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SYSTEMATIC DESIGN METHOD OF UX USING SMART GLASSES FOR THE EFFECTIVE APPLICATION OF AUGMENTED REALITY IN DIGITAL PRODUCTION

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Abstract: *Augmented Reality has become increasingly popular in the last decade and we can observe the stemming of a huge number of applications of this technology in the entertainment, education and in the industrial domains. The user experience can maximize technology adoption efforts in general, but when it comes to augmented reality applications it can play a decisive role in adoption. In this paper, we describe a user experience(UX)-centered method based on an integrated QFD-AHP approach to develop an Augmented Reality application for a specific application context.*
Key words: *user experience, user interface, technology adoption, digital transformation, augmented reality.).*

1. INTRODUCTION

Augmented reality (AR) has seen a significant increase in recent years for commercial support from big tech names like Google, Apple, Amazon, and Microsoft. In the Gartner's report is indicated that 100 million consumers had actively shop online by 2020 using AR and VR [1]; also the number of AR devices is expected to reach 2.5 billion by 2023 [2].

In the context of the current COVID-19 pandemic, many companies are looking for various strategies to maintain their market segment or access new ones; in some cases, the work is done with less staff, or even remotely if the type of activity allows. In this context, digital transformation (DT) becomes particularly important due to the benefits it can bring, and in order for their effect to be maximum, emphasis must be placed on user experiences in the phase of developing Augmented Reality (AR) applications.

Recently, the importance of understanding the user experience in design has been emphasized by Forlizzi and Ford–[3]. Over time, there have been several attempts to define the phenomenon of user experience. But a common understanding of the user experience is still lacking, even scientists have tried to find a common definition for it [4]. The main reason for a diversified understanding is the different training environments of researchers.

Augmented Reality (AR) differs from Virtual Reality (VR) as AR enriches the physical world around the user, while VR completely obscures it and immerses users in a fully artificial digital environment [5, 6]. In other words, AR represents the real-time overlap of virtual models over the real world. In order to augment the user's perception capability computer-generated data are used overlap over the real scene visualized by the user. The benefits brought by Augmented Reality have been demonstrated in several applications, such as entertainment, education, maintenance and repair, military and others [7]. One of the most important fields in which AR applications can be used is the industrial field. Since this is a vast area, from which several types of applications have been studied, we will analyze the implementation of AR in innovative human

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machine interfaces (HMI). Among the AR applications in HMI, we can identify two main directions, namely the interaction of the operator with a robot (human-robot interaction - HRI) or with a CNC machine.

In this paper the development of augmented reality application for human-robot interaction will be approached. The investigation is mainly focused on user's experience.

It is expected that the proper use of AR in such applications to bring significant benefits in terms of decreasing the operator's workload, as well to improve the performance and situation awareness, providing a positive impact on the safety and efficiency of the whole system.

The choice of the type of device used for augmented reality application in this paper was influenced by the work reported in [8].

2. AUGMENTED REALITY AND HRI

Innovations in the technical field, such as faster computers, more precise cameras, but also new computing algorithms, are echoing in other fields, and this leads to a broadening of the research area of AR.

In the recent years there were developed many applications of AR in robotics. An overview of AR research in robotics during the five-year period, from 2015 to 2019, classified these works into four categories: (1) Medical robotics: robot-assisted surgery (RAS), prosthetics, rehabilitation, and training systems; (2) Motion planning and control: trajectory generation, robot programming, simulation, and manipulation; (3) Human-robot interaction: teleoperation, collaborative interfaces, wearable robots, haptic interfaces, brain-computer interfaces (BCIs), and gaming; (4) Multi-agent systems: use of visual feedback to remotely control drones, robot swarms, and robots with shared workspace [9].

Meanwhile, robots are becoming ubiquitous in daily life, extending their traditional home in the industry to other domains such as rehabilitation robotics, social robotics, mobile / aerial robotics, and multi-agent robotic systems [10, 11].

The efficiency of human-robot interaction can be increased by adopting AR, so that the rapid transfer of essential information can be facilitated.

Wide-ranging applications of AR in HRI have been developed to enhance the human experience during interaction with robotic systems or wearables within a considered five-year period [9].

3. DEVELOPMENT OF THE HMI

Humans have a natural tendency to fear and reject what they do not understand, and this fear has its roots in the evolution of our species, more precisely in the instinct of self-preservation.

