Augmented Reality Technology and Art: The Analysis and Visualization of Evolving Conceptual Models

Vladimir Geroimenko
School of Art and Media
Plymouth University
Plymouth, UK
vladimir.geroimenko@plymouth.ac.uk

Abstract

This paper provides a logical and methodological reconstruction of the evolving concept of Augmented Reality (AR) and also of the paradigmatic shift in art, caused by this emerging technology. It starts with an analysis of the notion of Augmented Reality, that leads to the construction of a conceptual model and a definition which together capture the nature of present AR applications. This is followed by a detailed conceptual analysis of major types of Augmented Reality that contribute to an understanding of current concepts. Finally, the resulting conceptual models are applied to the newly emerging field of Augmented Reality Art in order to assess the paradigmatic potential of AR as a new artistic medium.

The paper puts a strong emphasis on the effective and adequate visualisation of the analysed conceptual frameworks, in order to promote a better comprehension of the logical structures underlying the notions of Augmented Reality and AR Art. This paper was intended to be presented at the opening of the First International Symposium on Augmented Reality Visualisation and Art, proposed and chaired by the author as part of the 16th International Conference on Information Visualization, IV2012.

Keywords--- **Augmented reality, augmented reality art, logical and methodological analysis, conceptual model, visualization, concept visualization**.

1. Introduction

The idea of Augmented Reality (AR) has been around for two decades, being from time to time successfully implemented in some, mostly scientific or military, projects. However, the arrival of smartphones and the advances in Mobile Augmented Reality in recent years have aroused a real interest in this technology among an extremely wide audience and many dedicated commercial companies. At the same time, research activity in the field of Augmented Reality has increased significantly. Our simple analysis based on the Google Scholar Search [1] has showed that while the number of academic works on Augmented Reality published in 2008 was 2100, in the following year 2009 there were 3700, 5600 in 2010, and 5100 in 2011.

Why has Augmented Reality become so popular? There are several reasons, some from the past and some recent. First, it's because Augmented Reality is a natural way of exploring 3D objects and data, as it brings virtual objects into the real world where we live [2]. Second, it's because the possibilities of AR are endless, such as information visualization, navigation in real-world environments, advertising, military, emergency services, art, games, architecture, sightseeing, education, entertainment, commerce, performance, translation and so on [3]. All the afore-mentioned features of AR have already been known for some time. What has really brought Augmented Reality to life in the recent years is that AR applications are now available on any smartphone or similar portable device (such as iPad) and, in other words, AR has moved from scientific labs to the pocket of the man in the street.

In principle, AR can be implemented on any computer and handheld device that use video-see-through technology that allows to "see through" the display to view both the real world and superimposed computer-generated objects. However, only the recent Mobile AR applications for iPhone, iPad and Android, such as Junaio, Layar and Wikitude [4] have brought this technology to the masses.

Information Visualisation and Augmented Reality Art seem definitely to be among the numerous areas where Augmented Reality is going to thrive in the near future. In terms of a commercial interest and success, the most promising AR applications could be in the field of AR games [5]. This new type of video games allows gamers to run around a level of their favourite game, and to battle life-size "bad guys" and monsters. AR games immerse the gamer not in an artificial world of Virtual Reality, but in the physical world, and therefore need to be played in a more active and healthy way, rather than sitting statically and staring at a screen. "Using AR, it is

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possible to achieve a level of immersion that is beyond what most people associate with video games" [2, p.7]. Some current games provided, for example, by Nintendo Wii are far from being passive, but they need to be played indoors. AR games take the gamers outdoors and immerse them in the vast physical world.

All the recent advantages in the field of Augmented Reality have led to the necessity of rethinking the evolving concept of AR and reconstructing underlying logical structures and conceptual models. The visualization of these abstract models could contribute significantly to their more adequate perception and a deeper understanding.

2. Augmented Reality: The Concept and Relationships with Physical and Virtual Worlds

The definition of Augmented Reality has had a rather long history, because most publications on AR include a defining statement that starts with "Augmented Reality is ..." On the one hand, the limited length of this paper does not allow us to research this history. On the other hand, such research would not have had a considerable impact on an up-to-date understanding of the Augmented Reality concept, since it has been evolving considerably all the time, following the advances in the AR technology. This is why our focus will be on just a few recent high-impact works that deal with the concept and definition of Augmented Reality.

