Introduction

1

Abstract

Augmented reality will do more than just give us directions, and visualizations of products. In time, Augmented Reality will integrate with body sensors to monitor our temperature, oxygen level, glucose level, heartrate, EEG, and other important parameters. We will in effect be wearing the equivalent of the tricorder.

Augmented Reality evolved from a laboratory experiment to the military and then industrial applications. The military, industrial, and scientific users, with specific and urgent needs and budget constraints were able to tolerate the limitations in comfort and performance of early systems.

Science fiction has long been a predictor of future technologies and there are many examples of augmented reality imagined by artists, writers and scientists before the technology to realize such devices, environments, and oblique ideas where not widely available (or available at all), but work was going on to make augmented reality practical.

Augmented reality is thought of as a visual system, augmented what we see with information and graphics. However, one's auditory senses can also benefit from augmented reality, with special location clues, and can be very helpful if one is blind, or partially blind.

1.1 Introduction

In 1956, Philip K Dick (1928–1982) wrote *The Minority Report* [1] and created the reality of augmented reality, information literally at our finger tips. Since then augmented reality has become—a reality.

From Pepper's Ghost to contact lenses: Augmented Reality—is where we all will live

J. Peddie, *Augmented Reality*, DOI 10.1007/978-3-319-54502-8_1

However, as prolific and prescient as Dick was, the first example of augmented reality was the concept of Pepper's Ghost used in the teleprompter developed in 1950 by Hubert Schiafly [2] (1919–2011).

We have spent the last century and half learning how to communicate with our computers, with each generation getting more natural. Starting with banks of switches, which evolved to punch cards and tape and typewriter-like keyboard, to graphics user interfaces and mice, touch panels, voice, and gesture recognition.

Augmented reality systems take us to the next phase in computer interfaces, and are unlike any interface we may be familiar with from the past. Prior to augmented reality our communications with the computer were via 2D, a flat, interface. Although amazingly effective in almost all situations, they are nonetheless limiting. Imagine seeing a tea pot floating in space in front of you, and having the desire to rotate it, to see how light bounces off it at various angles, or to see the manufacturer's or artist's name on the bottom. It can be done with a flat display, but how much more natural would it be if you could reach out to the image, turn it directly, and immediately with your fingers, and then pass it on to a companion or discard it?

Wearable augmented reality displays that overlay virtual data and images into the real world combined with new operating systems that enable a new kind of spatial computing will demand a new user interface. However, augmented reality systems are extremely complicated and complex, combined with the challenge of being lightweight, portable, and inconspicuous, and of course affordable (Fig. 1.1).

With an augmented reality system, we become part of the computer environment, rather than just an external, detached observer with limited interaction. Some commenters have said we will become the interface. This represents a revolution in computer interfaces and interaction. And because it's a revolution all the nuances and opportunities are not yet understood, nor will they be for a long time as developers and users experiment with this new way of communicating with a computer.

Now, with augmented reality, our bodies become a critical component in the process. Where are our eyes looking, where are our hands, what are we saying, and potentially what is our EEG saying?

Augmented reality mixes the completely real with the simulated or synthetic and projects images and information in the wearer's line of vision.

Almost everyone has seen the image of Princes Leia in *Star Wars* as a hologram projected from R2D2 onto some imaginary light field. As fantastic as that imagery was in 1977, we are now able to realize it with augmented reality. But instead of a science fiction light field, the ghost-like image can be seen with augmented reality.

The idea of having reams of concurrent and timely information immediately, or constantly available to you is a dream we have shared for a long time. The miracle of augmented reality is that we've taken our pocket computers and magically connected them to the enormous quantities of information stored in data clouds while feeding them our movements and locations in real-time, and accessing what we need from them. Augmented reality is also paradoxically about the efficiency of human action in relation to usable data and the avoidance of reality in the form of pictures and graphics. So, it could also evolve to a situation of "be careful what you wish for". If you have too many labels in a scene, or too many objects, it gets

Fig. 1.1 The many things an augmented reality smart glasses must accommodate (Suggested by Steve Mann)

confusing and is difficult to read. Without limits, and privacy protection (if there ever was such a thing), your augmented reality device could be inundated with unwanted and overwhelming information, advertisements, correspondence, reminders, and intrusions.

In 2006, Vernor Vinge (1944–) wrote his Hugo award winning science fiction novel, *Rainbows End*, a story about augmented reality and its moral implications and consequences. In Vinge's book, the concept of security in such an increasingly digital/virtual world with ubiquitous computing is imagined. He explores the implications of rapid technological change that empowers both the disgruntled individuals who would threaten to disrupt society and those that would seek to stop them, and the implications for the age-old "who watches the watchers" issue at the interplay between surveillance (oversight) and sousveillance (undersight). Later in 2013, augmented reality pioneer Steven Mann (1962–) gave a presentation (at TEDex) on his personal confrontations with surveillance and sousveillance [3].

Therefore, augmented reality is also paradoxically about the efficiency of human action in relation to usable data and the avoidance of reality in the form of pictures and graphics, and the balance with societal norms, expectations, tolerances, and regulatory agencies and their agents. That's a big job.

This book will identify the many aspects of Augmented Reality (AR), and will, when appropriate or necessary, refer to Virtual Reality (VR), but it should be clear to the reader that the two are quite dramatically different technologies and experiences.

Trying to describe virtual or alternate reality is tricky because it is interpretive, we all see it, and think of it a little differently from each other. Defining it in terms of the hardware used is inadequate because the hardware will change.

Augmented reality is not a thing, it is a concept that can be used by many things, and it will be a ubiquitous part of our lives just like electricity.

According to a report released in 2015 by the non-profit organization, Augmented Reality.org., Smart Glasses sales will reach one billion shipments near 2020, and surpass shipments of mobile phones within 10 years [4].

Augmented reality will completely disrupt the way we conduct our lives. Augmented reality is a new medium rather than just a new technology that will change people's lives in varied and profound ways, so it cannot be dismissed as just a topic for fiction.

A Gartner market research report predicted that the Field Service Industry could save about one billion dollars by 2017 as smart glasses enhances diagnosis and repair [5].

And, one size does not fit all, nor does one type of so-called immersive reality satisfy all markets, users, needs, or expectations.

There is no main feature to augmented reality. There are many benefits that we will get from this. I can't emphasize it too much; the name of this technology truly depicts what it is. It will generally (and greatly) augment us, and by augment that means expand, be better, be more. We will literally be capable of doing more things than we have before. Augmented reality will help (it won't completely do it, but it will greatly help) reduce the friction in our lives. We encounter friction as we go through life. Imagine you are going to go to the store. When you get to the store you find it's very crowded and you just want to get a loaf of bread. You ask your smart glasses, "Where can I get a loaf of bread where it's not crowded?" And then, up on your glasses, comes some information that says go left here and so forth. Imagine you're driving around downtown and you can't find a parking lot that's not full, your glasses will tell you where to park.