Another reason for this tendency is due to the fact that the co-creation process is poor, with very little interaction with the end-user.

In order to increase the degree of technology adoption, we designed the interface based on a user-centered methodology.

As it can be seen in Figure 1, for the development of the human-machine interface, considering the UX, we include the following steps:

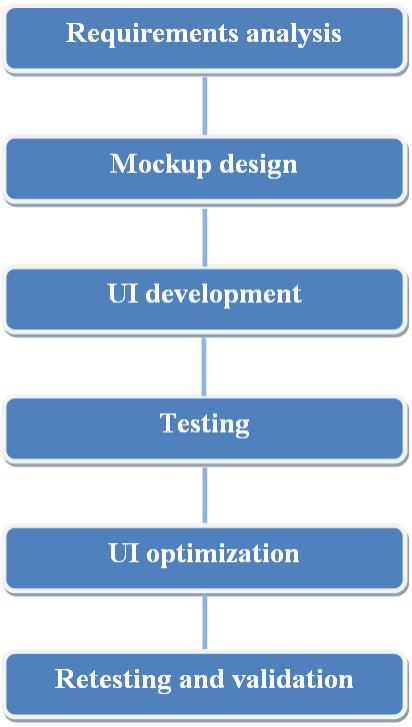


Fig. 1. Method flow

- **Requirement's analysis** - what we follow in the part of assistance and efficient planning, performed by the QFD method. Quality function deployment (QFD) is a successful tool to help a company's product development team systematically translate customer requirements (CRs) to appropriate product features [12]. Such information can assist the team to effectively identify critical processes and production factors in product development [12].
- **Mockup design** - based on scientific methods and testing [heuristics, sample testing, improvement (PDCA / SCRUM). The Deming Cycle also named as PDCA is an established tool for continuous improvement. As the initial licensing followed the classic cycle of Plan, Do, Check, Act, the Deming Cycle was used for further improvement [13]. There are several different software design and programming methodologies in use today and one of the most commonly leveraged is the Agile Software Development with SCRUM [14, 15]. By capturing the conceptualization underlying Scrum, the reference ontology can address semantic conflicts and thereby support the development of integrated data-driven solutions for decision making [16].
- **UI development** - based on scientific methods - lean-agile approach (small increments that are tested (CSDT / AFD / TRIZ). Regarding the adoption level of Agile and Lean software processes in the software development industry, what was initially considered as a fad has been progressively consolidated; nowadays, a great extent of the software industry follows these methods [17]. Agile methodologies speed up the process of building software with more frequent deliveries to customers; agile practitioners often drive their attention to understand customer's needs, trying to answer the question of how useful the developed software can be, focusing on providing an appropriate functional scope [18].
- **Testing** based on scientific methods (AIDA / DoE). The AIDA model assumed that consumers progress through a series of stages from cognitive and affective to behavioral. The four stages (attention, interest, desire, and action) assist the marketer in understanding how target audiences change over time [19].
- **UI optimization** - in this stage, the implementation of the observations and suggestions collected during the test takes place, this step can be seen as a process of continuous improvement and aims to increase the degree of acceptance.
- **Retest and validation -** this is practically the final stage of the process, and if the results are satisfactory, the development process ends; if the results are not satisfactory, a new optimization of the UI can take place.

3.1 Requirements analysis

We conducted a survey to collect end-user requirements about the design of human-machine interface used to interact with a robot.

The questionnaire was created in Google Form and the survey was conducted online, on a number of 57 respondents. Out of the total respondents, 74% graduated high school, 5% graduated from a post-secondary school and the difference up to 100% have completed bachelor's degree. Regarding the field of activity: 42% work in the automotive industry, 21% work in logistics, 16% work in the army, 16% work in the media, and 5% do not work.

According to the answers of the respondents, the interface with a robot should:

- Allow changing the ratio of display interface.
- Include a login page.
- Allow changing text color.
- Allow changes of the background.
- Allow sizing buttons.
- Buttons must have text.
- Buttons must have icons.
- Page with the names of the robots. Page where can be chosen the robot application.
- The name of the robot which we are connected to must be highlight.

