

Requirements of Augmented Reality for Outdoor Environments

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Resumo: Este artigo apresenta uma nova adequação da tecnologia de Realidade Aumentada para os utilizadores finais em ambientes externos. Para encontrar lacunas no campo, é feita uma pesquisa no estado da arte das características desta tecnologia e nas preferências dos utilizadores finais para interações adequadas com as mãos livres e adequada quantidade de informação em atividades ao ar livre. É necessária uma adaptação contínua das informações devido a diferenças ambientais, contextuais e de atividades, e por último, evitar a sobrecarga de informação. Traz melhorias significativas em relação aos sistemas portáteis de Realidade Aumentada atuais. Este trabalho apresentado aqui tem implicações profundas na aceitação da tecnologia, pois apresenta valor agregado ao proporcionar aceitação e agilidade com interações mãos livres, sejam elas atividades turísticas, esportivas, de lazer ou de jogos.

Palavras-chave: *Realidade Aumentada, Ambientes Outdoor, Informação por Atividade, Interação Mãos-Livres.*

Abstract: *This paper presents a new adequacy of Augmented Reality technology for end-users in outdoor environments. To find gaps on field is made a research in state of the art, survey technology characteristics, and end-user's preferences to adequate hands-free interactions, and amount of information in outdoor activities. A continuous adaptation of information is needed due to environmental, contextual and activity differences and avoid information overload. It brings significant improvements over current Augmented Reality portable systems. This work presented here has profound implications for technology acceptance, because it only presents an added value when provide acceptance and agility with hands-free*

interactions, be it touristic, sportive, leisure or gaming activities.

Keywords: *Augmented Reality, Outdoor Environments, Information by Activity, Hands-free Interactions.*

I. Introduction

Augmented Reality (AR) is a recent technology where end-users can interact with the information displayed and, eventually, perform tasks more intuitively and efficiently. Its main purpose is to increase the user's perception about the real world by adding virtual information to it [1] [2]. The interest in new technologies such as AR is growing, either by industry or by private users. AR is ready to receive all kinds of applications developed, so the public can enjoy its benefits. AR is an advanced technology for a richer experience that has been developed over more than 40 years and still is subject of research, namely in terms of its usability, where issues still arise, like the need for it to be better adapted to people and personalized contexts, e.g., in outdoor environments [3] [4]. But it is needed adequacy of AR technology for outdoor activities to better acceptance by end-users. Brings significant improvements over current AR portable systems in outdoor environments better than Google Speech Recognition and Microsoft HoloLens©.

The rest of the paper is organized as follows. Section II presents author motivations. Section III questions and issues of this study. Section IV is the state of the art, which surveys AR applications, system characteristics, and technology acceptance. Section V presents the methodology adopted for AR requirements and adequacy. Section VI shows the analysis of results of the main research lines, followed by

Section VII the conclusions, followed by last section, the future work, in Section VIII.

II. Motivation

Author is a lover of outdoor activities. So he needs an AR framework that recognize complex activities [5] like tourism [6] [7], sport [1] [8] [9], leisure [6] [9], game [10] [11] and auto adjust these activities to the kind of information like geographic, climatic, biometric, social, with adequate handsfree interaction [12] for outdoor environments where exist Internet access constrains [13] [14].

III. Questions and Issues

There are questions needing to be addressed, such as: What are the end-users' preferences for better technology acceptance? Can an AR system auto-adjust information by preferred activities of users through device's sensors, and users' emotions, avoiding the information overload? Also, what are better suited hands-free interactions without needs of Internet access?

IV. State of the Art

AR technology is a huge field of research with four decades of studies and development applicable to several areas of society, but it is needed survey AR applications, characteristics, outdoor activities, and end-users' preferences to adequate this technology for outdoor environments. See following subsections: AR applications and system characteristics; activities for AR, and adequacy innovation, all for outdoor environments' context.