In his book "Augmented Reality Browsers for Smartphones" [4, p. 4], published by Wiley/Wrox in 2011, Lester Madden attempts to provide a broader and all-encompassing view of AR, and defines Augmented Reality as a technology that has the following five features:

- It combines the real world with computer graphics
- It provides interaction with objects in real-time
- It tracks objects in real-time
- It provides recognition of images or objects
- It provides real-time context or data

This example makes it obvious that the job of defining Augmented Reality is far from being easy. The provided definition has captured some essential features of AR, but not all of them. As illustrated in Figure 1, it is overlapping with an "ideal" definition of AR (intersection 1), but is not identical to it for two reasons. Firstly, some features have not been included into the proposed definition (shown as area 2). For example, location-based AR is one of the main types of Augmented Reality, but it does not comply with all of the 5 features, since it doesn't track objects and isn't based on recognition. The second reason is that the proposed definition allows the inclusion of things that can hardly be named as AR, such as fiduciary markers that by no means "are the truest form of AR" [4, p. 5], barcodes and QR codes [4, p. 6-7]. On the Euler diagram in Figure 1, it's shown as area 3.

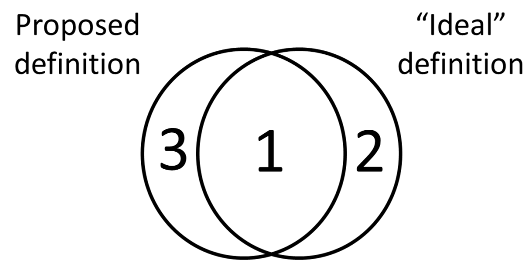

Figure 1 A comparison of the proposed definition with the "ideal" definition of AR

According to Wikipedia, Augmented Reality is a live view of physical, real-world environments whose elements are augmented by computer-generated sensory input such as sound, video, graphics or GPS data [3]. In general, this is a good definition, though, for example, in the case of Audio AR no view or any visual display can be provided. In addition, in many AR applications, we are dealing with AR objects that are embedded in the whole physical environment rather than augmenting any particular elements of it.

We will try to construct a definition of Augmented Reality using the "analysis – synthesis" approach. This approach is the most effective one, traditionally used in philosophy and methodology of science. It consists of two stages: analysis (when we analyse and "disassemble" the concept in question in order to reveal its bare logical structure) and synthesis (when we try to "assemble" the logical structural elements and to express their organisation in one of the most appropriate verbal forms).

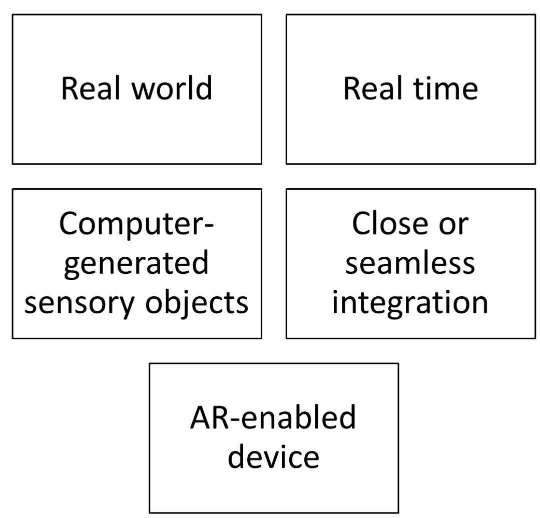

Figure 2 A logical structure of the concept "Augmented Reality"

Figure 2 shows the results of our conceptual analysis. The logical structure of the concept

"Augmented Reality" consists of the following "building blocks": (1) the presence of the real world; (2) real time; (3) the presence of computer-generated sensory objects (sensory means related to or using human's senses of sight, hearing, smell, taste, or touch); (4) close or seamless integration between the real environment and the computer-generated content; (5) the use of an AR-enabled device.

The analytical stage of the approach provides a logical framework for a definition that can be synthesised from the conceptual building blocks. At this stage, some suitable verbal expressions have to be found, to present the definition in a clear and comprehensible form. As the result of the synthesis, our definition can be verbalised as follows:

Augmented Reality (AR) is a real-time device-mediated perception of a real-world environment that is closely or seamlessly integrated with computer-generated sensory objects.

The description and especially visualization of the relationships between Augmented Reality, on the one hand, and the Real World and Virtual Reality, on the other hand, is highly important for an in-depth understanding of the nature of Augmented Reality.

