox"/> Yes <input type="checkbox"/> No
I can save files to the desktop	<input type="checkbox"/> Yes <input type="checkbox"/> No
I can create a new word processing document (Word, LibreOffice Writer, etc)	<input type="checkbox"/> Yes <input type="checkbox"/> No
I can use a url or web address	<input type="checkbox"/> Yes <input type="checkbox"/> No
I can use the refresh/reload button on my browser	<input type="checkbox"/> Yes <input type="checkbox"/> No
I can create and use bookmarks or favorites	<input type="checkbox"/> Yes <input type="checkbox"/> No
I can search the web using a search engine (Google, DuckDuckGo, etc)	<input type="checkbox"/> Yes <input type="checkbox"/> No
I can download and install programs or plug-ins	<input type="checkbox"/> Yes <input type="checkbox"/> No
I can send and receive e-mails	<input type="checkbox"/> Yes <input type="checkbox"/> No
I can attach a file to an outgoing e-mail message	<input type="checkbox"/> Yes <input type="checkbox"/> No
Domain experience	
Do you know what is augmented reality?	<input type="checkbox"/> Yes <input type="checkbox"/> No
Do you know what is a marker?	<input type="checkbox"/> Yes <input type="checkbox"/> No
Do you know what is a 3D model?	<input type="checkbox"/> Yes <input type="checkbox"/> No

Usability Scale (SUS) [17] to measure user satisfaction (see Table IV).

TABLE III
SEQ. SOURCE: [16]

	1	2	3	4	5	6	7	Very easy
Very difficult	<input type="checkbox"/>							

C. Data Extraction Stage

This phase does not involve the users, the questionnaires and the recorded videos are collected. We proceed to evaluate, according to ISO 9241-11, these three usability measures:

- Effectiveness: It is measured with the completeness of each task: (1) The user completed the task with ease and did not require help (2) The user completed the task with difficulties and required help and (3) The user could not complete the task. We also count the number of mistakes made for each task.
- Efficiency: We measure the time it took for the user to complete each of the proposed tasks.

TABLE IV
SUS. SOURCE: [17]

	Strongly disagree	Disagree	Neutral	Agree	Strongly agree
I think that I would like to use this system frequently	<input type="checkbox"/>				
I found the system unnecessarily complex	<input type="checkbox"/>				
I thought the system was easy to use	<input type="checkbox"/>				
I think that I would need the support of a technical person to be able to use this system	<input type="checkbox"/>				
I found the various functions in this system were well integrated	<input type="checkbox"/>				
I thought there was too much inconsistency in this system	<input type="checkbox"/>				
I would imagine that most people would learn to use this system very quickly	<input type="checkbox"/>				
I found the system very cumbersome to use	<input type="checkbox"/>				
I felt very confident using the system	<input type="checkbox"/>				
I needed to learn a lot of things before I could get going with this system	<input type="checkbox"/>				

- Satisfaction: It is measured with the score obtained in the SUS questionnaire and the perceived difficulty according to the SEQ questionnaire.

VII. RESULTS

We have obtained the following results for each usability metric according to the standard ISO 9241-11:

A. Demography

A small sample of five to eight users can identify 80–85% of usability problems. If we add more test users, we are less likely to find more usability problems [18], [19].

The tests were carried out with 5 users (4 women and 1 man) between 17 and 22 years, they are all freshmen students pursuing an architecture career. All of them meet the user profile of the proposed target user in subsection III-B.

- None of them had used a commercial or academic HCDF before.
- They all had the basic IT skills required according to the “Basic computer technical skills assessment” section of Table II with an average of 16/17 questions answered affirmatively.
- Prior to the test, only 2 users had heard about the concept of AR and none of them understood the concept of a natural marker. After the training phase, we ensured they

understood clearly these concepts. On the other hand, they all know what a 3D model is.

B. Effectiveness

According to Figure 9, all the students were able to complete all the tasks, either with or without the help of the evaluator. However, Task 2 was more complex to complete and was the task in which users made more mistakes as seen in Table V.

From what we observed during the evaluation process, Task 2 included creating a project with two components and most users were unaware that a project could include more than one component of type “Augment marker”, they also did not know how to move from the component manager (column 2) to the component editor (column 3) of the general interface of the editor shown in Figure 2.