These are functions that can somewhat be done today on a smartphone, except that you have to pick up the phone and look at it. That's friction. Because now you're interfering with your normal travel, your normal communications, etc. You've got to stop some process in order to look at the phone. With augmented reality, you don't have to stop—the data will be right in front of you while you are going to where you are trying to get to; these are benefits.

That's for the consumer. It's different for the industrial applications, because industrial applications, with the exception of first responders, don't move around that much. Typically, with augmented reality in an industrial application, you go to the thing (the airplane, car, production line, pump, etc.) without the glasses on and then you put them on and you take care of the job. If you're a designer, for example, and you go into the design studio, and then you put the glasses on and you do your design, take the glasses off and you go home. Consumers will wear the glasses more often because they'll use them for everyday stuff.

Head-up displays in automobiles and buses, helmets with displays, and augmented reality glasses will be commonplace and make us uncomfortable when not available. First responders will be able to see and anticipate obstacles. Educational aspects from sports training to remedial education will be assisted by augmented reality. Entertainment will evolve to new exciting, immersive, and amazing heights.

Real time visual translations will be used daily. Game playing will reach across the world and throughout it, and military battlefield operations will be even more deadly and effective. Surgeons will operate and diagnose remotely, and we will visit museums, potential new homes, and wondrous travel vistas that had been out of our reach.

1.2 The Promise of Augmented Reality

Augmented reality headsets will do more than just give us directions and visualizations of products, they will integrate with body sensors to monitor our temperature, oxygen level, glucose level, heartrate, EEG, and other important parameters. We will in effect be wearing the equivalent of the tricorder from StarTrek, and that information will be available to us, and people/organizations we authorize (such as family physicians, or trainers).

And not just our bodies, but our environment as well. Augmented reality helmets for first responders will measure oxygen, methane, Co_2, as well as other gases and pollutants we can't see, and give early warning to explosive or poisonous situations. In pollution-heavy areas an individual's augmented reality glasses can alert the wearer of conditions that can be dangerous for people with respiratory conditions. That includes dosimeters that will measure the amount of radiation absorbed by the wearer, as well as detect radon and other harmful sources.

Augmented reality will be like having X-ray vision

These augmented devices will amplify us, make us feel like a super hero, enable and empower us as never before, and free us from tyranny and fear.

And we will use it without being aware of it, it will become invisible. As I and others have pointed out over time:

Technology works when its invisible

And books will continue to be written about it as new ideas and capabilities continue to emerge. Aren't we there yet? No, not for a while, but we can enjoy and benefit from augmented reality now.

1.3 The Dangers of Augmented Reality

Ericsson ConsumerLab has been conducting consumer surveys for over 20 years studying people's behaviors and values, including the way they act and think about information-and-communications-technology (ICT) products and services, and as a result have provided unique insights on market and consumer trends. Ericsson ConsumerLab consumer research program is based on interviews with 100,000 individuals each year, in more than 40 countries—statistically representing the views of 1.1 billion people.

In October 2016, Ericsson ConsumerLab conducted a survey and used the data to produce their *10 Hot Consumer Trends 2017* report [6]. In that study, they found three out of five smartphone users think their phone makes them safer, and therefore take more risks.

These days, we take our phones everywhere we go. If we get lost we can call, text, look up information on the internet or navigate using GPS—all with our phones. For example, more than half of smartphone users already use emergency alarms, tracking or notifications on their smartphones. Another three in five have emergency contacts stored in their phone. But what happens if you lose your phone while still looking for your destination? Or you have an accident in a remote area of town while your phone is not charged? In many ways, the basic features of your smartphone can make you safer—and around two in five citizens in five major cities surveyed agree. But here's the paradox: three in five of those who say so take more risks because they rely on their phone to keep them safe.

As consumers learn to rely on their augmented reality glasses, the same risk of over confidence will likely develop.

The fact that more than half of advanced internet users would like to use augmented reality glasses to light up dark surroundings in order to highlight potentially dangerous objects, and/or people approaching may not be surprising. But more than one in three would also like to edit out disturbing elements around them, such as graffiti, garbage, or even badly dressed people. They would like to modify surroundings by adding birds, flowers, or to mimic their favorite movie or TV show.

At least as many would like to erase street signs, uninteresting shop windows and billboards. Although this could be a nightmare to brands that do not manage to capture consumer imaginations (they might simply be wiped from view for good) it also creates the risk that the wearers of augmented reality glasses may become blasé' and lackadaisical about urban dangers—losing their "street smarts" so to speak.

Consumers want to use augmented reality glasses to change the world into something that reflects their own personal moods. Around two in five want to change the way their surroundings look and even how people appear to them.

Almost as many would like to have augmented reality glasses that let you find and pick up digital game items, like in an augmented reality game such as Pokémon GO. It is very likely that this will not be the only game to become integrated in people's physical reality. They would like to make people look like aliens, elves or even characters from their favorite movie.

As augmented reality glasses become popular and commonplace, people are going to have to learn how to use them, just as they are learning how to use (or not use) a smartphone.

1.4 Augmented Reality Skills

To design, build, manufacture, and support an augmented reality device a company has to have an extensive and bewildering range of experts: engineers, scientist, technicians, doctors, mathematicians and managers. They have to understand and know how to integrate:

- Audio technology
- Camera technology
- Display technology
- Ergonomics and user interfaces
- Geometric and trigonometric mathematics
- Image processing techniques and processes
- Manufacturing engineering
- Optics and optometry
- Physiology
- Positional, tracking, and location methodology
- Power management
- Processors (CPUs. GPUs, DSPs, FPGAs, and special purpose) and memory
- Semiconductor technology
- Software engineering, operating systems, APIs, drivers, computer graphics, game engines

More than one augmented reality supplier has told me this was the most difficult thing he had ever done.

It's difficult just to explain it because there are so many aspects to it. Nonetheless, the rest of this book will attempt to do just that. You won't be able to design an augmented reality system after reading this book, but you will know how they work, what they can, and cannot do, and why you and I can't wait to get our own.

1.5 Seeing Augmented Reality

There are three ways to visually present an augmented reality.

Visual see-through is the primary method of creating an augmented reality view. This is the design Sutherland developed in the early 1960s, a see-through lens (such as glasses, or a helmet's faceplate) which leaves the user's perception of the real-world unmodified (or restricted) and displays the information and/or graphics-augmented reality as an overlay by means of transparent displays, or mirrors and lenses or miniature projectors.

Within visual see-through augmented reality systems, there are several classes:

- Contact lens
- Helmet

- Head-up Display (HUD)
- Smart-glasses
  - Integrated
  - Add-on display and system for conventual, sun, or safety glasses
- Specialized and other

These classes of augmented reality see-through systems are discussed further in Chap. 2 “Types of Augmented Reality Systems”, Sect. 2.1.