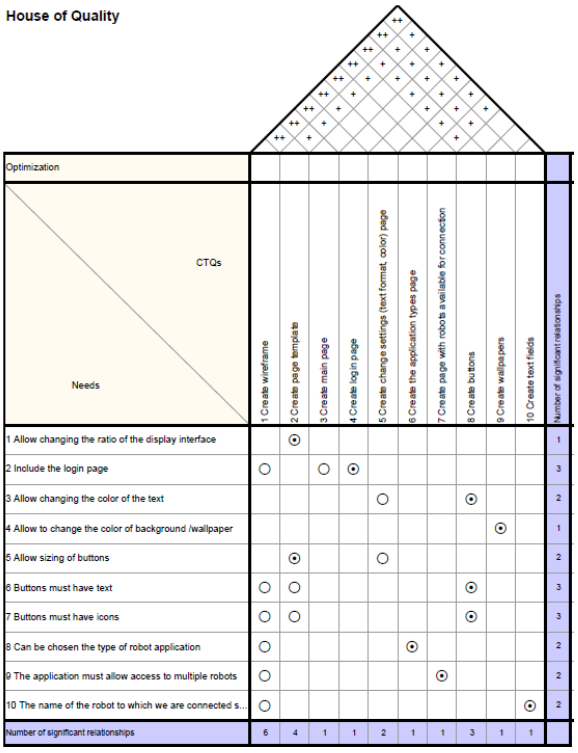


Fig. 2. Analysis of requirements

The requirements were prioritized using the QFD method, as it can be seen in Figure 2.

3.2 Mockup design

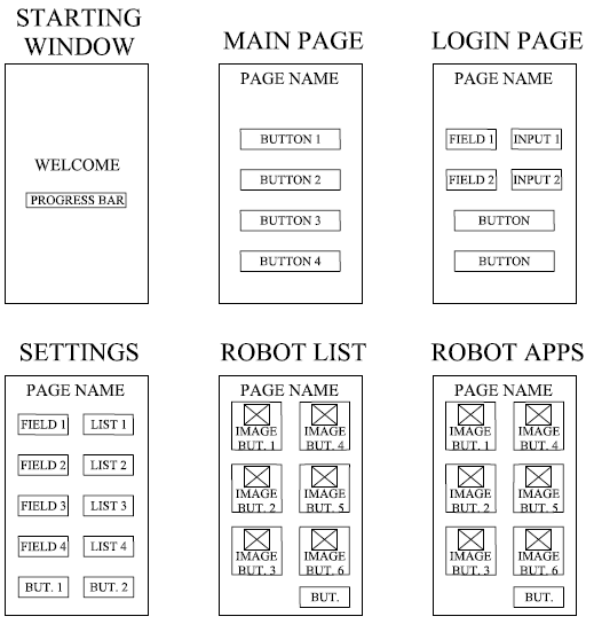


Fig. 3. Wireframe

The wireframe (fig. 3) was design according to the requirements analysis; being created the six pages: opening page, main page, login page, settings page, robot list and application list.

The wireframe was drawn with the help of AutoCAD 2020 software, but it can also be made with a pen or a pencil on a paper sheet.

Wireframe helps us to save time and resources in the application development process; this is basically a sketch of how the application should look and it is usually drawn and presented to the client at an early stage of the project.

In this stage changes of the design can emerge, but their implementation is less expensive here than in a later phase.

After the approval of the wireframe by the client or its updating and approval, the next step is the creation of the mock-up design (Fig. 4).

The mockup design represents the transposition of the wireframe elements in the program with the help of which the application will be created, and in this stage no links will be created between buttons and pages; no shares will be allocated. Changes can also occur at this stage.

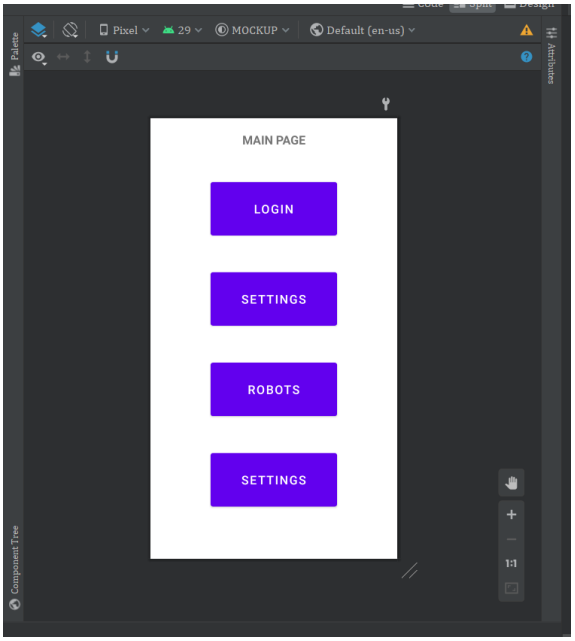


Fig. 4. Mockup of the Main Page

3.3 UI development

For project management, two methods are mainly used: waterfall and agile; both methodologies can help development teams to produce high-quality software.

