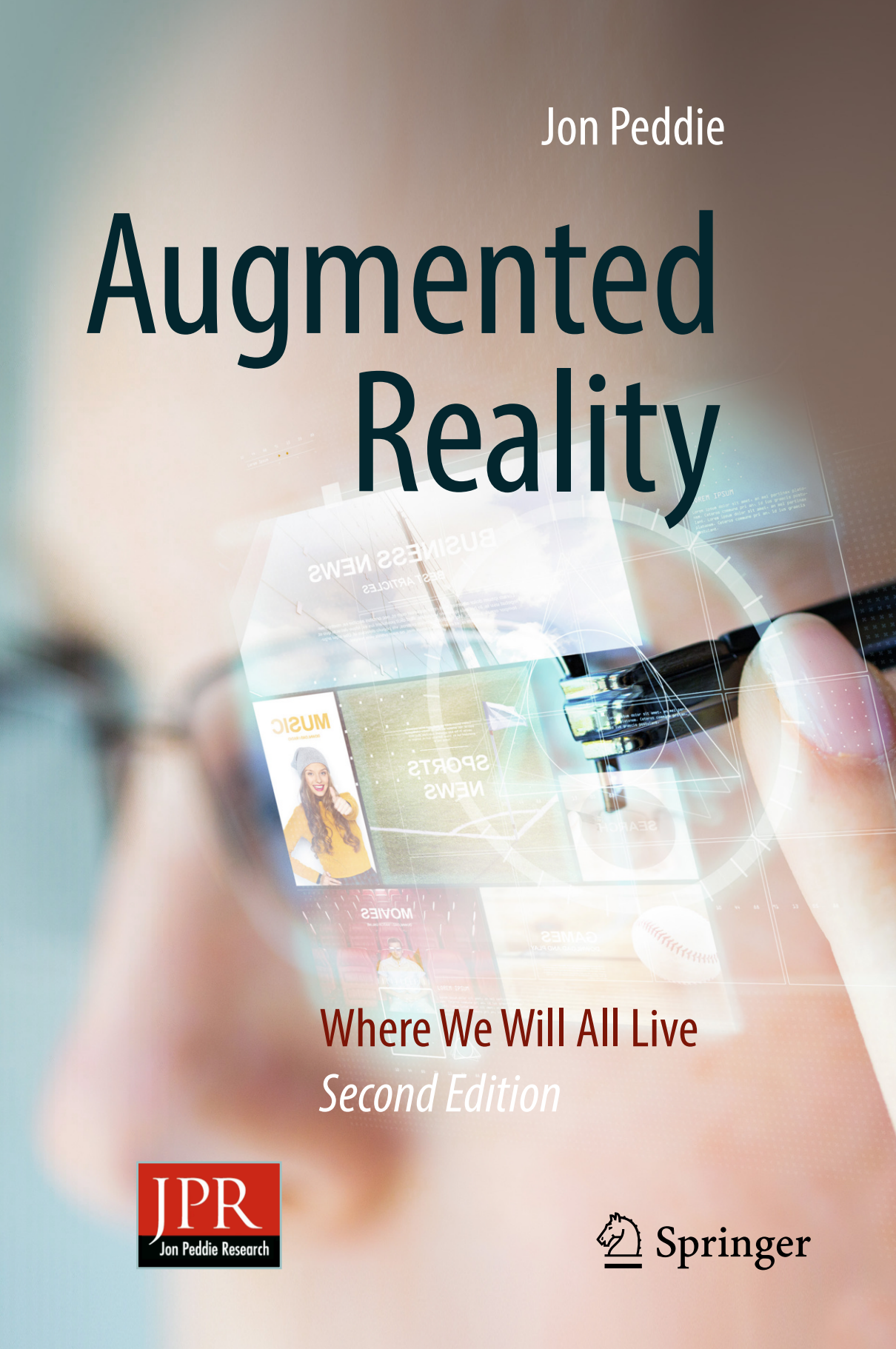
Jon Peddie

Augmented Reality



Where We Will All Live

Second Edition

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To Kathleen Maher, my best friend, supporter, nudger, editor, and wife—couldn't have done it without you darling

Foreword to the First Edition by Thomas A. Furness III

During the mid-1980s, there was rush of media exposure related to the Super Cockpit[1] project I was working on at Wright-Patterson Air Force Base, Ohio. I was inundated by people out of the blue asking me about the possibility for applications of virtual interfaces beyond the military. One such individual was a golf pro from Australia. He wanted to create a better way to instruct novice golfers how to swing the golf club. He told me that he had tried everything. He started by saying to these novices, "watch me" and "do as I do" then demonstrating how to stand, hold the club, and swing the club. He would show them videos of their own swings and point out corrections. He attempted to stand behind them as they were gripping the club…but the students still didn't get it. Finally, in frustration he asked me, is there any way you can use this virtual interface stuff to put me inside the student…like a ghost. So that when the students wear a headset they see my arms and feet coming out of their own bodies and, in turn, just position their real feet, hands and club where I position and move mine in the ghost image. This way they have a "personal" or "inside-out" view rather than the typical "outside-in." The golf pro's problem with novice golfers was clearly one of perspective…that is, switching from a third person, or "outside-in" perspective to that of a first person perspective.