A. AR Applications and System Characteristics

A pioneer in AR is Ronald Azuma on his last work, he writes about some problems for ubiquitous consumer deployment, like precise

tracking across large environments to support pixel-accurate registration, both indoors and outdoors [15] [16], and in all weather conditions, including at night [17]. Another look, there are several types of outdoor environments, like silent environments, others with noise and distractions, e.g., traffic, industry, animals, or wind. Pascoal, et al. proposed an environmental taxonomy to identify performance differences with speech recognition. On the one hand, there are open questions needing clarification like with the organization of information in relation to the number of possible combinations and arrangements between the several variables, e.g., biometric, geographic, climatic and social [1] [18]. On the other hand, social rejection of AR technology is other issue and may occur like with the case of Google Glass [19]. The first version of the equipment was withdrawn from the market. The advances in mobile computing systems, especially the inclusion of cameras in mobile phones, has accelerated the development of innovative AR applications [20]. There are needs to survey technology acceptance and suitability to gain true value [4]. Moreover, understand AR gadgets in terms of real usability, where there must be a balance between the amount of given information. The quality, in terms of information gain, that is presented to an end-user of AR must be judiciously determined for the information needs of end-users interacting with AR, especially in poorly controlled, wild, or even uncontrolled environments.

Managing, processing and selecting data such as statistical machine learning must be employed, and by emotion analysis [18] [21]. Several health applications have been focused on tracking activities to activity recognition [22] [31]. Finally, there is the question of designing effective, simple, and usable ways for the user to interact with the AR system using natural language processing or movements, as well as the need to define criteria for amount of information to be presented to user, that is, without overload [1] [13] [23].

About AR system characteristics, it is verified, there is a proportionality between the weight of the equipment and battery life, e.g., when the weight is higher, shorter is the autonomy time of the battery and more uncomfortable for end-users in outside. About outdoor environment conditions, the AR display must work across a wide variety of lighting conditions, from bright sunlight to a moonless night [15], e.g., the Microsoft c HoloLens is not adequate for outdoor using, because of three things: (1) the weight of the equipment (579 grams); (2) the battery life (2-3 hours), and (3) the sun reflex on the smart glass in outdoor environments. Other characteristic is monocular vision versus binocular vision of smart glasses. Akihiko Kitamura et al. concluded the monocular presentation is superior for real-world tasks than binocular presentation, even when observers need to pay attention to an AR image and the image is less visible in monocular presentation [24]. Also, the parallax problem, binocular displays where both eyes see the same image causes significantly more discomfort than monocular displays, both in eye strain and fatigue [25].

B. Activities for AR in Outdoor Environments

This research covers the use of AR technology only in outdoor environments, specifically in autonomous systems in activities like sports, tourism, leisure, games and the need of their adaptation to the constraints present in outdoor environments. The goal is adequacy and technology acceptance with these outdoor activities and their suitability with information data, such as, climatic, geographic, biometric and social. This information can be automatically presented by AR system or requested manually by user's voice, which is, providing real benefits and agility with hand-free interactions.

1) Sportive activities for well-being or competition such as cycling, athletic or walking is relevant for outdoor users. For instance, tracking the personal training of the end-user, track training quality and success to give

feedback to the users, as well as, to engage and motivate regular exercising, e.g., some kind of Gym Skill for activity recognition and for on-top skill assessment [9] [31]. Or a mobile sensing system for cyclist experience mapping leveraging opportunistic sensor networking principles and techniques. A multifaceted sensing system and explores personal, bicycle, and environmental sensing using dynamically role-assigned bike area networking. A real-time and delay-tolerant uploading of data via a number of sensor access points to a networked repository, e.g., some king of Bike Net to quantifies cyclist performance and the cyclist environment [8].

2) Touristic activities for recreation or learn such as visiting cultural places. For instance, an intelligent tourist system. That is equipped with a unique combination of sensors and software. GPS receiver, a lapel micro-phone plus an earphone, a video camera and a head-mounted display. A multimodal interface to take advantage of speech and gesture input to provide assistance for a tourist. The software may support natural language processing, speech recognition, machine translation, handwriting recognition and multimodal fusion. A vision module is trained to locate and read written language, is able to adapt to new environments, and is able to interpret intentions offered by end-users [7]. The aim can be to make a mobile augmented reality application with cultural heritage resources such as historical pictures and information [6].

