Collaborative Content Generation Architectures for the Mobile Augmented Reality Environment

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Abstract

The increasing adoption of smartphones by the society has created a new research area in mobile collaboration. This new domain offers an interesting set of possibilities due to the introduction of augmented reality techniques, which provide an enhanced collaboration experience. As this area is relatively immature, there is a lack of conceptualization, and for this reason, this paper proposes a new taxonomy called Collaborative Content Generation Pyramid that classifies the current and future mobile collaborative AR applications in three different levels: Isolated, Social and Live. This classification is based on the architectures related to each level, taking into account the way the AR content is generated and how the collaboration is carried out. Therefore, the principal objective of this definition is to clarify terminology issues and to provide a framework for classifying new researches across this environment.

Keywords: augmented reality, architectures, distributed and collaborative AR, AR content generation, AR classification.

Index Terms: H.5.1 [Information Interfaces and Presentation]: Multimedia Information Systems – Artificial, augmented, and virtual realities.

1 Introduction

During the recent years the mobile world has experienced an extremely fast evolution not only in terms of adoption, but also talking about technology. Smartphones have become a reality allowing users to be permanently connected to the Internet and to experience new ways of communication.

Handheld devices are nowadays able to support intensive resource demanding applications, what makes possible for developers to create applications that change the way end users experience the world and communicate with each other. This kind of applications can be created using the power of context sensors that are present in this new series of phones. Another important characteristic of this innovative scenario is the integration of applications with social networks that enables mobile collaboration.

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Developers have recognized in augmented reality (AR) technology combined with smartphones' power, a rich environment that offers a wide range of exciting possibilities. One of the best is the use of mobile AR to improve collaboration among users.

Mobile collaborative AR is today an active field of research since applications using these concepts are being deployed every day. The most accepted applications are the ones running on mobile phones compared to other possibilities that are still in a research progress, such as wearable AR.

Within the mobile collaborative AR environment as it is a relatively young technology, there exists a lack of conceptualization. Taxonomies that would allow standardization processes are required. They would be also useful to optimize the research and development processes.

The way of generating and sharing the content is a concrete attribute that differs from one mobile collaborative AR application to another. It can be found that some applications just provide information overlays to users who cannot add any feedback or extra content. Some other applications let the end users add simple or complex content in order to enrich the entire system, even connecting with social networks. There also exists another type of applications based on real time content generation and sharing. Studying these differences in content generation and analyzing directly related parameters such as the architecture and technology needed by each type of application, and the user perceived impact, we have defined a new taxonomy. The taxonomy we present in this paper is called Collaborative Content Generation Pyramid. It consists of three different levels in which the applications can be classified: Isolated, Social and Live. Each level is technologically and architecturally supported by the lower levels.

We show the advantage of this new taxonomy by using it in order to analyze and classify the currently deployed and well known applications.

The structure of the paper is as follows: the next section introduces the background of our research, explaining the current context in which this work is based. We then move on to define the proposed Collaborative Content Generation Pyramid, in section 3. We explain next in section 4, how it can be used to classify the current environment, also presenting some interesting ideas of potential Live Level developments. Finally, the last section presents the conclusions revealed after the research was carried out and summarizes the ideas for future work.

2 Background

Before starting with the description of the Collaborative Content Generation Pyramid concept and the different architectures related to it, we are going to provide an overview of the context behind our research in the mobile and AR areas, regarding to how both of them are contributing nowadays to improve the collaborative experience in the mobile world.

2.1 A New Age in the Mobile World

When talking about the mobile world, we notice that it has been evolving very fast in the recent years due to the evolution of mobile devices.

Since the appearance of smartphones, more specifically the Apple iPhone in 2007, the mobile market has drastically changed. Consequently, all the mobile companies are trying to imitate it, therefore it is not wrong to say that the iPhone was a disruptive change in the mobile devices world.

Due to this evolution, a set of technical characteristics have been assumed in order to design mobile devices. Probably the most important thing to take into account is that now the telecommunication companies focus the design considering the user first [1], instead of the technology itself.

A good example of this assertion is the use of multi-touch, which has completely revolutionized the mobile user experience. Perhaps the most important characteristic of this new series of mobile devices is their integration with social networks, in order to be able to provide mobile collaboration by interconnecting the mobile and the Internet worlds via the Social Web, as Reynolds said in [2].