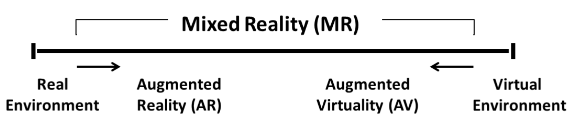

Figure 3 The Reality-Virtuality (RV) Continuum, according to [6]

The widely cited "Reality-Virtuality Continuum" is a concept, introduced by Paul Milgram et al [6], that describes and visualises a continuous scale between completely Real and completely Virtual Environments (see Figure 3). It also uses the concept of Mixed Reality (MR) in order to describe two possible combinations of Real and Virtual Reality, namely Augmented Reality (the virtual augments the real) and Augmented Virtuality (the real augments the virtual).

Despite the fact that Milgram's Reality-Virtuality Continuum was intended to show ***continuity*** between the virtual and the real, it actually presents four different ***states*** as all the possible combinations of the virtual and the real: "Real Reality", "Augmented Reality", "Virtual Reality" and "Augmented Virtuality". These four states can be visualised in the context of a different (non-continuous) conceptual model that provides a slightly dissimilar view of the construct "Real/Virtual/Mixed Reality". For example, Figure 4 visualises the four possible combinations of the two realities using an "interpenetrating" conceptual model.

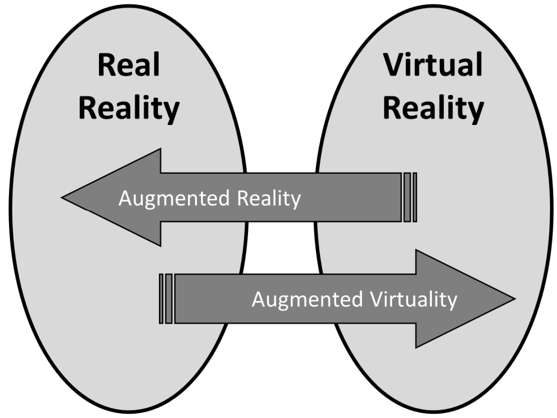

Figure 4 An interpenetrating conceptual model of the relationships between the Real (Physical) Reality and Virtual Reality

Figure 5 represents another conceptual model that can be titled "The Yin and Yang of the Two Realities". In our opinion, it's a rather obvious interpretation of the concept of Yin Yang that is used in Asian philosophy to describe how polar opposites or seemingly contrary forces are interconnected and interdependent in the world [7]. "AV" stands for "Augmented Virtuality".

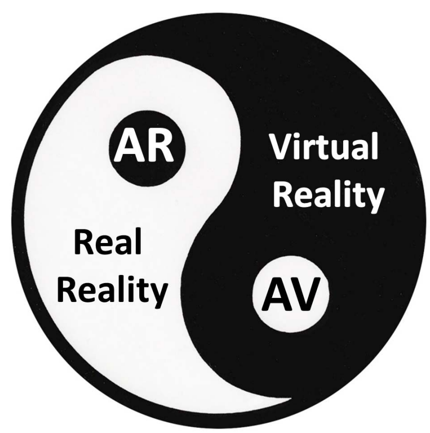

Figure 5 The Yin and Yang of the real and the virtual

Work on the construction of a variety of conceptual models and visualisations is important because it can significantly contribute to the understanding of the notion of Augmented Reality, providing either diverse or just slightly different views.

3. Types and Conceptual Models of Augmented Reality

The definition of Augmented Reality is the most important step in the understanding of its concept, but it is only the first one. The next step that can contribute significantly to our understanding is the analysis of different types of AR and their possible classifications. This step is not as strictly logical as the definition of AR. Classifications can be based on a variety of principles and therefore can be rather dissimilar. There is no lack of taxonomies in the literature on Augmented Reality. Many authors and publications name and analyse the existing and future types of AR [2; 3; 4; 8; 24]. In this paper, we will try to consider only those types of AR that seem to be the most important and central for the further understanding of the conceptual models on which the notion of AR is based.

Let's start with a simple question and a simple answer. "... What exactly is AR? In its simplest form, AR is the art of super-imposing computer graphics over a live view of the real world" [4, p.xxi]. Definitely, this is an answer, but does it refer to Augmented Reality as a whole, or merely to a particular type of AR that exists alongside with several others? Augmented Reality based on computer graphics is not the only type of AR related to human senses, i.e. the five natural powers of sight, hearing, feeling, taste and smell. Figure 6 shows a sensory-based classification of AR.