Obstructed view, where the user wears a head-mounted display (HMD) that blocks the real world, and displays in the HMD are fed a view of the world from a front facing camera in the HMD. This is the closest model to mixed reality and is also referred to as video see-through. The augmented information or graphics is overlaid or blended into the video feed. This technique restricts the field of view of the user, and can restrict it to just a flat 2D view if only one camera is used.

Projected augmented reality is a technique where the augmented reality overlay of information and/or graphics, is projected from the headset or HMD out onto the real world and objects within it resulting in projective displays.

The three techniques may be applied at varying distance from the viewer: head-mounted, hand-held and spatial.

Visual perception is the key to understanding, information transfer, and memory. Edgar Dale (1900–1985) was an American educator who developed the Cone of Experience. He postulated that we remember 10% of what we read, and 50% of what we see and hear (Fig. 1.2).

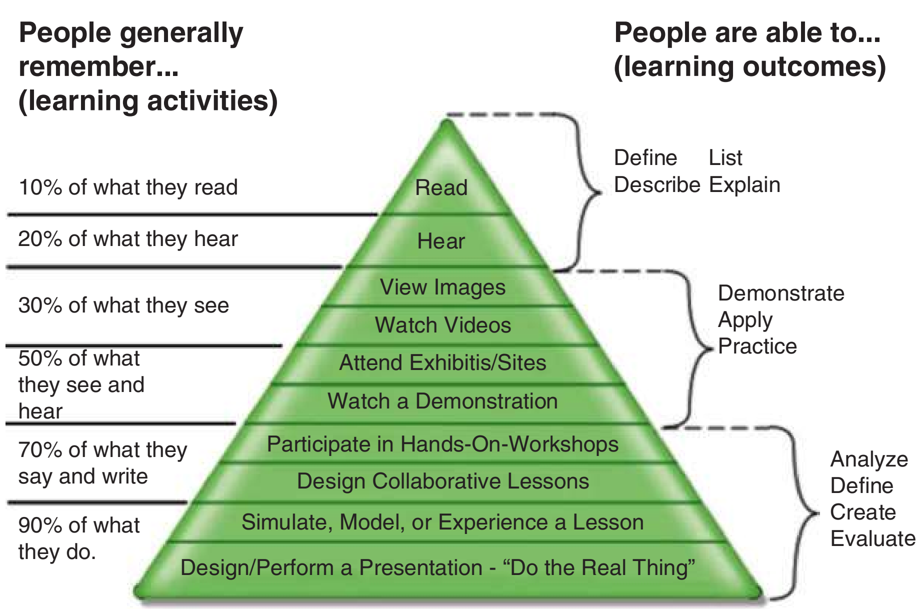

Fig. 1.2 Edgar Dale’s Cone of Learning does not contain percentages as listed here. It relates to abstraction vs. concrete and the greater use of senses (Credit: Jeffrey Anderson)

Dale's "Cone of Experience," which he intended to provide an intuitive model of the concreteness of various kinds of audio-visual media, has been widely misrepresented. Often referred to as the "Cone of Learning," it purports to inform viewers of how much people remember based on how they encounter information. However, Dale included no numbers and did not base his cone on scientific research, and he also warned readers not to take the cone too seriously [7]. The numbers originated from 1967, when a Mobile oil company employee named D. G. Treichler published a non-scholarly article in an audio magazine titled Film and Audio-Visual Communications.

However, academic, and pedantic issues aside, it is pretty well accepted (if not fully understood or quantified) that we take in the majority of our information through our eyes, and augmented reality devices enhance that information level. And then as they learn and gain experience, the information is turned into wisdom.

1.6 The Realities

Immersive reality is a multidiscipline multi-labeled and massively confusing collection of technologies, applications, and opportunities. It, or they, go by many labels (Table 1.1).

And whatever modality is used to describe the holodeck.

Table 1.1 Reality has many names

Alternate	Interactive	Spatial-augmented
Another	Magic	Super vision
Artificial	Mediated	Synthetic
Augmented	Merged	Trans
Blended	Mirrored	Vicarious
Cognitive	Mixed	Virtual augmented reality
Digital	Modulated	
Digitally mediated	Perceptive	Virtual Environment
Dimensional	Projected	Visual
Diminished	Previsualization	Window-on-the-world
Extended	Spatial augmented reality (SAR)	
External	Second	
False	Simulated	
Hybrid		
Immersive (Tactical, Strategic, Narrative, and Spatial)		

1.7 Augmented Reality's Place in the Metaverse

There are so many technologies with conflicting names and purpose it's helpful to sort them out and label them for ease of conversation and commination, and in so doing take steps toward constructing a taxonomy and definition.

The Metaverse is a collective virtual shared space, created by the convergence of virtually enhanced physical reality and physically persistent virtual space, and is a fusion of both, while allowing users to experience it as either. The term came from Neal Stephenson's (1959–) science fiction novel *Snow Crash* [8], (1992) where humans, as avatars, interact with each other and software agents, in a three-dimensional space that uses the metaphor of the real world.

Industry, investors, governments, and consumers alike recognize there's something special about augmented reality, virtual reality and mixed reality head-mounted displays, but many wonder if it's something they would actually use in everyday life. That means we're not quite there yet, but we're getting there faster than ever before.

The way we interact with our devices has evolved. Every advancement in computing technology has required a new method of input: from keyboard, to mouse, to touch. Yet, next-generation devices are using limited methods of control, like head, hands, and voice, which are carried over from the generations of devices before them. These interactions must evolve as well. Augmented reality systems are going to break those paradigms, and invite new natural user interfaces such as voice, and eye-tracking, abandoning earlier approaches borrowed from touch screens, and virtual reality gesturing. Proponents of natural eye-tracking say it transforms intent into action through your eyes.

1.7.1 Translating the World

Humans see, and for the most part think in 3D. We can imagine the back side of an object, and grasp the size relative to its place in the environment. It's one of the advantages of having stereoscopic vision, and cognition.

However, we have had to deal with projections of 3D objects on to flat 2D surfaces in the form of drawings on paper, maps, and illustrations of people.

Illustrations and maps on paper, or a monitor or smartphone screens are cognitively limiting, challenging, and often confusing. They are difficult to understand. For one thing, they must be simplified, to accommodate the medium, and very often that makes it difficult for our brains to process and understand; and/or translate into necessary actions.

Translating 2D spatial information really works the brain as it tries to move from one dimension to another and back and forth until the 2D representation is fully understood—sometimes it never is.

And if there are a series of 2D images and you are required to remember their sequence in order to perform some task, there's a very good chance you won't and you will have to repeat the steps to refresh your memory.

Table 1.2 The seven mass media vehicles

1. Print (books, pamphlets, newspapers, magazines, etc.) from the late 1400s
2. Recordings (records, tapes, cassettes, cartridges, CD's, DVD's) from the late 1800s
3. Cinema from about 1900
4. Radio from about 1910
5. Television from about 1950
6. Internet from about 1990
7. Mobile phones from about 2000

Augmented Reality systems overcome this cognitive dimensional challenge by providing 3D information superimposed and correctly aligned with the environment. Metavision and Accenture conducted a survey in 2016 which they presented at the 2106 International Symposium on Mixed and Augmented Reality (ISMAR), on this subject, titled, "What Works Better: 2D or 3D Instructions?" [9].