Furthermore, it is important to remark that the power of the current mobile devices is in some cases comparable with the one of a computer, and if we also take into account the context devices they have (e.g. camera, GPS, compass, accelerometer...), there exist a lot of possibilities to enable collaboration in several ways.

2.2 The Rebirth of Augmented Reality

Related to the previous section, we can talk about a recent innovation that has appeared in that context: the use of AR in mobile applications. An AR system, according to Azuma et al [3], must have the following properties:

- Combines real and virtual objects in real environments.
- Runs interactively and in real time.
- Registers real and virtual objects with each other.

As Vaughan-Nichols said in [4], although it is nowadays a hot topic, AR is in fact an old technology.

The first appearance of the "Augmented Reality" concept is attributed to Tom Caudell while he was working for Boing in 1990. However there existed systems that achieved the properties mentioned before ever since 1960s and there are several areas where AR found many applications during the recent years, as we can see in [5] and [3]. It was in 1994 when the idea of AR was perfectly established due to the Milgram`s Reality-Virtuality continuum [6]. He defined a continuum of real to virtual environment, in which AR takes one part in the general area of mixed reality. Throughout the years, the other parts of the continuum (augmented virtuality and virtual environments), have not reached much importance in the mobile world, and for this reason we are not going to talk about them in this paper.

Returning to AR, we can say that it has changed the common mobile applications inputs, replacing them with new ones: registration and image acquisition, physical or virtual location, data from the compass and the accelerometer or user's touches. Consequently, the way a developer works has also changed, because he or she must take into account these new kinds of inputs in order to be able to achieve a complete AR application.

Besides this, the way users interact with these augmented systems has changed radically from the traditional mobile applications, because in some manner they interact directly with the real world throughout the application, having a lot of possibilities to live an innovative user experience.

2.3 Mobile Collaborative Augmented Reality

As introduced before, the use of AR in mobile applications is a consequence derived from the set of possibilities that these kind of devices offer to developers. If also we take into account the importance that the collaboration has achieved nowadays in the mobile world due to the penetration of social networks like Facebook or Twitter, the joint of both areas (mobile collaboration and AR) is a direct outcome. This is proved taking into account that several of the 10 disruptive technologies from 2008 to 2012 proposed in [7] are implicated in the mobile collaborative AR.

In the recent years, there have been developed some significant examples in this area with different results. On the one hand, considering wearable mobile devices, Reitmayr and Schmalstieg [8] designed a system capable of providing 3D workspaces for collaborative augmented reality environments. In this way, Mistry et al. [9] defined a wearable gestural interface system capable of showing information into the tangible world (in some cases obtained from the Internet), due to the use of a tiny projector and a camera. Also there is another example like the project developed by Hoang et al. [10], whose main objective is to connect users through Web 2.0 social networks in a contextually aware manner based on wearable AR technologies.

On the other hand, there exist examples of non wearable systems such as the face to face application developed by Henrysson et al. [11] called AR Tennis, which is based on fiducial markers to carry out the tracking.

Nevertheless, in this paper we are going to focus on mobile collaborative AR systems that track without using wearable technologies or fiducial markers, because the great amount of AR applications nowadays are supported by mobile phones that normally do not use these tracking techniques. Furthermore, it is important to point out the existence of requirements established by the society for the wearable AR systems to be sufficiently attractive, comfortable, optically transparent and inexpensive, in order to be used in everyday collaboration by users, as Feiner said in [12].

In relation to this, we think that mobile phones are now the best devices to promote collaborative mobile AR applications, because of their world wide acceptance, and more specifically the smartphones are achieving a high affirmation that is going to increase in the next years as we can see in [13].

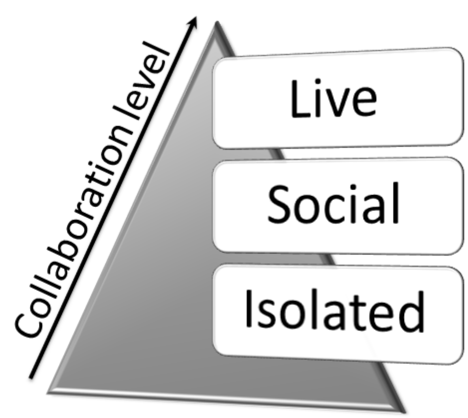

Figure 1. Collaborative Content Generation Pyramid

3 COLLABORATIVE CONTENT GENERATION PYRAMID

As AR is already an active and dynamic research and development area, and due to its immaturity and rapid growth, there still exists a lack of conceptualization. As a consequence, some interesting properties like the content generation differences between applications are not placed in any existing taxonomy. Definitions and taxonomies are essential tools that lead to a better understanding and optimization of research and development processes. Nowadays, a big effort is being made to achieve this kind of tools, as can be seen in the work of the World Wide Web Consortium (W3C) to define standards for managing common AR resources including geolocation [14] and camera [15].