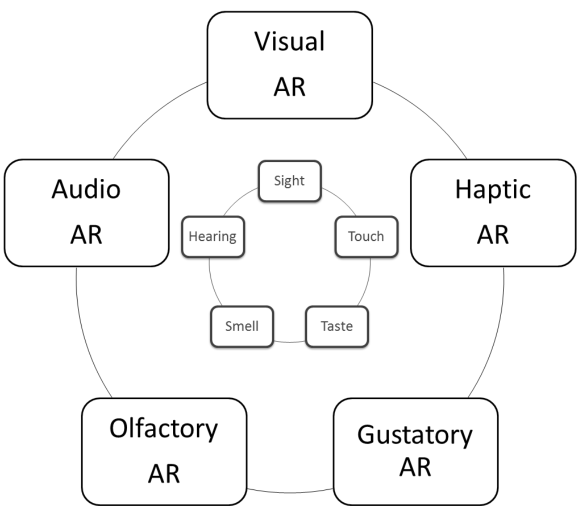

Figure 6 A classification of Augmented Reality based on human senses

Visual Augmented Reality is the most common type of AR and is often described as simply "Augmented Reality". In the case of Visual AR, computer graphics, embedded in the real world, is not visible to the naked eye and hence requires the use of a display, such as a computer monitor, a television or a smartphone. Audio AR embeds not digital graphics, but digital sound into physical world [9]. Haptic AR is a type of AR that allows the user to touch and feel augmented reality objects placed into a real-world environment (see, for example, [10]). To achieve this effect, the user needs, for instance, to wear a special Virtual Reality (VR) gloves, well researched and developed in the field of Haptic VR (see, for example, [11]). The remaining two type of sensory-based AR that could augment the real world with smell and taste are possible in principle, but they can hardly be implemented successfully in the near future. They can be called Olfactory AR and Gustatory AR respectively.

We can imagine an example that presents an application of Olfactory AR (Figure 7). It shows a future generation of smartphones that allows you to smell a rose or other flowers just by pointing the smartphone's camera at an image of the flower. Although, this looks like a distant future, some research into "Smell Enhanced Augmented Reality" is being conducted at present [12].

Figure 7 An imaginary example of an Olfactory AR application

The classifications of AR are not cast in stone; they are evolving, following the progress of AR technology. Let's analyse the main types of AR in the context of their conceptual evolution. To start with, AR applications can be divided into two classes depending on whether or not they are using a marker. Sometimes these two types of Augmented Reality are called "Marker and Markerless AR" [2; 4]. It's important to note that this classification implies that "Marker AR" is the main type of AR, because it can be used for defining the other type of AR as "Markerless AR".

What is a marker? In the broadest sense, an AR marker is an image or a view of real-world objects that provides a unique pattern that can be captured by an AR camera and recognized by AR software. The pattern may range from an obvious one (such as a barcode) to a concealed one (such as a landscape painting or even a human face). After a marker has been recognized by AR software, the software calculates the correct position and orientation of a relevant virtual object and embeds it in real time into the real environment on the top of or near the marker.

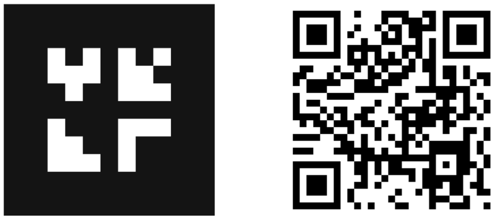

Figure 8 An example of fiduciary markers: a FLARToolKit AR marker (on the left) and a Quick Response (QR) code (for the VG Art Gallery www.geroimenko.com)

Historically, the notion of the marker was a starting point in the definition of AR. It was used to define the opposite type of AR as “markerless”, i.e. not based on a marker. The term “Marker AR” seemed to be adequate for a long time during which different types of fiduciary markers were used (see Figure 8). However, the latest development in the field of AR has led to the use of human faces as a marker and, as a result, made the term “Marker AR” less suitable for describing this particular type of AR. Therefore, it is a good idea to try to replace it with another term that could sensibly be applied to the entire range of “markers” – from printed QR codes and AR markers to human faces. What is common between them is not the concept of a marker (it’s rather inhumane to classify a human as a marker), but the notion of pattern or image recognition. From this point of view, the term “Recognition-based AR” seems to be the most appropriate one. Since it can be a contentions question, we will consider it in more detail.