This creates a knowledge-based augmented reality system which can be used to explain how to perform 3D spatial tasks, such as assembly of furniture or the repair of equipment.

In 2006 former telecoms executive and tech author Tomi Ahonen (1943–) developed the list of the seven mass media vehicles or experiences (Table 1.2).

The 8th mass media will be augmented reality predicted Raimo van der Klein, founder of Layer (see Sect. 6.1.3.1).

1.7.2 Consumers vs. Industrial, Military, and Scientific

Augmented Reality evolved from a laboratory experiment to the military and then industrial applications. The military, industrial, and scientific users, with specific and urgent needs, and the necessary budget we are able to tolerate the limitations in comfort and performance the early systems had because of the desired result. Later in this book I identify several, but far from all, Augmented Reality applications and use cases for the military, industrial and scientific/medical fields.

The consumer applications are just as far reaching, but only slowly being realized due to prices, applications, and appearance/comfort. Also, consumers are not as aware of Augmented Reality, although that is changing rapidly. Once there was a clearer understand of the broad applications of Augmented Reality, interest and excitement spiked.

However, in all consumer studies it was pointed out that glasses must be lightweight and look "normal", especially for those who don't wear glasses. Almost everyone wears sunglasses, and that has become the metaphor in most consumer's minds for how they will engage with Augmented Reality for an extended period. Smartphones and head-up displays in automobiles were the second use model.

Fig. 1.3 The augmented reality eye of The Terminator evaluates the situation and provides suggestions for action (Source: Orion Pictures)

Consumers quickly extrapolated the use of augmented reality beyond games like Pokémon GO to use augmented reality in cases such as shopping, fitness tracking and health monitoring, museums and travel information, video calls and social media interchanges, education and training, collaboration and virtual assistance, and a teleprompter to name a few. The idea of being able to have the web and your phone instantly visible and interactive any time, and all the time, truly lit up the imagination of consumers.

1.7.3 Movie Metaphors and Predictors

Science fiction has long been a predictor of future technologies. One reason the concepts developed by artists, writers and scientists, and the flights of imagination and extrapolation are prescient is because at the time they were writing we lacked the technology to realize such devices, environments, and oblique ideas.

Two such persistent and compelling concepts and images are the *Star Trek*'s Holodeck (1974) [10] and *The Matrix* (1999) [11], a thematic concept proposed by Philip K. Dick in 1977 [12]. In the case of augmented reality, there is frequent reference to the *Minority Report* (2002) [13], and for devotees of the genre, John Carpenter's (1948–), *They Live* (1988) [14], and several others. (Interestingly, the *Minority report* was based on a book by Philip K. Dick) [15] . And in 1984 the movie, *The Terminator*, written and directed by James Cameron (1954–), depicted a menacing robot from the future with an augmented reality eye (Fig. 1.3).

According to Ori Inbar (1965–) of Games Alfresco [16], the use of augmented reality in movies can be traced back as far as 1907 when French magician and

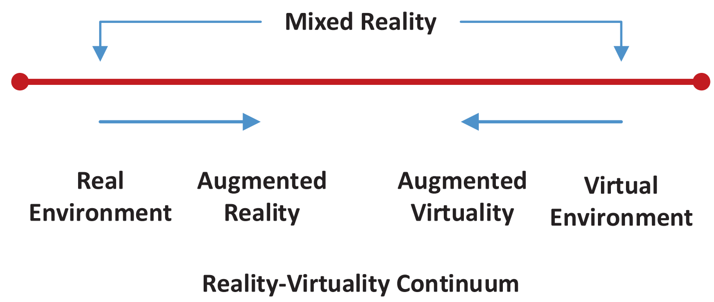

Fig. 1.4 Simplified representation of an metaverse continuum (Milgram 1994)

moviemaker George Melies (1861–1938) created his *Hilarious Posters*. Characters in the posters came to life and interacted on screen [17].

Augmented Reality is one part of the metaverse. Paul Milgram (1938–) and Fumio Kishino, defined augmented reality in 1994 as part of the continuum middle ground between virtual reality (completely synthetic) and telepresence (completely real) (Fig. 1.4) [18].

Telepresence is the experience of "being there," and is commonly implemented in the form of a remote control and display device for teleoperation, and called "virtual presence" in the case of computer-generated simulation. You may have seen examples of a computer screen on a stand that is eye height, with a motorized platform at the bottom.

Steve Mann (1962–) took the concept further and added mediated reality based on the fact that no matter what we do, the technology modifies our world in some way, and doesn't merely add (augment) to it. Sometimes this modification is deliberate (e.g., Mann's augmented reality welding helmet that darkens the image in areas of excessive light) or accidental (the way that a smartphone, for example, changes our view of the world when looking through it while using an augmented reality app.). Mediated Reality takes place anywhere that one's perception of the world is mediated (modified) by the apparatus being worn i.e., augmented reality glasses [19, 20]. Video cameras are used both to warp the visual input (mediated reality) and to sense the user's world for graphical overlay (Fig. 1.5).

Through the use of such artificial modification of human perception by way of devices for augmenting, the wearer could deliberately diminish, and alter sensory input (Fig. 1.6).

The origin R denotes unmodified reality. The x-axis connotes the Virtuality axis V which is the continuum from reality augmented with graphics (Augmented Reality), as well as graphics augmented by reality (Augmented Virtuality). However, the taxonomy also includes modification of reality or virtuality or any combination of these.

The y-axis is the mediality continuum, which includes diminished reality and generalizes the concepts of mixed reality, etc. It includes the virtuality reality continuum (mixing) but also, in addition to additive effects, also includes multiplicative effects (modulation) of (sometimes deliberately) diminished reality.