While studying the AR environment and the coexisting applications, we have noticed that there is a concrete characteristic that differs from one application to another. This characteristic is the way that the content to be shown as information overlays is generated; the collaboration capabilities each application enables is directly related to this characteristic. According to the idea of different content generation approaches, there are some applications that use a centralized content creation and management approach. Others present information generated by the end user in a real time manner. Between these counter approaches there is still a wide range of others, each of those requiring a different kind of technology and architecture.

To overcome the lack of a general taxonomy that represents the previously discussed characteristic, we propose a new categorization: the Collaborative Content Generation Pyramid (illustrated by Figure 1). This taxonomy classifies the AR environment starting from a main criterion which is the content generation as introduced before, but taking into account some other strongly related concepts such as the technology and architectures needed and the user perceived impact. Following these ideas we have defined three different levels (Isolated, Social and Live), which will be explained in details in the following sections. The pyramidal structure of the classification comes from the fact that each level is supported by the architecture and technology of the lower levels.

In the next subsections this classification is presented by describing its levels and their characteristics. In section 4, the use of this classification as a categorization tool is illustrated.

3.1 Isolated Level

This level includes any application that uses a centralized content generation and management. That is, every application in which the information forming different overlays is created or gathered by the application team and managed only by the application's servers. The user receives a content that is related to the point of interest (POI) that he is looking at, only if this point is registered with associated content in the application's server. There is no contribution made by the end user to the content repository as the user is just a consumer of information and does not participate in the generation nor improvement of the content. As a result, the collaboration in this level is minimal.

However, this is an important level to study not only because of the existence of applications matching with its characteristics, but also because it is the technological and architectural base for the upper levels.

Figure 2. Isolated Level architecture.

The architecture that supports this kind of systems is in most of the cases similar to the one showed in Figure 2. The main part of the scheme is the application server, which contains all the content to be shown as information overlays. This level is named isolated because this server is not related with other services, appearing as the only source of information for the client part. The client part may be a smartphone containing different physical context devices such as camera, compass and accelerometer, being able to access external context devices such as the GPS. Diverse final applications use different sets of these devices to achieve AR.

The applications of this level are mainly based on context awareness. They use the environmental information around the user in order to enhance the mechanisms of AR, improve their performance [16], and be aware of this environment and react accordingly to the user's context [17].

3.2 Social Level

The Social Level is located in the middle of the previously defined pyramid and it refers to any application that presents information layers generated by the collection of different content sources. Not only corporations such as Wikipedia, Ebay, Amazon or the application itself share their data, but also the end users generate and share contents via social networks (Facebook, Twitter, Blogger, etc) or by direct upload to the application server. The user is able to select a POI and attach some information to it that will be stored and shown to other users. The social environment of each user is collaborating dynamically in order to create content that leads to context generation.

In this case, the architecture becomes more complex due to the fact that it has to support the collaboration among many participants, as shown in Figure 3. The application server must allow dynamic content addition. The client part is similar to the one described in the Isolated Level, with the extra capability of uploading content to the server and accepting it from diverse sources.