“Marker AR” technology uses fiduciary markers as a point of reference that defines the position, orientation and scale of an AR object in the physical world. If the object is a 3D one, then by rotating the marker the user can view it from 360 degrees. We can argue with the assertion that “fiduciary markers are the truest form of AR because they are used to track objects in the real world” [4, p. 5]. Firstly, a marker is not a form of AR, but merely an important part of a particular AR technology. Secondly, what makes the specifics of AR is not tracking, but embedding digital objects into a real environment.

Can standard barcodes and QR codes be considered as forms of AR because they include the process of recognizing a marker [4, p. 6-7]? We think not. Image recognition is an important part of Marker-based AR, but this is not the essence of Augmented Reality. Image and object recognition is a broad and relatively independent field, and we cannot label its numerous applications as “Augmented Reality”, because it is simply a technology, effectively used in a particular type of AR. We would suggest that this line of argument can help to distinguish between two major types of Augmented Reality, namely Recognition-based AR and Location-based AR.

For a deeper understanding of the nature of “Markerless AR”, we will consider the following statement: “Markerless tracking is where AR is used to track objects in the real world without using special markers. Face recognition is an excellent example” [4, p. 9]. Strictly speaking, face recognition is not an example of Markerless AR. Despite the fact that human face is something rather different from a printed AR marker, functionally it works in the same way as any other marker and is, actually, a very specific and highly complicated type of marker. We can talk of a human face as of a “natural marker”, for example, but functionally it still is a marker.

The following simple experiment could clarify the concept further. Imagine a person that is holding a live-size photograph of their face. You are using a smartphone to explore AR objects “connected” to the person’s face as well as to the photograph. If face recognition software works well enough, we can experience absolutely the same results. It means that in this experiment we are dealing with two examples of Marker-based AR. For AR software, a human face is the same marker as its photograph and the software is able to recognize it only because a digital image of the face has been stored in its database alongside with other type of markers, such as printed ones.

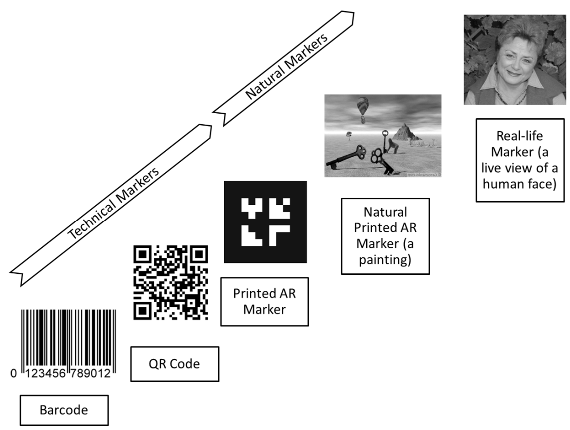

Figure 9 The evolution of markers in pattern/image recognition technology related to AR applications

In other words, we can distinguish between the following three types of AR markers: digital markers (for example, an image on a computer screen), printed markers (for example, a photograph in a magazine), and natural markers (for example, a human face). In addition, AR markers can be classified as technical (for example, a QR code) and natural (for example, a photograph, a human face or a view of a real-world environment).

Technical markers are nothing else but clearly visible geometrical patterns and therefore they do not look user-friendly (see Figure 9). Natural markers, such as the cover of a magazine or an advertising poster, can be used in the same way, but they are much more attractive and common for the user.

Though the difference between a printed AR marker or QR code and a human face might look massive, in terms of recognition technology, both of them contain some visual patterns (the pattern of a printed AR marker or QR code is quite obvious and the "pattern" of a human face is deeply concealed) that have to be identified, extracted and compared with a reference pattern on the server. Hence, we are dealing with different levels of the pattern recognition technology, rather than with different types of AR. All of the above examples are examples of Recognition-based AR applications.

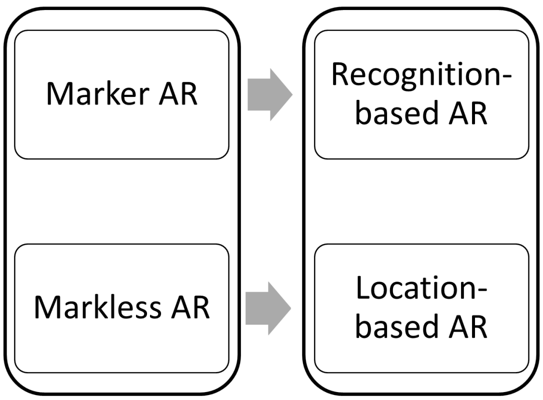

Figure 10 The evolution of the conceptual model of Augmented Reality

An interesting comparison between Location-based AR and Recognition-based AR can be achieved by conducting another simple "experiment". Imagine that you have an example of each of them and then you simply cover the camera lens of the smartphone. In the case of Recognition-based AR, AR objects will have disappeared and there will be nothing on your display. In the case of Location-based AR, all AR objects will be still shown, even when the view of the physical world will have disappeared. Lester Madden [4, p. 5] rightly points out that because the use of the camera in this case is largely superficial (the application neither knows nor cares about what camera sees), some people can argue that this is not a true example of AR.