We chose the agile methodology approach because it is team-based and focuses on the rapid implementation of a functional application, with an emphasis on customer satisfaction.

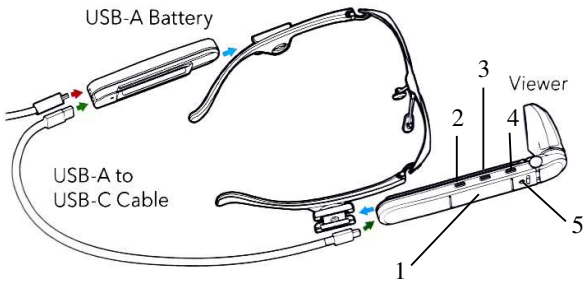
This methodology defines a time phase called sprint with a defined duration of two weeks. There can be several sprints during a project. A sprint contains all the stages that the waterfall method contains, but it is much more flexible.

Once the project steps were defined, the proper development of the application began.

The design of the application focused on User Experience (UX), on the general pleasure that a user can have navigating the pages of the application. We put a special emphasis on graphics elements, layout, and technical elements, such as page load speed, all of which have the potential to affect the experience positively or negatively.

The development was also done with the help of Android Studio, and the programming language used was Java, and the starting point was Mockup design.

3.4 Test



1 – Touch pad
2 – Navigate back
3 – Navigate center
4 – Navigate front
5 – Power button

Fig. 5. Vuzix M400 Smart Glasses used for testing

Fig. 6. Example of testing the UI

After completing the UI development, it was downloaded and installed on a pair of Vuzix M400 Smart glasses, a scheme is presented in figure 5.

A focus group was selected for this test. During the test, the sanitary norms in force were observed. After each test, the touched objects are sanitized, and the room was ventilated, as can be seen in the figure 6.

Before actually starting the test, respondents were instructed on how to use smart glasses: how to start, how to launch an application and how to navigate inside the application.

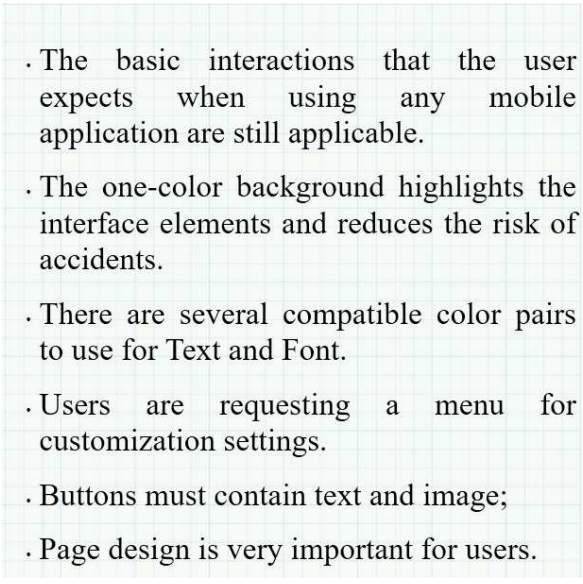


Fig. 7. List of observations

The functionality of the application was tested with different brightness settings, the colors of the buttons and their text were changed; other colors and images were also used as background.

A list of observations and suggestions was collected during the test to be implemented in the optimization stage; the top of that list can be seen in figure 7.

3.5 UI optimization

User interface optimization focuses on the elements of the page that people use to navigate and gather information. UI improvements can increase the chances of users accepting the application.

The application design and functionality were updated according to the requirements collected in the previous stage; a part of the elements was re-designed, and some were deleted also some parts of code were rewritten.

In order to optimize the application, we used Code Cleanup command from Analyze tab and Remove Unused Resources command from Refractor tab.

Properly optimized and smooth application greatly improve the user experience, and also save the battery. In figure 8, the differences between the non-optimized program at the top and the optimized one at the bottom can be observed; for example, the memory used was reduced from 26.4 MB before optimization to 22.2 MB after optimization.