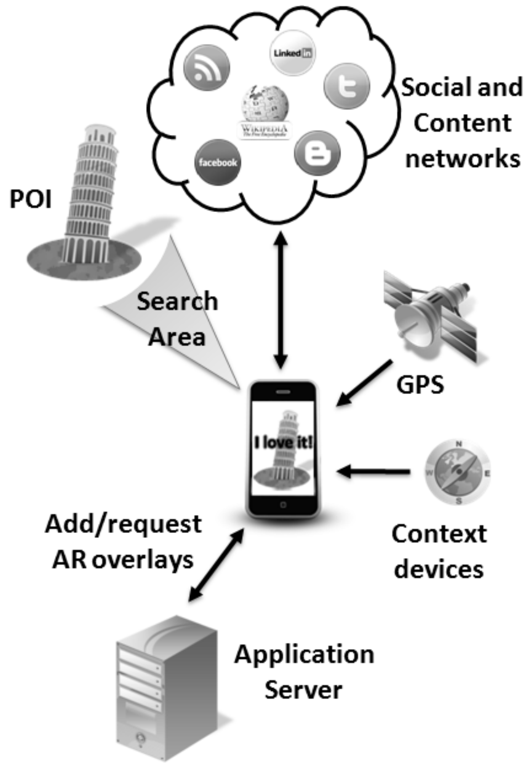

Figure 3. Social Level architecture.

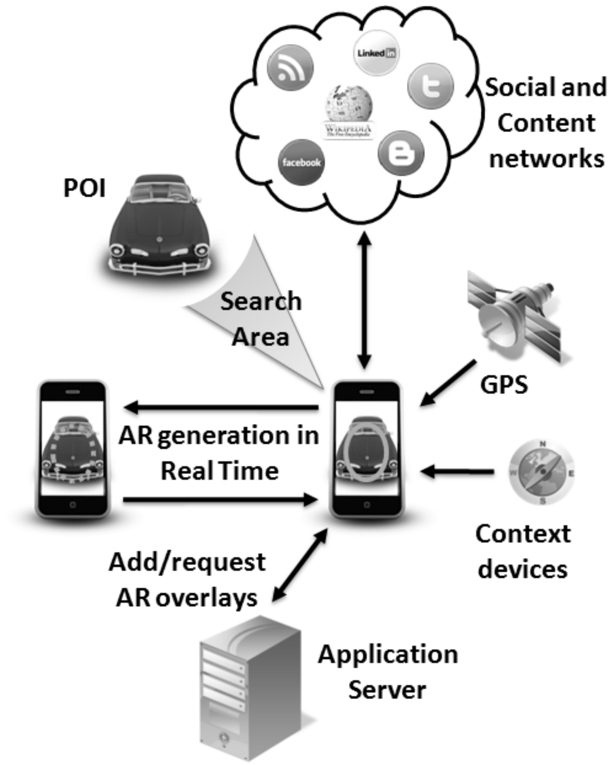

Figure 4. Live Level architecture.

From the entire explanation, the mobile collaborative AR starts in this level. The power of social networks combined with the potential of AR and the characteristics of mobile devices, enables the creation of real collaborative applications in which the end user is the one that creates the most interesting information. Other users will consume it as overlays over the real world. Social awareness is generated in this level, what can be used to enable many different types of collaborative applications [18]. The majority of applications being developed and released nowadays takes place in this level of the pyramid and since their importance and acceptance are growing, new ways of collaboration are to be opened.

3.3 Live Level

The top level within the Collaborative Content Generation Pyramid corresponds to the applications that share information overlays generated in real time. More explicitly, in these applications two or more users connect with each other and contribute in the live generation of AR content as layers over the POI captured by one of the users. The generated content can be stored in order to be available for future use, or it can be simply session persistent. This level also takes advantage of the social networks as explained in the Collaborative Level.

To support such kind of applications, a completely distributed architecture is needed. Therefore there is more than one possible solution, including P2P. In Figure 4, an abstraction of a possible architecture is represented, showing the interaction among users, the generation of content over the search area of one of the users, and the sharing of the content. Applications based on this level require all the technology offered by the lower levels and additionally a technological solution for real time communication.

Focusing on collaboration and new ways of interaction among users, there is still a lot to explore in this level. Real time collaboration using AR appears to be in its early stages of development and there is a lack of working applications supporting it, but the opportunities are endless as will be discussed in following chapters.

3.4 Analyzing the Pyramid Characteristics

Depending on a certain level of the pyramid, different characteristics can be identified apart from the ones included in each category definition introduced above. Therefore, applications that are placed in different levels of the classification have common attributes.

One of the attributes studied has to do with the resources needed to support the application that vary from one level to another. This concept can be put as a combination of the technological and architectural requirements, where by technological requirements we understand the complexity of the client and server parts (from physical context retrieval devices to fast processing capabilities). When studying the resources needed for each level, it is easy to determine that applications categorized as mainly isolated require less resources. They are based on a centralized server demanding a simpler architecture and network capabilities and they do not allow users to publish their own content, simplifying the client part of the application. The applications classified in the Collaborative Level need more complex server and client parts to allow different sources to generate and include content. This makes an exhaustive use of the network and demands a well defined and in most cases, distributed architecture.