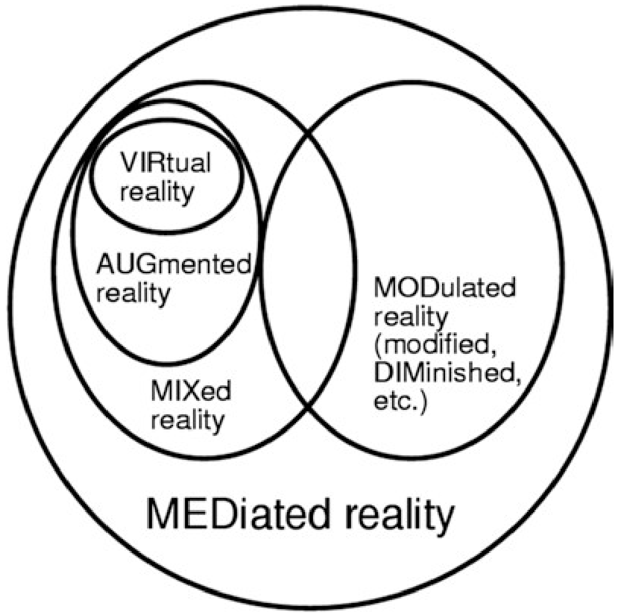

Fig. 1.5 Mixed reality with mediated reality

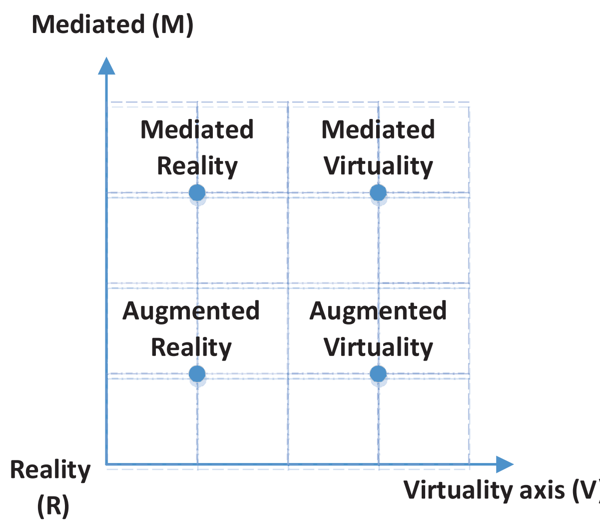

Fig. 1.6 Mann's taxonomy of reality

Mann extended the concept to include Augmented Reality devices that could block out advertising or replace real-world ads with useful information) [21].

Augmented reality mixes the completely real with the simulated or synthetic. The idea of having reams of concurrent and timely information immediately or constantly available to you, is (as mentioned above) a dream we have shared for a long time. But it could also evolve to a situation of "be careful what you wish for." If you have too many labels in a scene, or too many objects, it gets confusing and difficult to read. Without limits, and privacy protection, your augmented reality device could be inundated with unwanted and overwhelming information, advertisements, correspondence, reminders, and intrusions.

Animator and futurist Keiichi Matsuda (1984–) made a video in 2015 depicting the potential world of hyper-reality that we may face [22] (Fig. 1.7).

Fig. 1.7 Keiichi Matsuda vision of riding a busy while using a smartphone to play a game, get alerts, be inundated with advertisements, and get a phone call (Source: Keiichi Matsuda)

Matsuda's vision is funny, and frightening, and one which will no doubt find its way to regulators and privacy organizations, as the nascent industry develops standards and codes of ethics. Will the user of augmented reality smart glasses have the option of blocking such messaging?

Another short film, *Sight*, creates a scenario of augmented reality using contact lenses (and can be seen at: https://vimeo.com/46304267).

The problem with wearing augmented reality glasses, as unobtrusive as they might be, is that they will probably distract your gaze from whomever you are speaking. I can envision a scene where the other person, who may be your superior, or the police, say, "Take off your glasses when you talk to me." In the case of it being the police, that would put you at risk for not being able to record the incident. So now we have a new freedom of speech issue.

Then there is the possibility of augmented reality contact lenses, will they overcome the gaze issue and let you look normally at people while viewing data? Samsung, Google and others have filed patents for such devices. Issues of powering and connecting to them are challenges, but also a concept originating in science fiction stories, so it would seem it's just a matter of time for the technology to catch up with the concept.

Another scenario might include an interviewer asking to tap into the feed of the eye-tracking in your glasses to see if you are lying, and look at the recent history to see if your questions or comments are legitimate.

However, the more positive visions of the use of augmented reality smart-glasses is people will no longer bump into each other or objects as they do now while looking down at their smartphone while walking.

And Matsuda's vision of an over cluttered barrage of adverts and information will be mitigated by machine learning and training so your smartglasses only deliver the information you want, and don't interrupt you when you are with someone else.

It does however suggest some regulation and code of ethics needs to be instilled, just as Asimov proposed for robots. Steve Mann has suggested a code of ethics for augmented reality, and John Rousseau has proposed laws for mixed reality.

1.7.4 The Code of Ethics on Human Augmentation

In 2004, Steve Mann introduced the "Code of Ethics on Human Augmentation" in his Keynote Address at Transvision 2004, Second annual conference of the World Transhumanism Association.

This code was further developed at the IEEE International Symposium on Technology and Society [23].

As we augment our bodies and our societies with ever more pervasive and possibly invasive sensing, computation, and communication, there comes a point when we ourselves become these technologies [24]. This sensory intelligence augmentation technology is already developed enough to be dangerous in the wrong hands, e.g., as a way for a corrupt government or corporation to further augment its power and use it unjustly. Accordingly, Mann has spent a number of years developing a Code of Ethics on Human Augmentation, resulting in three fundamental "laws".

These three "Laws" represent a philosophical ideal (like the laws of physics, or like Asimov's Laws of Robotics, not an enforcement (legal) paradigm:

1. (Metaveillance/Sensory-Auditability) Humans have a basic right to know when and how they're being surveilled, monitored, or sensed, whether in the real or virtual world.
2. (Equality/Fairness/Justice) Humans must (a) not be forbidden or discouraged from monitoring or sensing people, systems, or entities that are monitoring or sensing them, and (b) have the power to create their own "digital identities" and express themselves (e.g., to document their own lives, or to defend against false accusations), using data about them, whether in the real or virtual world. Humans have a right to defend themselves using information they have collected, and a responsibility not to falsify that information.
3. Rights and responsibilities
   (a) (Aletheia/Unconcealedness/TechnologicalAuditability) With few exceptions, humans have an affirmative right to trace, verify, examine, and understand any information that has been recorded about them, and such information shall be provided immediately: feedback delayed is feedback denied. In order to carry out the justice requirement of the Second Law, humans must have a right to access and use of the information collected about them. Accordingly, we hold that Subjectrights [6] prevail over Copyright, e.g., the subject of a photograph or video recording enjoys some reasonable access to, and use of it. Similarly, machines that augment the

human intellect must be held to the same ethical standard. We accept that old-fashioned, hierarchical institutions (e.g., law enforcement) still have need for occasional asymmetries of surveillance, in order to apply accountability to harmful or dangerous forces, on our behalf. However, such institutions must bear an ongoing and perpetual burden of proof that their functions and services justify secrecy of anything more than minimal duration or scope. Application of accountability upon such elites—even through renewably trusted surrogates, must be paramount, and a trend toward ever-increasing openness not thwarted.

(b) Humans must not design machines of malice. Moreover, all human augmentation technologies shall be developed and used in a spirit of truth, openness, and unconcealedness, providing comprehensibility through immediate feedback. (Again, feedback delayed is feedback denied.) Unconcealedness must also apply to a system's internal state, i.e. system designers shall design for immediate feedback, minimal latency, and take reasonable precautions to protect users from the negative effects (e.g., nausea and neural pathway overshoot formation) of delayed feedback.