3) Gaming activities for entertainment or competition. For instance, challenges of making outdoor augmented reality games playable were discussed in 2nd CREST Workshop on Advanced Computing and Communicating Techniques for Wearable Information Playing. History has shown computer technology and society acceptance of that technology has been driven in part by the entertainment computing industry. Future outdoor games will be in the form of playing with AR technology and will increase the number of possible concepts of outdoor mobile games [11], e.g., the influence of

Pokémon© Go game on physical activity, which leads to significant increases in physical activity over a period of 30 days, with particularly engaged users, i.e., those making multiple search queries for details about game usage, increasing their activity by 1.473 steps a day on average, a more than 25 percent increase compared with their prior activity level.

4) Leisure activities, which can may be a combination of the three previous activities. For instance, can be a combination of sport, tourism, game, and for share messages, photos and videos on social networks, which can be associated with social information. Furthermore, the example of Pokémon© Go can be for leisure people who do not like exercises too much, but gradually they are doing exercises. In particular, we find that Pokémon© Go is able to reach low activity populations or leisure people, whereas all 4 leading mobile health applications studied in this work largely draw from an already very active population. Future studies are needed to investigate potential long-term effects of these applications [10].

Rui Pascoal et al. developed a survey questionnaire to know end-users' preferences about these activities, and the results from 114 respondents were:

- 70% preferred sports.
- 76% preferred tourism.
- 58% preferred games.
- 63% preferred leisure.

If adds touristic activities to the game or sports will have 61%, but tourism is 77% - most favorite. This preference for tourism activities is reinforced by 99 participants who preferred geographic information, i.e., 88% of 114 participants (questionnaire in: goo.gl/5D36N4). Mode details of this survey questionnaire are in methodology.

C. Adequacy Innovation for AR in Outdoor Environments

The study of this adequacy began in the year 2016 through an AR prototype. Rui Pascoal et al.

starting research with a full paper and his master's dissertation in computer engineering on Information Overload in Augmented Reality [1]. See Figure 1.



Figure 1. Empirical tests with end-users through a quantitative approach. Source: “*Information Overload in Augmented Reality: The Outdoor Sports Environments*” [1] and “*Realidade aumentada nos desportos outdoor: desenho, implementação e avaliação de protótipo*” [26]

Figure 1 shows the empirical tests to end-users through a quantitative approach. End-users were confronted with three versions of this AR prototype. The goal was measure information overload and execution of features by them. Shows the starting evolution of this AR prototype. Some information was not adequate and was considered irrelevant or information overload, like direction information [1]. So, the results were: some information are not adequate to show them, because it causes difficulties when are executing AR features, e.g., like - take a photo, make a video, send a message, or call to someone, while they are receiving information in same time. There was some degradation in their interactions. See further developments for suitability in hands-free interactions and reduction information presented to end-users in years 2017 and 2018 (Figure 2).

Even more, on this topic making adequacy for AR technology in outdoor environments, a real way of perceiving the user's behavioral intentions may have to pass through emotion sense of end-users, because smart phones and smart glasses are equipped with sensors, which has enabled human activity

recognition. The daily activities of end-users can be monitored, this for, inducing behavior change, e.g., for a healthier and active lifestyle. This activity recognition can use a machine learning algorithm before listing the challenges of activity recognition [27] [31]. See last topic, on the future works, for more details.

(a) Old version in year 2017



(b) New version in year 2018



Figure 2. Evolutions of the Adequacy of AR prototype to human capabilities and user preferences

V. Methodology

The methodology analyzes the state of the art of AR applications, system characteristics, and outdoor activities for better adequacy. Compares side-by-side these variables to find gaps and go beyond.

To help this finding, author has been developing an AR prototype with the aim of deploy all features, or system functionalities, current used in outdoor activities, e.g., to take a

photo, to film, to call and messaging, or to speech with the AR system, which end-users may ask by voice specific information about geographic, climatic, biometric and social, for the activities of tourism, sport, leisure and game. End-users may interact with the microphone easily for hands-free and receive information by headphones. End-users may trigger AR system by a suggested keyword “mighty computer”. A new version of this prototype is under development. See following Figure 3 - the structure of interactions with this AR prototype, which simulates AR for outdoor environments.