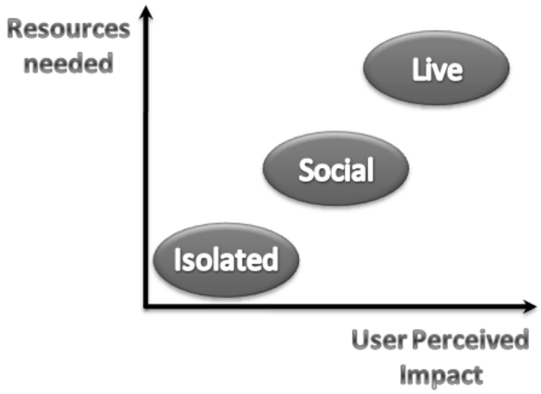

Figure 5. Resources vs Impact comparative.

Those applications classified in the Live Level, as any other real time application, need the most of the network to enable live content generation and exchange among different users. Its architecture must be completely distributed, which implies a high complexity, thus each client needs some extra functionalities (e.g. P2P support).

Another characteristic that can be considered is the impact perceived by end users. Starting from the bottom end of the pyramid, the Isolated Level, its users usually perceive a limited impact. Once a user is used to the AR experience an application using a static content source makes them perceive it as an ordinary guide, with no impression of a significant extra value, as it does not allow any collaboration.

As we follow the pyramid, the user perceived impact grows with the collaboration characteristic. According to the social media success, allowing collaboration gives extra value to users' interactions and experiences. At the top end of the categorization, the Live Level applications make users perceive the highest impact as they let them observe and participate in real time in the content generation.

The comparison between the resources needed and the user perceived impact, following the statements introduced above, is represented in Figure 5.

4 CLASSIFYING PRESENT APPLICATIONS

After defining the Collaborative Content Generation Pyramid, it is time to use it to evaluate and classify the current environment in AR applications.

We have analyzed a set of applications to present a general view of the current situation. Following the ideas explained in the early sections we take into account only mobile applications, leaving apart systems like wearable AR. Furthermore we have focused on the real market avoiding work-in-progress researches; therefore we have selected the most important applications mainly from the Android Market and the AppleStore. It is necessary to remark that nowadays no deployed applications fit into the Live Level of the pyramid. However we present some possible future developments that could take advantage of this top level collaboration.

This section illustrates how this new classification can be used to classify existing applications. It also shows how it could guide a developer to place his application in the proper level in order to find out the resources needed as well as the density of competitors existing in that level.

4.1 Isolated Level

If we focus our attention in the applications located at the first level of our taxonomy, the Isolated Level, we quickly discover that these kinds of systems were the initial AR applications developed years ago for the mobile markets, because they are quite simple compared to the current applications.

We have selected two examples corresponding to that level. First, the Nearest Tube [19] developed by Acrossair to provide an AR map to inform people about where the nearest tube station is. As we can see, this application only has content generation in one direction: from the application's servers to the smartphone user client.

Another example is Theodolite [20], which offers information about position, altitude, bearing, and horizontal/vertical inclination of the user's smartphone using the context devices and the GPS to consult these data to the application's servers. As we can see, both (Nearest Tube and Theodolite), correspond to the Isolated Level architecture illustrated by Figure 2, since they are based on context awareness techniques and also, they only use the application's servers to get the AR overlays.

4.2 Social Level

The second level of the pyramid is populated by the latest applications developed. These are the most representative existing examples of how the AR can be used to enable collaboration.

In this case, while studying the social applications available in the different markets, we have found that each application enables a different level of collaboration. Therefore, it is possible to divide this level in two sublevels, low social and high social.

Some applications such as Layar [21] and Junaio [22] belong to the lower part of the Social Level due to the fact that they let users to add simple pieces of information (comments, ratings, etc.) to existing POIs, but the creation of POIs is only achievable for developers. Becoming a developer for this kind of applications requires programming skills, so the average user is not able to generate complete content.