(c) Systems of artificial intelligence and of human augmentation shall be produced as openly as possible and with diversity of implementation, so that mistakes and/or unsavory effects can be caught, not only by other humans but also by diversely completive and reciprocally critical AI (Artificial Intelligence) and HI (Humanistic Intelligence).

A metalaw states that the Code itself will be created in an open and transparent manner, i.e. with instant feedback and not written in secret. In this meta-ethics (ethics of ethics) spirit, continual rough drafts were posted (e.g., on social media such as Twitter #HACode), and members of the community were invited to give their input and even become co-authors.

1.7.5 Laws of Mixed Reality

In 2016, John Rousseau proposed three "laws of mixed reality [25]" to ensure that augmented and virtual technology positively impacts society.

Rousseau said, "The future of human consciousness will be a hybrid affair. We will live and work in a ubiquitous computing environment, where physical reality and a pervasive digital layer mix seamlessly according to the logic of software and the richness of highly contextual data. This is mixed reality."

We're not there yet, though this vision is far from science fiction.

Rousseau, citing Isaac Asimov's "Law of Robotics [26]," suggested three "Laws of Mixed Reality" that will help us shape the discourse and future development of mixed reality with an emphasis on preferable outcomes. The Laws are aligned to three significant problem areas, covering the individual, society and economics.

1. Mixed reality must enhance our capacity for mindful attention.
2. Mixed reality must embody a shared human experience.
3. Mixed reality must respect boundaries between commerce and data.

Rousseau noted in a blog post that as mixed reality starts to take over, “data will become more valuable and easily manipulated to serve other interests.”

1.7.6 Augmented Reality Can Help and Monitor

With an always on augmented reality system, in your smartphone, or smart-glasses, that has a camera, geo-location sensors, and motion sensors, the augmented reality device can call for help if you fall, record the fall, and possibly offer live saving information when help arrives.

The augmented reality device can make almost anything appear in the display. It could be monsters in game, or, directions to your dinner date. The direction can be a map, or explicit instructions consisting of bright yellow arrows along the roads of your travel. You will be able to shop at home and see how a piece of furniture you are interested in looks in your living room, and be able to walk around it, see how it looks in the evening or bight daytime. We will all be experts now, and without any special training repair or install home appliances, or repair or service our automobiles, with interactive instructions highlighting exactly which part needs to be replaced and alerting you if you’re doing it wrong. And some companies offering either cloud service, or devices, will be positioned to profit from every interaction: not just from the hardware and software it will sell but also from the flow of data the device and/or cloud services provider will collect, analyze–and resell.

We will all be big brother

Augmented reality will be an aid, a monitor, a snitch, and sadly a spy. How we and government restrictions mitigate and manage this flow of information will be discussed and worked on for decades. Not only will big brother be watching us, but we will be big brother.

1.7.7 Augmented Reality in Games

Augmented Reality is anchored on practical use, but can cross over to fun. In the popular (and sometimes intense) first-person shooter (FPS) games, the protagonist (you) often has a augmented reality head-up display (HUD) to show the status of life support, weapons, nearby enemies, etc.

One such popular game of 2016–2017, and longer (because it keeps getting upgraded), is *Fallout4*, a post-apocalyptic story where the world has suffered a massive nuclear war, everything is left in ruin. The player has an Augmented Reality

Fig. 1.8 Augmented reality head-up display in a first-person shooter game, Fallout 4 (Source:Bethesda Softworks)

device strapped to his or her wrist and it provides information on the player's health, location and destination, supplies, and condition of clothing or armament (Fig. 1.8).

Generations of game players have had this kind of experience without having a name for it, although the term HUD has been used in FPS games since the late 1990s, beginning with just a few characters of text at the bottom of the screen. That was due to the level of technology at that time. Today PCs and mobile devices have processors thousands of times more powerful with thousands of times the memory, running hundreds, if not thousands of times faster, making the issue of displaying more robust head-up display images and data almost trivial. So almost by osmosis, game players have been involved with augmented reality for decades and take it for granted. Those generations of users will adopt to augmented reality without hesitancy when comfortable, non-obtrusive devices are available. If anything, they represent a pent-up demand for the technology.

1.7.8 Auditory Augmented Reality

Augmented reality is thought of as a visual system, augmenting what we see with information and graphics. However, one's auditory senses can also benefit from augmented reality, with special location clues, and can be very helpful if one is blind, or partially blind.

For location assistance audible instructions, such as directions, can be helpful for the sighted as well as for people with limited or no vision. For athletes and people active in sports such as running, bicycling, and skiing, getting information on your distance from your destination, rate of speed, as well as your body functions such as heart rate in real time is extremely useful.

Audible translation of street signs, notices, and restaurant menus for the sighted or limited sighted person will be greatly empowering and offer new levels of engagement, exploration, and enrichment.

1.8 Definitions

In this section, we will define the most commonly used terms in this book, and the ones that are critical to understanding the issues and opportunities in augmented reality. An expanded glossary of terms can be found in the appendix.

1.8.1 What Is Augmented Reality?

Augmented reality, not to be confused with virtual reality, superimposes digital content (text, images, animations, etc.) on a user's view of the real world. Augmented reality and virtual reality devices, also known as head mounted-displays (HMDs), share similar problems around mobility and power consumption.

Encyclopedia Britannica gives the following definition for augmented reality: "Augmented reality, in computer programming, a process of combining or 'augmenting' video or photographic displays by overlaying the images with useful computer-generated data" [27].

Augmented reality is a real-time view of information overlaid on a view of the real world. The information is generated by a local processor and data source, as well as a remote data source/data base, and is augmented by sensory input such as sound, video, or positional, and location data. By contrast, virtual reality (virtual reality) replaces the real world with a simulated one.

The technological requirements of augmented reality are much greater than those for virtual reality, which is why the development of augmented reality took longer than that of virtual reality. However, the key components needed to build an augmented reality system have remained the same since Ivan Sutherland's pioneering work of the 1960s. Displays, trackers, and graphics computers and software remain essential in many augmented reality experiences.

Various technologies are used in augmented reality rendering including optical projection systems, displays, mobile devices (such as tablets and smartphones), and display systems worn on one's person in the form of glasses or a helmet. Augmented reality devices are also characterized as a wearable device (Fig. 1.9).

Augmented reality devices (glasses, helmets, HUDs, etc.) employ several technologies:

- A GPU to drive the display(s).
- Display/projection device(s) to create images.
  - Optics to route the images to your field of view.