Location-based AR is one of the two main types of Augmented Reality. It places computer-generated objects into a real-world environment based not on its visual features than can be used as a marker, but on the position (the latitude, longitude and altitude) of the AR object in the physical environment. The AR objects can be closely or seamlessly integrated with physical objects in both cases, but because of the different nature of the two types of Augmented Reality, obstructing the camera's view will have a different effect. In the case of Recognition-based AR (aka Marker AR), the AR objects will have disappeared, in the case of Location-based AR (aka Markerless AR) they will not have disappeared, but it's easy to program their disappearance when no structured input from the camera is available. Figure 10 summarises and visualises the evolution of the conceptual model of Augmented Reality from "Marker/Markerless AR" to "Recognition/Location-based AR".

4. AR Art and its Paradigmatic Conceptual Model

It stands to reason that Augmented Reality Art is a recent phenomenon in the field of art, because it is based on AR technology and therefore could not come into existence before a certain point in time. However, despite this obvious logic, some implicit conceptual prototypes of this radically new type of art can be found in the cultural history. We will consider just two of them to serve as examples.

In the famous children's novel "The Wonderful Wizard of Oz" [14] written by L. Frank Baum and published in 1900, there is something that could be clearly interpreted as an early conceptual prototype of architectural AR art. The story describes the adventures of Dorothy and her friends in the Land of Oz, where they follow the road of yellow bricks to go to the "Emerald City" or "City of Emeralds" (see Figure 11).

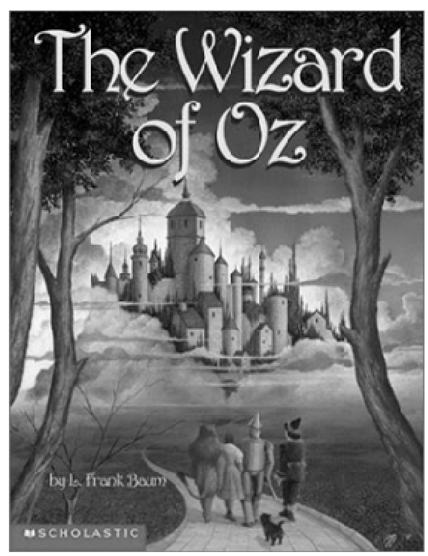

Figure 11 The cover of the book "The Wizard of Oz" depicting the green-coloured Emerald City (image from [15])

In our opinion, the Emerald City can be understood as a piece of augmented reality art created by the Wizard of Oz. A "translation" of this part of the well-known story into today's language of AR technology could go as follows. Because all citizens and visitors of the

Emerald City had to wear green AR spectacles, they were seeing not ordinary grey architecture, but an AR masterpiece where "the streets were lined with beautiful houses all built of green marble and studded everywhere with sparkling emeralds" [14]. Quite obviously, the City of Emeralds was not only an ideological and architectural creation of the Wizard, but also a brilliant AR artwork.

Furthermore, the Wizard used other features of the AR spectacles. He himself appeared as something different to each of the visitors: Dorothy saw a giant head, the Tin Woodman saw a ravenous beast, the Scarecrow saw a beautiful woman, the Cowardly Lion saw a ball of fire. It was like a miracle, but nowadays it would be easy to implement such "transformations" using AR technology, its marker or face recognition features and a pair of specialist AR glasses, or just any smartphone.