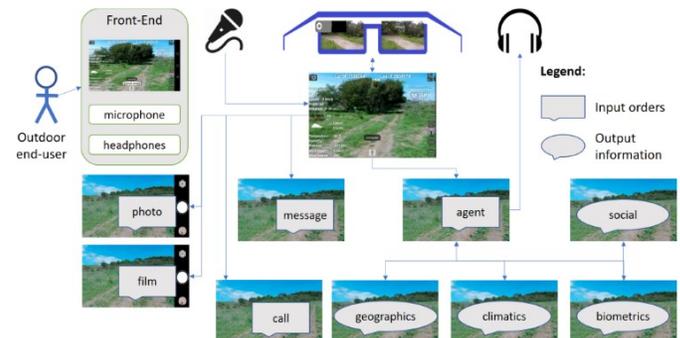


Figure 3. Wireframe of interactions with an AR prototype

Figure 3 shows details of the AR system prototype and all possible interactions. It was developed in an android smartphone, because, such operating system is the starting point for future plans on mobile AR devices based on android operating system. This prototype can also be equally integrated in other mobile Operating Systems, such as Microsoft c Windows or Apple c iOS [13]. Figure 3 also shows the wireframe of interactions with AR prototype. It shows in detail the overview of all interactions with the features and variables (climatic, geographic, biometric and social) for outdoor activities. In fact, some work has already been conducted and led to the presentation of a paper on an adaptation of a speech recognition system in AR for mobile devices in outdoor environments [13].

An Automatic Speech Recognition (ASR) is used for speech recognition and able hands-free interaction, without dependence of internet access, it is the CMU Sphinx recognition

[28], and the sentences used to return from system features and information are as follow. The keywords “*mighty computer*” trigger the AR system (better than only one word e.g., “*computer*”, because of the environmental noises). See following Table I, few examples:

Table I: Execution of prototype features

Input Order	Output Result
I would like a photo please	Photo Feature
film, thank you	Film Feature
I want to call to alice	Phone Feature
message to marry, thanks	Message Feature
give me geographic information	All geographic information, e.g., “near of Sintra, traveled distance of 1,7 kms, goal Palacio da Pena of 3,5 kms”
what is my goal	Specific information, e.g., “my goal is Trigo da Aldeia Coffee, reaching in 2,4 km”
please house in faro thanks	Specific information, e.g., “Hotel Faro, address, Praça Dom Francisco Gomes 2, 8000-168 Faro,” Phone number: 289 830 830.”

According to Table I a specific grammar was developed to help and execute same functionalities in several ways, i.e., few examples of several ways of saying the same, makes hands-free interactions in various spoken forms easier: It was conducted in previous work. See following a grammar graph.

The goal is: to have several ways of saying the same [13], for instance: “*I what a photo*”; “*I would like a photo, please*”; “*photo, thanks*”, and the same for the other features. See Figure 4 on following section.

The execution core of these features is some suggested keywords. They are: “*photo*”, “*picture*” or “*photography*”, to execute photo feature. To execute film feature users must say at least: “*film*”, “*video*” or “*record*”. To execute a call, they must say: “*call*” or “*communication*”, and to execute message feature must say: “*message*”. At last to ask to system specific information users must say at least: “*agent*”, “*operator*” or “*system*” [13].

In previous work, to studding technology acceptance, was developed a survey questionnaire. Aiming at a better understanding of the user’s expectations and anticipation of a possible outdoor application enhanced via AR, a small questionnaire with only ten questions was devised and made publicly available via a Web link (goo.gl/5D36N4) and using survio.com R tool. Starting with a very brief explanation, illustrated with three images, of what was be intended by the AR technology concept. The questionnaire starts by collecting users’ personal information, such as (1) age (to be manually fed) and (2) gender (dichotomous), followed by a yes/no/maybe question (3) to assert if the respondent had previous acquaintance with AR. The following questions aimed to understand to which degree many of the previously mentioned variables influenced or not the respondent. For that, a 5-degree Likert scale was always used. The remaining questions sequence is: (4) degree of social influence by friends or next of kin; (5) price importance; (6) degree of preference towards: dedicated AR devices, complemented with smartphone, with a smartwatch, a bracelet, and a belt; (7) importance towards customized and auto-adaptable AR devices; (8) importance of the design for AR glasses; (9) degree of importance given to AR per type of outdoor activity: sports, tourism, game, and leisure; and finally (10) degree of importance of information availability pertaining: geography, weather, biometry, social events.