There is another type of applications like Wikitude [23], WhereMark [24] or Sekai Camera [25] that fit in the higher part of the Social Level. The reason is that by using these applications any end user is able to create POIs and to attach simple information that will be visible for the rest of the community.

4.3 Live Level

As we remarked in the subsection 3.3, the Live Level is a research area with a motivating future. The reason for this is that nowadays we cannot find commercial applications that are capable of interconnecting several users to generate AR content in real time and in a collaborative way, following the architecture illustrated by Figure 4.

For this reason, now we are going to set out some possible use cases interesting for different areas of knowledge that will have the live properties we described before.

4.3.1 Entertainment

Building applications for this area is probably the best way to achieve high use of the Live Level. In order to establish this level architecture in the mobile world, a lot of small games for the different mobile markets could be quickly developed. Of course more complex games similar to, for example, World of Warcraft, would be killer applications in this area due to the massive users registered and the possibility of being integrated in social networks like Facebook.

4.3.2 Education

We can think about a lot of excellent use cases in this context when we talk about such kind of applications. A lection could be given following a 1 to N user connection model, where there would be one teacher and N students receiving the teachings through the screen of their mobile devices. In this way, interacting with the group by creating AR contents that everybody could see in a real time collaborative experience could be possible. Additionally, if we take a step forward, the application could record the classes in order to reproduce them in the future. Also it exists the possibility of adding AR notes and share the videos with the rest of the class in a social way via Facebook, Twitter, and so on.

4.3.3 Medicine

If we think in an isolated geographical zone (like a small town or village) where it is difficult to access and, as a consequence, receiving medical assistance is complicated, the use of live applications would be quite useful. Thus, we could use an application following the Live architecture to connect directly to the family doctor to for example, show him a person's wound and then ask him how to clean it.

Another use in this context is focused on medical distance examinations, because using the camera we could show a sick person to the doctor, and then he could explain us how to treat the illness via generating graphical or textual information overlays in a real time manner. Furthermore, if we think in an uncommon illness, with this kind of application, we could interconnect a group of experts from different medicine areas to make a medical examination in a collaborative way.

5 Conclusion and Future Works

Along this paper we have proposed some important definitions to conceptualize and classify the current paradigm in collaborative mobile AR applications, in order to clarify what are the architectures behind these systems.

We started with an analysis of the current background related to this field, discovering that the joint of both worlds (mobile collaboration and AR) has created a new area where everyday new mobile applications emerge.

Then, we defined the Collaborative Content Generation Pyramid, a taxonomy divided in three levels according to the way the AR content is generated in these mobile applications. Also, the architectures used to build this kind of systems are described to help developers understand what type of application they want to achieve, and what the necessary components are.

After that, we used the taxonomy to classify a set of real applications present in the different mobile markets. Besides, we proposed some use cases of Live Level applications in order to remark that this level is nowadays an interesting research area.

Furthermore, we believe that one of the most important problems of the taxonomy's top levels, i.e., the real time graphic rendering of all the AR content overlays in the client side, will be solved by initiatives like OnLive [26], which pretends to carry out all the graphic rendering related to a gaming platform using cloud computing techniques. Therefore, with this kind of methods, the generation of the AR content for the mobile devices in a cloud computing way could help to reduce the charge on the client side.

Following the idea of using cloud computing techniques in this area, we propose to use cloud-based content and computing power resources to improve the scene, the rendering and the interaction as Luo said in [27], because it is an important factor to increase the power of mobile collaborative AR applications.

Additionally, taking into account that current AR applications have different models to identify POIs, we think that it is important to create standard APIs or communication formats, in order to be able to share overlays created by each user in any application domain, instead of repeating the same AR content in every application related to the same POIs. With this is mind, we have been following the outcomes from the W3C Workshop: Augmented Reality on the Web, where some related research work was proposed. One of it was the suggestion of Reynolds et al. [28] to exploit Linked Open Data for mobile augmented reality applications in order to solve the previous problem of content redundancy.

One more interesting research line could be the addition of another dimension to the taxonomy described along this paper. The purpose of this new dimension would be to analyze and illustrate the social impact of using this kind of applications, i.e., the number of users collaborating at the same time and how this affects the user experience.

Finally, to conclude, we believe that the definitions presented in this paper can help to order and classify the current confuse AR environment, and also, they are solid foundations capable of supporting all the present existing AR applications, and all the future and exciting ideas that certainly will appear in this area.

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