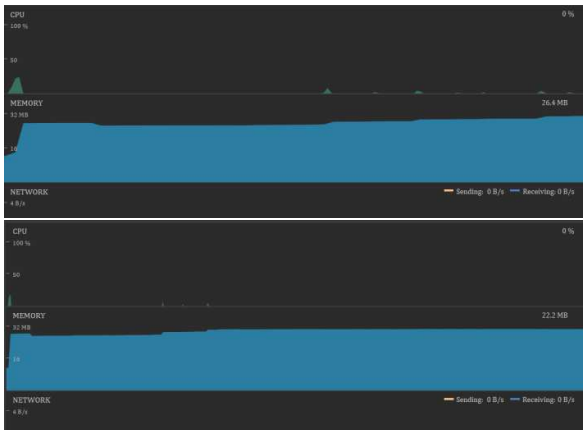


Fig. 8. Project before (up) and after (down) optimization

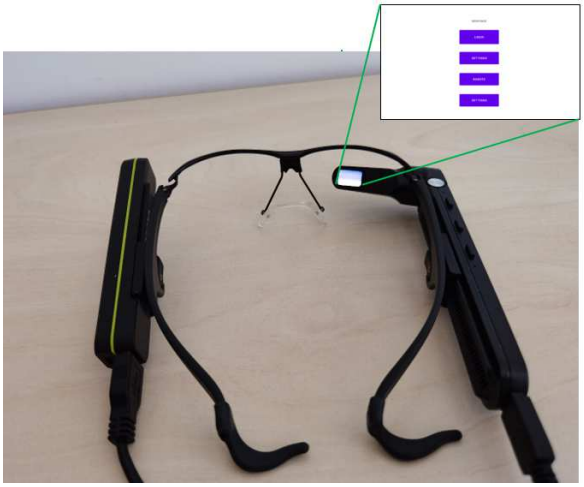


Fig. 9. One application page projected on Vuzix smart glasses

The resources saved by optimizing this application may seem insignificant if we refer to the technical data sheet of the Vuzix M400 smart glasses, according to which the CPU is Qualcomm XR1 Octa core of 2.52 Ghz, the battery autonomy period is 2-3 hours and the internal memory is 6GB, but in the case of complex applications, which include 3D models, audio - video materials, etc., the resources saved will be higher.

It should also be taken into account that applications can be scaled and modularized.

3.6 Retest and validation

This time the application (Figure 9) worked much better, and the degree of acceptance also increased, from 80% during test to 95% during retest, the number of observations and suggestions for improvement decreased considerably, from 17, in faze of test, to 4 observations during retest.

4. CONCLUSION

The proposed methodology facilitates the obtaining of an augmented reality application

used for as an HMI and that has a high degree of adoption due to the UI and UX approach.

The data were taken from people with different backgrounds; the main idea was to find out how an application can be designed so that it provides the experience that users want.

Based on these findings, professionals aim to gain a deep understanding of users, in order to develop successful solutions that meet the requirements of users. The expectations, emotions and needs of the users were considered to be important factors.

Due to the nature of the design practice, designers need to have a thorough understanding of users in order to be able to design positive user experiences.

This study shows the practical situation in certain organizations regarding the knowledge about the user experience. In organizations, user experience must be understood as a strategic factor.

Lean agile methods facilitate faster product development at low costs, due to flexibility in design and development.

The activities undertaken by a company and an individual designer affect the expected and perceived user experiences. Product quality, company brand and design activities are attached to the development of the user experience.

Properly optimized and smooth application greatly improve the user experience, and also save the battery.

Future researches can focus on visually impaired people who use smart glasses in environments with variable brightness from industry.

Another area of research can analyze use of the smart glass's projector on the left and then the right eye during eight hour cycles of time.

5. ACKNOWLEDGMENTS

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Metodă de proiectare sistematică a UX folosind ochelari inteligenți pentru aplicarea eficace a realității augmentate în producția digitală

Rezumat: Realitatea augmentată a devenit din ce în ce mai populară în ultimul deceniu și putem observa rezultatul unui număr mare de aplicații ale acestei tehnologii în divertisment, educație și în domeniile industriale. Experiența utilizatorului poate maximiza eforturile de adoptare a tehnologiei în general, dar când vine vorba de aplicații de realitate augmentată, aceasta poate juca un rol decisiv în adoptare. În această lucrare, descriem o metodă centrată pe experiența utilizatorului(UX) bazată pe o abordare integrată QFD-AHP pentru a dezvolta o aplicație de realitate augmentată pentru un context de aplicație specific.

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