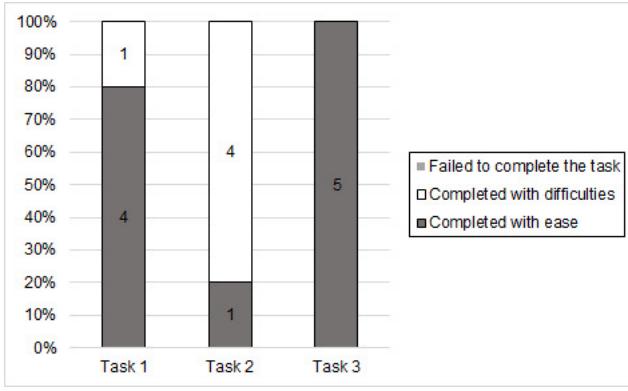


Fig. 9. Task success

TABLE V
ERRORS MADE BY THE USER PER TASK

Errors	Minimum	Average	Maximum
Task 1	0	0.8	2
Task 2	2	3.6	6
Task 3	0	1.2	2

Once the users get used to our HCDF, they could complete the tasks normally. Furthermore, taking into account that for the majority of test users this is their first approach to AR, we can say that our proposed HCDF allows the non-expert user to be effective in implementing basic AR tasks.

C. Efficiency

Figure 10 shows the average time it takes a user to complete each task and its standard deviation.

- Task 1 involves creating a component without configuration and takes an average time of 72.8 seconds.
- Task 2 involves creating two components, each one with its configuration and takes an average time of 246.2 seconds.
- Task 3 involves creating a component with a complex configuration and takes 117.6 seconds to complete.

In any of these 3 cases, our proposed HCDF allows the users to create simple or complex AR applications in less than 5 minutes.

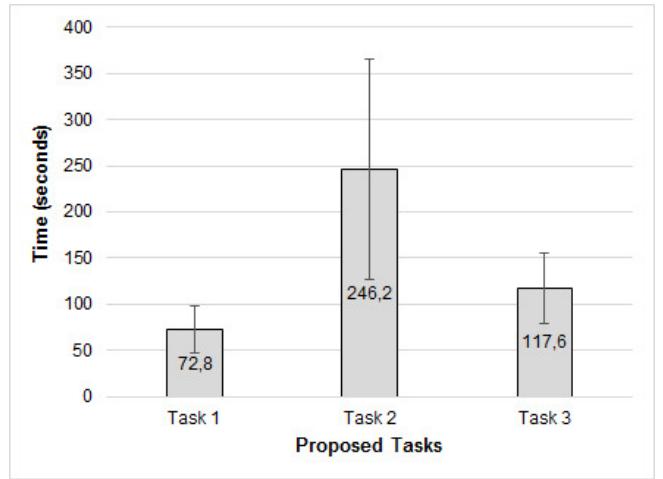


Fig. 10. Completion times per task

D. Satisfaction

None of the users rated any task with a score lower than 5 on the SEQ questionnaire. The averages obtained were 6.6, 6 and 5.8 for Task 1, Task 2 and Task 3 respectively. This suggests that the user does not perceive almost any difficulty when using the proposed framework.

Regarding the SUS questionnaire, [20] provides a comparison of SUS scores with adjective ratings and acceptability ranges. The average score obtained in the SUS questionnaire is 71.5, which is considered as “Highly acceptable” and “GOOD ” as seen in Figure 11.

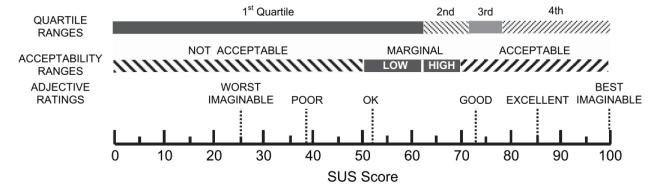


Fig. 11. SUS scores by quartile, adjective ratings, and the acceptability ranges.
Source: [20]

VIII. CONCLUSIONS AND FUTURE WORK

We reached the following conclusions:

- 1) We presented an HCDF adaptable to any AR programming framework, and we demonstrated its implementation with Vuforia.
- 2) We designed a usability evaluation methodology based on the standard ISO 9241-11.
- 3) We proved that the proposed framework meets the usability goals of ISO 9241-11: it is effective, efficient and satisfies the user.

- 4) Our proposed HCDF can be easily used by users with little or no programming knowledge.

Further research needs to be done, we propose the following future works:

- 1) Adapt the proposed HCDF to other AR programming frameworks such as ARCore, ARToolKitX and Wikitude.
- 2) Define an evaluation methodology that allows the comparison with other HCDFs of different types of user interfaces.
- 3) Compare the proposed HCDF with other commercial and widely accepted alternatives such as Wikitude Studio and Layar.
- 4) Perform subsequent iterative tests with small groups of users (5 to 8 test subjects) to find new usability problems and therefore improve the HCDF.
- 5) Implement new events and actions for component configuration.

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