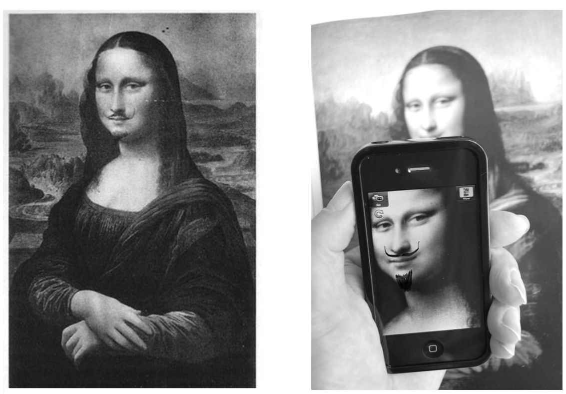

Figure 12 Marcel Duchamp's artwork (on the left, image from [16]) and our AR-based implementation of the same idea using the Junaio AR browser

Another example that could be interpreted as a pre-technological conceptual prototype can be found in the Dada movement. In 1919, one of the leading Dadaists Marcel Duchamp pencilled a moustache and goatee on a reproduction of Leonardo da Vinci's Mona Lisa. The idea of the augmentation of real-world objects by using them as AR markers and putting some AR objects on top of them is one of the major techniques in the current Augmented Reality Art. This is why the Marcel Duchamp's idea is "native" to AR Art and can be easily implemented at the present time. Figure 12 compares the Marcel Duchamp's implementation of the idea with our AR prototype. It is interesting to note that our AR "artwork" can be viewed not only on any reproduction of Leonardo da Vinci's Mona Lisa, but also on the original in the Louvre Museum.

Despite the fact that some early implicit ideas can be found in the cultural history (and not everyone would have agreed with such interpretation of them), Augmented Reality Art is a novel phenomenon that is based on the utilisation of the creative potential provided by AR technology [21; 22; 23]. In order to understand "how big" this phenomenon could be, we will consider its underlying conceptual model and a possible paradigmatic shift in art caused by the arrival of Augmented Reality technology.

Augmented Reality Art, as a mode of creative expression, could exist in numerous forms, many or even most of them impossible to imagine at the current initial stage of its development. For this reason, only a general definition of AR art is possible at the moment, and it can be articulated as follows:

Augmented Reality Art is artwork exhibited in a real-world environment using AR technology.

The underlying conceptual model of AR Art is so different from all previous forms of art (we will call them collectively "Pre-AR Art") that AR Art can be named as "the next big thing" or "a new paradigm" in art, because it can lead to revolutionary changes in the distinct concepts and thought patterns about how artwork can be produced and presented to the audience in real-world locations and environments.

Figure 13 compares some of the main features of Pre-AR Art and AR Art. It shows that AR Art has several big advantages over its "predecessor". AR Art is not limited spatially, it's not expensive to produce and exhibit, and it can be easily made interactive, animated and multimedia.

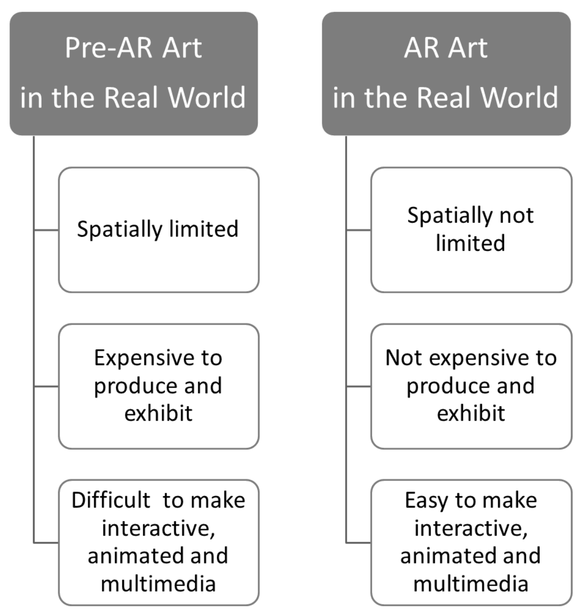

Figure 13 A comparison between Pre-AR Art and AR Art

In order to construct an initial conceptual model of Augmented Reality Art, we need to consider these and other defining characteristics of this novel form of art in more detail.

The first major feature of AR Art is that this is art without spatial limits. Artwork can be exhibited in any location at any time. For example, artists can display their paintings on trees in a park, on the Empire State Building, on the seabed or in any other real-world places they can only imagine. From technological point of view, it does not matter at all, though from creative, artistic and cultural points of view, it does.

The "chosen" and most attractive locations for exhibiting AR Art are those where artwork is supposed to be exhibited, namely famous art galleries and museums. In an era of AR Art, artists do not need to wait until their masterpieces are selected for displaying in the Louvre or other world famous art museums and galleries. They can put their artwork in there right away and without asking for permission.