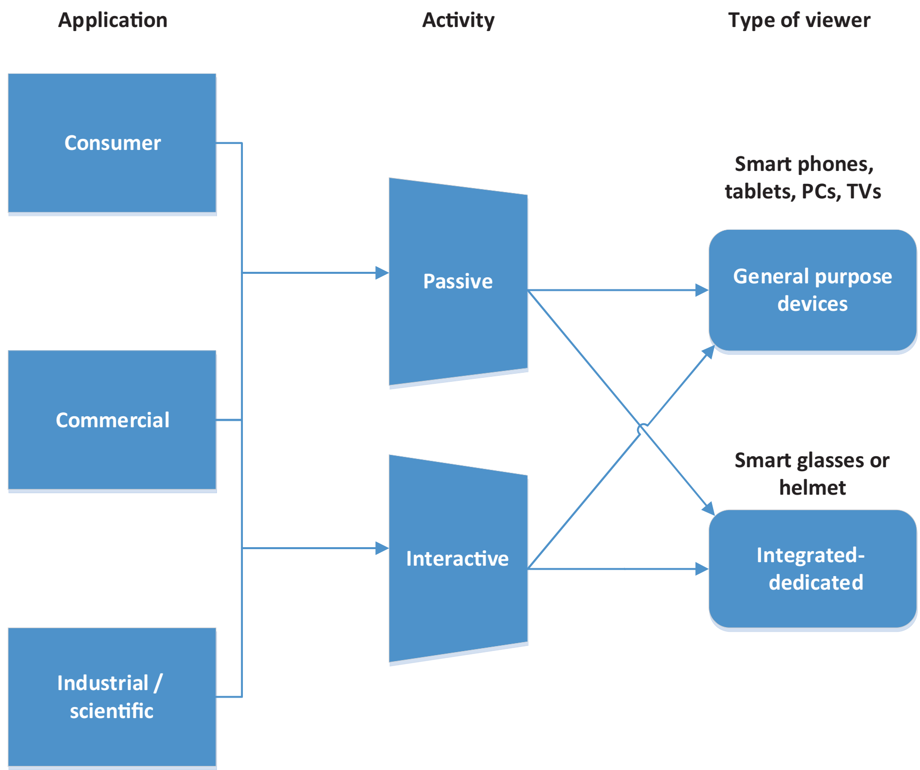

Fig. 1.9 Augmented reality uses various devices and is used in various applications

- Sensors:
  - Forward-looking to see the world you are looking at (i.e., the camera)
  - Real-world position to map the world in 3D
  - Motion sensor(s)
  - Elevation sensor
  - Eye sensors to track where you are looking.
- Audio systems (microphones, processing and speakers) for communications and augmentation of the real world. (A microphone is another sensor).
- Object identification and categorization systems that recognizes what your glasses are looking at (table, chair, floor, walls, windows, glasses, etc.) to position virtual images on top of or near them (some systems use markers for object identifications).
- An operating system to control the virtual images with voice, eyes, hands and body motions.
- Wireless communications to a server-like device (could be your smartphone).

Augmented reality allows for every type of digital information—videos, photos, links, games, etc.—to be displayed on top of real world items when viewed through the lens of a mobile or wearable device.

The concept of a wearable computer or personal computer interface has been discussed since the late 1950s, first in science-fiction, later as a technological development. Through micro-miniature electronics, sensors and displays, always connected communication, and modern manufacturing techniques, appliances, wearable, connected, and augmenting devices are changing our lives forever, and for the better.

Augmented reality can employ 3D models of the world around us from previously generated data sets and/or from scanning sensors in the augmented reality headset, helmet or glasses. It is possible to generate extensive 3D representations of data sets that can lead to remarkable discoveries of complex relationships.

Visualization technologies with easy to use interfaces have introduced new and innovative ways of viewing and interacting with big data sets through portable lightweight devices; devices that look like normal sun glasses, or corrective glasses.

Augmented reality is often associated with visual discovery, which in turn is defined as a technology that fulfills a user's curiosity about the world around them by giving them information and relevant content when objects and images in the field of view are selected. Visual discovery requires an initial display or layer of information to appear instantly, by pulling the most relevant links related to the object being examined. The information can come from local storage, or via a link to the web. In some applications with AI and neural networks, the more people that use the application, the smarter it becomes by anticipating the user's requests or needs.

1.8.2 Internet of Things

The Internet of Things (IoT) is a system of interrelated computing devices, mechanical and digital machines, objects, animals or people that are provided with unique identifiers and the ability to transfer and receive data over a network without requiring human-to-human or human-to-computer interaction.

1.8.2.1 Wearables

Wearables are portable devices that collect and/or deliver information to the person wearing it. Smart watches, and activity trackers are examples. Body cameras and personal GPS devices are other examples. Wearables that have a Wi-Fi or internet connection capability are part of the IoT universe.

Smart Glasses and Augmented Reality

Smart glasses and augmented reality devices that are connected to a network or Wi-Fi, or even blue ray to another device (which in may be connected to some network) are connected-wearables, and therefore a subject of wearables which in turn are a subset of IoT.

Therefore, one can describe augmented reality devices as an IoT device, and/or a connected-wearable device Augmented reality actually was initially called wearable computing by pioneers like Steve Mann, Jaron Lanier, and others in the early 1980s and wasn't labeled augmented reality till 1990 by Thomas P. Caudell, and David Mizella while at Boeing.

1.8.2.2 Augmenting Reality

Augmented reality devices that superimpose information on your view of your surroundings are different from using a device like a smartphone to give you information about your location or surroundings, or even your destination. Your phone gives you your location, directions and/or information on where you want to go and will give you images of your destination. That is not augmented reality, that is just a sophisticated 2D map. Granted, places of interest and other information may also be available, and that is augmenting the overall informational content of the map. And since your phone can locate you, the information about your destination, and points of interest will change as you move.

1.8.3 Types of Augmented Reality

The difference between mixed reality versus augmented reality and cognitive reality, is mostly a semantics issue, but deeply critical to some people working in the field. In the broadest definition, augmented reality can have data overlaid on the real world from any digital source, video, games, 3D models, or locally captured information. Mixed reality has a specific knowledge of your world and where things are. Cognitive reality can employ artificial intelligence, analysis from deep learning processes, and neural networks.

1.8.3.1 Mixed Reality

Mixed reality (MR) in the virtual reality or simulation world refers to the combination or merging of a virtual environment together with a real environment where both of them can co-exist. Sometimes people also refer to it as “Hybrid reality”.

In mixed reality, a user can navigate through the real world and a virtual environment seamlessly, and simultaneously. The virtual objects are accurately positioned in the real-world space. If one moves towards an object it will get larger and vice versa. And when one moves around it, the virtual objects are seen from different angles and perspectives—just like the behavior of real objects. Some people describe the experience to that of viewing holographic objects.

Users are able to manipulate the virtual objects in mixed reality. Users can interact with their concepts in virtual object form as if they existed in front of them.

Like augmented reality, mixed reality employs several technologies (see Sect. 1.8.1). To build a mixed reality system, you have to substitute the open real world view one gets with augmented reality smart glasses or helmet (or HUD) with a camera view since the display (typically a smartphone) screen occludes your view. And in order to overcome the feeling of looking through a toilet paper tube, you need to broaden the FOV of devices camera. Therefore, developers add a fish-eye lens to the assembly in front of the high-resolution front-facing camera of the smartphone.