VI. Analysis of Results

Analyzing the studies for gaps, it sees that AR technology for the external environments must be adequate to be technologically accepted. It is important to adjust and reduce the information to be presented to users. It also involves suppressing information that is not appropriate for them, such as direction information (e.g., north, south, east, west) as well as latitude and longitude information, because they only increase information overload [1].

Strong need to improve the hands-free natural language recognition system, for instance, increase grammar and finetune the speed of operation considering external noises. In previous works the author improved the off-line ASR and opted for CMU sphinx recognition, because it does not need Internet access unlike google speech recognition system [13]. See following Figure 4 - the grammar language developed by author.

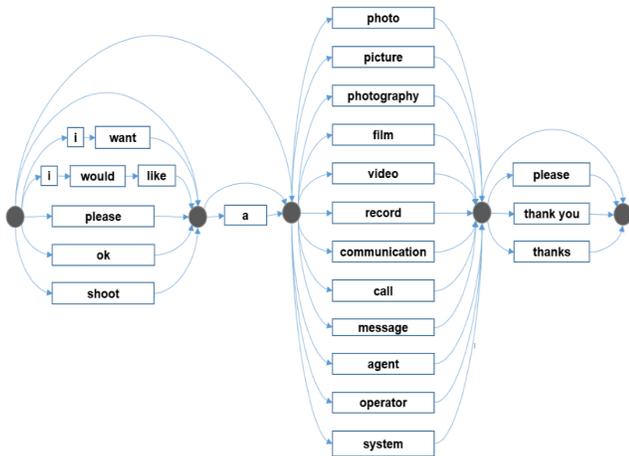


Figure 4. Grammar Graph for Speech Recognition

Figure 4 shows actual grammar development of the author. End-users may say, e.g., I would like a photography please to run the photo method or may say “I want a photo thank you”, and so on. These sentences have the common meaning, i.e. to take a picture. Strong need of hands-free interaction plus information interaction, to quickly and easily access different features, such as take a photo, shoot a film, make a call, and send a message. But there are different information requests that must be fulfilled like geographic, biometric, climatic or social information. This grammar must be improved and is under development.

In other study, the author developed a research questionnaire to know the preferences of end-users about these outdoor activities, i.e., tourism, sport, game, and leisure activities, and the results were: people prefer mostly tourist and sport activities, and less game and leisure. See following Figure 5.

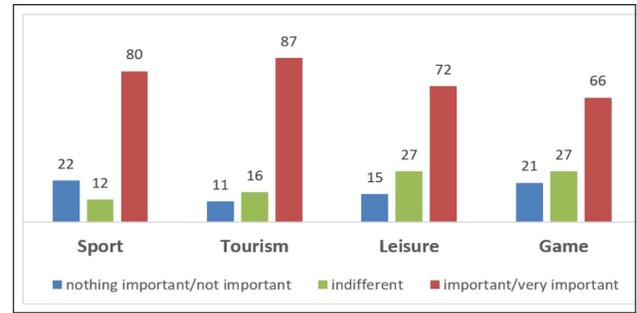


Figure 5. Sport, Tourism, Leisure, and Game Activities

It has been found that if AR is developed for smart glasses the monocular vision should be preferred because it has superiority compared to binocular vision due to comfort [24]. Also, an AR system should be lightweight, comfortable and have a large battery life for outside.

VII. Conclusions

The purpose of this study is to contribute through an AR framework based on previous works of author and the state of the art of AR to find gaps. So, it is needed develop a framework for automatic activity recognition with voice recognition specifically for outdoor environments. Such application must be flexible enough to accommodate the improved off-line speech recognition of commands, i.e., under several ways of saying the same by a simple word or long sentences.