For example, a New York-based artist Amir Baradaran infiltrated the Louvre Museum on 27 January 2011 to permanently install his artwork titled "Frenchising Mona Liza". It is a 52-second video, streaming live over Leonardo da Vinci's painting [17]. Another example could be the "Art Invasion" AR exhibition in the MoMA (The Museum of Modern Art in New York), which was opened on 9 October 2010 to show the radical new possibilities and implications that Augmented Reality is bringing to the cultural and creative field [18].

In AR Art, the expense of producing and displaying artwork is minimal and does not depend on the size and the number of copies. For example, we can imagine a project in which an AR artist could easily create a 50-metre tall statue and then put a copy of it on each square kilometre of the land surface of our planet (i.e. about 150 million statues in total).

Figure 14 An iPhone screenshot showing Boffswana's Proto in a real-world environment (in the university's office of the author of this paper)

Since AR Art is, basically, digital art embedded into a real-world environment, it can easily be made animated and interactive. Also, any multimedia elements can be added to AR artwork. Animation and interactivity may play a crucial role in adding a 3D digital object to the real world in such a way that it appears to belong to the physical environment. For example, Proto is a green three-eyed creature created by the Boffswana Company [19] from Australia using the String™ technology. Proto is animated and interactive: from time to time, he scratches himself, and tapping on the screen makes Proto move around to any place you command him to go (see Figure 14).

In terms of time, AR Art has big advantages over physical Pre-AR art. AR artwork can be exhibited forever (or, at least, for as long as an AR server is alive and available). AR artwork cannot be stolen, vandalized or damaged by the elements, even if it is being displayed outdoors in a public place, such as in the middle of a city square.

AR Art has several other features that make it quite different from Pre-AR art. One of them is the possibility of exhibiting numerous artworks in exactly the same location at exactly the same time. For example, ten AR artworks by ten different artists may be displayed at the same time in the middle of a city square, such as Red Square in Moscow. Each of them can be viewed using different AR channels or applications.

Another remarkable feature of AR Art is the possibility of not only adding AR objects to a real-world environment, but also of hiding and replacing physical objects. It should be noted that a similar artistic technique has sometimes been used in "traditional physical art" as well. A good example is the wrapping of the Reichstag in Berlin and Pont-Neuf Bridge in Paris by Christo and Jeanne-Claude [20].

Real World and Technology Based	• AR Art is artwork exhibited in a real-world environment using AR technology
Any Exhibition Space	• Art without spatial limits • Can be exhibited anywhere
Any Size, Low Price	• Not expensive to produce and exhibit • Size and number of copies doesn't matter
Animated and Interactive	• Easy to animate and add multimedia • Easy to make interactive
Everlasting	• Potentially eternal art • Cannot be stolen, vandalised or damaged
Total Coexistence	• Several pieces of AR Art can be exhibited in the same space at the same time
Addition and Subtraction	• AR objects can be added to the real world • AR objects can hide/replace real-world objects
Viable Alternative	• Is able to replace most of Pre-AR art forms • Can be an alternative to physical artwork

Figure 15 A basic conceptual model of Augmented Reality Art

The above description of the conceptual model on which the notion of Augmented Reality Art is based has hopefully been able to capture some of its main components, but it is far from being finished, because currently AR Art is an area of extremely quick and deep transformations. More work is required in order to comprehend the nature of these changes and the rapidly evolving conceptual models of this emerging novel form of art.

Figure 15 summarises our reasoning and findings. As a whole, it shows the paradigmatic importance of emerging Augmented Reality Art and its great potential for the further development, which could lead to the replacement of many current real-world art forms by their AR Art alternatives.

Conclusions and Future Work

The recent advantages in AR applications have led to a significant shift in the understanding of the nature and types of Augmented Reality. This has generated a need for a logical and methodological analysis of this evolving field, and the construction of conceptual models that can facilitate a better and deeper understanding of Augmented Reality and its novel areas of applications, such as AR Art. A combination of a traditional analytical/synthetic method with effective visualisation and the use of simple examples and imaginary experiments have allowed us to research and clarify the definition of Augmented Reality, its most significant types, and the underlying logical structures and conceptual models, including in the emerging area of AR Art.

However, the current progress in the field of Augmented Reality and AR Art requires constant logical and methodological attention. This work is just a step toward further understanding the evolving concept of Augmented Reality. Future work is needed to improve several aspects of the proposed conceptual models and we are open to discussion.

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