Some examples of the mixed reality technology are Microsoft’s HoloLens, Magic Leap, Occipital, and Canon’s MREAL System. Some contend that HoloLens is under the augmented reality category, Microsoft, possibly for marketing and product differentiation reasons, insists it should fall under the mixed reality domain.

Another approach to mixed reality is the projected augmented reality approach taken by CastAR, where a pair of 3D shutter glasses with polarized lenses are combined with a forward facing, head mounted 720p pico-projectors. The projector casts 3D images on the viewer's surrounding environment.

The system creates a hologram-like image, that can be unique to each viewer in what the company calls "Projected Reality". A tiny camera is placed between the projectors to scan for infrared identification markers placed on a special retro-reflecting surface. The image bounces off a retro-reflective surface back to the wearer's eyes.

This approach keeps the viewer's eyes focused naturally (no eye strain or near-eye optics needed). It allows multiple people to see the surface simultaneously. The glasses have a camera sensor that tracks infrared light-emitting diodes (LED) points in the physical world into point data (AKA a point-cloud).

There's a radio frequency identification (RFID) tag that sits underneath the reflective surface. Any object also equipped with an RFID tag can be tracked across the surface with centimeter-level accuracy and uniquely identified.

1.8.4 Difference Between Virtual Reality and Augmented Reality

Often used interchangeably, Virtual Reality and Augmented Reality are not the same thing. Also, one is not a subset of the other, and the only attribute they share in common is the term "reality." They do share some underlying technologies, but offer distinctly different experiences.

Virtual reality takes you into a completely isolated computer generated world, typically with only three-degrees of freedom (3DOF), while augmented reality gives you additional visual information overlaid on the world around you, and six-degrees of freedom (6DOF).

From a graphics perspective, augmented reality is functionally similar to virtual reality, with the main difference being a transparent screen to allow the wearer to see both the actual view and the computer rendered overlay. Therefore, the hardware to display the graphics and software tools are similar. However, augmented reality has additional requirements in optics and tracking that make it a more difficult task to do well. Augmented Reality as described above superimposes computer-generated data and objects on the real worldview of the user. Virtual Reality creates an artificial environment and totally obscures the real world.

Virtual reality takes you totally out of actual reality, whereas augmented reality enhances your actual reality.

Virtual reality and augmented reality are used for training, education, and entertainment, but augmented reality has capabilities to allow you to see data superimposed on objects, diagrams, and instructions overlaid on equipment needing repair or maintenance, or locating a proposed change of the kitchen on top of the existing walls and room. Most agree that this additional capability will command a greater market share once the technical details are resolved.

In Augmented Reality, the computer uses location, motion, and orientation sensors and algorithms to determine the position and orientation of a camera. Augmented reality technology then renders the 3D graphics as they would appear from the viewpoint of the camera, superimposing the computer-generated images over a user's view of the real world. As mentioned above, augmented reality is possible with a smartphone, helmet, tablet, PC or glasses. Virtual reality only uses a head-mounted display, and one that does not provide any direct view of the real world; however, the head-mounted display can be a simple as Google's Cardboard.

Because the wearer of an augmented reality headset can see real objects, tracking and positional information is more critical. Consider looking at a table with an augmented reality generated vase on it. A vase that moves in and out of the table, or vibrates when the table is still is distracting and ruins the effect. As you walk closer to the table, you expect everything to match in terms of perspective, scaling and changes in occlusion as if the computer-generated objects were actually on top of the real object. This requires smooth tracking, awareness of the positions of real objects and the ability to compete with ambient lighting and extremely fast and accurate image generation. Otherwise the optical distortion mapping, rendering of objects, and geospatial attributes of computer imagery are functionally identical for virtual reality and augmented reality.

The optical solution is critical to the success of fusing virtual and real scenes. If the eye focuses at the virtual screen image, then looks at an object four meters away, there will be a mis-match between the focus. That will throw the user out of the illusion. That problem is what is hoped will be managed by the so-called light field displays that match the apparent focal lengths.

While most people aren't technical enough to explain why various augmented reality solutions don't work, they are capable of deciding if it isn't working for them in seconds of viewing.

That is another major difference between augmented reality and virtual reality—the focal length. In virtual reality, there basically isn't one. In augmented reality, it is absolutely critical.

One other thing about the difference between augmented reality and virtual reality—in augmented reality you can always see your hands, feet, and other parts of your body. And although not completely impossible, no one has complained of augmented reality sickness.

Commentators [28, 29] have observed that the most exciting thing about virtual reality is that it is the stepping stone to augmented reality—the real revolutionary tech.

1.8.4.1 Dual Modality

Some suppliers and industry observers have suggested a headset with dual modality, that is it could be an augmented reality headset in one case, and a virtual reality in another.

The closest you can come to such a dual modality, is a virtual reality headset with a camera, but this fails because it blocks your peripheral vision.

A planetarium is a (passive) virtual reality experience, a CAVE (Cave Automatic Virtual Environment) is an interactive virtual reality experience. I tell audiences, and clients, a virtual reality headset is a CAVE on your face.

A well-designed simulator is a virtual reality experience, and interactive.

iMAX approaches a passive virtual reality experience.

It's about immersion, and presence.

As for 360 video, it is indeed virtual reality. The difference is the type of content. 360 video is passive, whereas a game is interactive. If you engage either one in a totally obscuring viewer environment, it is virtual reality.

1.8.5 AR Preferred over VR if Forced to Choose

In late 2016 Qualcomm conducted a survey of consumers in focus groups in the US and China to assess their attitude and awareness of augmented and virtual reality. The focus groups felt augmented reality is anchored on practical use, but can cross over to fun.

The consumers generally had less awareness of augmented reality (unlike virtual reality). However, augmented reality is considered a cool technology. Initial perceptions and value center on practical daily life and learning.

Once the focus groups were made aware of augmented reality their eyes were opened, and they commented thatthe "possibilities are endless" and the versatility feels "limitless". Once there was a clearer understanding of the broad applications of augmented reality, interest and excitement spiked.

In China, augmented reality is perceived as a 3D Baidu (China's search engine like Google) which can reduce the need to search for things.

Mainstream users felt more comfortable with augmented reality and see it as an introduction to learn VR.

Because the focus groups saw a role for both augmented reality and virtual reality in their lives, they would like to combine VR & augmented reality into one device.

However, the glasses must be lightweight and look "normal", especially for those who don't wear glasses.

1.9 Summary

Augmented reality will completely disrupt the education sector from training for sports to remedial education. Head-up displays (HUDs) in automobiles, buses, and motorcycle helmets will be commonplace, and make us uncomfortable when not available. First responders will be able to see and anticipate obstacles. Entertainment will evolve to new exciting, immersive, and amazing heights. Real time visual translations will be used daily. Game playing will reach across the world and throughout it, and military battlefield operations will be even more deadly and effective. Surgeons will operate and diagnose remotely, and we will visit museums, potential new homes, and wondrous travel vistas that had been out of our reach.

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