When analyzing this work of AR applications, technology suitability characteristics of AR systems, it is clear, there is much work to be done to make a future real contribution for adequacy of AR in outdoor environments, technology usability, and social acceptance. On the one hand, there was preference to the tourist and sport activities than leisure or gaming activities. On the other hand, people prefer an AR system that auto adjust information by specific activity to avoid information overload. Besides, about system characteristics in most AR smart systems, when the weight is higher, shorter is the autonomy of the battery and more uncomfortable for end-users in outdoor activities.

Future developers of AR should consider the meaning of these conclusions to better adequacy and use of AR technology in outdoor environments.

VIII. Future Work

The future work can be pass with a better understanding the outside behavior of end-users' emotions, i.e., to improve evaluation the users behavioral intentions to adapting an AR application to their preferences in outdoor places by personal activities. It is necessary a kind of adaptive mobile platform [29]. Future research may involve adapting eye tracking to anticipate the behavioral intentions of users, in this case, using the most developed human eye sensor like Tobii Pro © smart glasses 2, but its price is very high for technology acceptance, i.e., high price of medium-high smart AR equipment (has a typical cost range of \$10,000-\$30,000).

Future work involves going beyond the researchers as Mahadev Satyanarayanan et al. They have been focused to improving the quality of citizens life through several technological interactions to relate the citizens' emotions to city's areas. The techniques used to do the acquisition of the citizens' emotions involve, heart rate (HR), heart rate variability (HRV) and galvanic skin response (GSR) [21]. But now adding more data from other sensors to better fit information to specific activities.

It is relevant to use GSR because is not intrusive and not uncomfortable for outdoor users to better technology adoption. About no intrusive in the context of social well-being to better adequacy can be used a tracking activity, such as fitness habits in outdoor environment. Other studies have developed application tools to capture and to infer social interaction patterns [22]. See following Figure 6 to describe future work of classification patterns by kind of activities that author must conduct.

Figure 6 shows, for instance, tourism activity needs geographic and climatic information, game

activity needs geographic and biometric information, and so on.

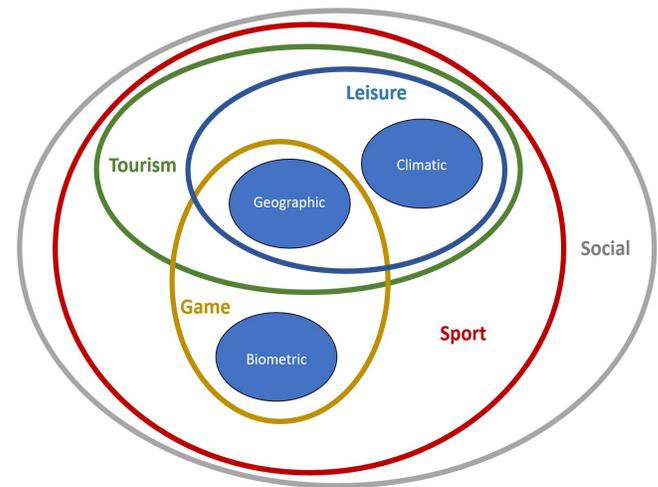


Figure 6. Kind of Information by Activities.

This kind of activity capture can be used to auto adjust an outdoor AR system and promotes better acceptance and use of AR technology. So, can be used a monitor of behavior to understand the correlation and the impact of interactions and activities on the emotions of individuals, i.e., depending on the kind of end-user behavior can modify the information output, both in terms of sensing operations based on the analysis of the available information about the user, and its outdoor environment [29]. Awaiting discovery be an entirely new world in which mobile computing seamlessly augments users' cognitive abilities via compute-intensive capabilities such as natural language processing, computer vision, machine learning, planning and decision making [30]. Finally, the goal is building an AR framework prototype for outdoor environments, helping future developers to implement specific AR applications for outdoor environments, be it sportive, tourism, leisure, and gaming activities.

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