This question opened a flood of ideas for other applications of virtual interfaces beyond the military ones that I was pursuing. I thought of the notion of virtual embedded experts, for training, remote operation, and physical therapy. For example, an embedded expert cohabiting a person's body could show them how to repair a jet engine, perform brain surgery, or go through a physical therapy session ("put your arm where mine is" or "put you hand *in* mine"). My wife suggested, "let me show you how to knit from my perspective or learn American Sign Language." Interestingly, this cohabitation can all be done equally well in a remote setting where the "co-inhabitor" and "co-inhabitee" are not physically present in the same location. In this way, a remote surgeon could, in real time, show a medical corpsman in the battlefield how to perform a life-saving procedure while looking through the corpsman's point of view and then saying: "follow my hands and do what I am showing you to do."

[1] The Super Cockpit is a virtual cockpit that the pilot wears. Using devices embedded into the pilots helmet, flight suit, and gloves, the super cockpit creates a circumambience of visual, acoustic, and haptic information that can be superimposed over the real world.

Wow, the implications of this switch in perspective are enormous!

I began my journey in developing and applying virtual interfaces in 1966 when I was assigned as an Air Force Engineering officer to what is now known as the Air Force Research Laboratory at Wright-Patterson Air Force Base. My job was to research, design, build, and test better fighter aircraft cockpit interfaces that would improve system performance of both pilots and their machines in military operations. But it was clear that this wasn't going to be easy. The most daunting constraints were the small cockpit space into which we needed to place a myriad of instruments and controls (maybe 300 switches and 75 instrument displays). This made addition of sensor image displays (so that the pilot could see at night) darn near impossible. That is when I turned to virtual interfaces[2] as a means to better couple the pilot's sensory capability to the complexity of the machine. Virtual images, when tied to the pilot's helmet, allowed us to create sensor displays with sufficient size and resolution that better matched the pilot's eyes. The addition of helmet tracking then allowed us to position those sensors in synchrony with pilot head movement so as to create a moving portal or "picture window" to see through the cockpit and at night. Furthermore, these virtual displays could be populated with other relevant information in the form of graphics that related to threats and aircraft dynamics, such as orientation, navigation, airspeed, altitude, and other parameters. The helmet tracking also allowed the pilot to aim various weapon systems to line of sight. Significantly, all of these crucial features would be added without taking up any cockpit space!

I was not the first to think about these issues.[3] Much of the initial thinking about advanced cockpit concepts using virtual interfaces such as helmet-mounted display and graphical displays overlaid over the outside world evolved in the early Army Navy Instrumentation program that began in 1953. The motivation of the program was to take a user-centered approach for cockpit design, starting with the pilot and working toward the machine rather than the traditional way of working from the machine to the pilot. It was this program that established the platform for inspiring my further work in virtual interfaces, visual coupling aids, and eventually the Super Cockpit.

Certainly another part of my willingness to go down the virtual path was inspired by my interest in science fiction. I have been a sci-fi junkie and dreamer since my childhood, beginning in the 1940s. One of my favorites was *They Shall Have Stars* by James Blish. It was the first of his novel series: Cities in Flight. Interestingly, when published in 1956 its original title was: *Year 2018*. In the novel there was a vivid description of construction workers building an unusual bridge on the planet Jupiter using blocks of frozen ammonia. Because of the harsh environment on Jupiter, the workers were physically located on a moon orbiting Jupiter but were telepresent on the "surface" of Jupiter. This was made possible by using sensors and displays at both ends to transport the eyes and hands of the construction workers to

[2] By virtual interfaces, I mean the *appearance* of virtual, acoustic, and haptic images or interfaces in a location in three-dimensional space surrounding the pilot, without the object creating the image actually being there.

[3] Even though I seem to have inherited the moniker "the grandfather of virtual reality," I was not the first to begin thinking about these approaches. But to my credit I am probably among the few that have worked continuously in the field of virtual interfaces since 1966.

the construction equipment at some distance. Other novels in the same genre extended these notions, such as Heinlein's *Waldo* and *Starship Troopers*. The *Lensman* space opera series by Edward Elmer "Doc" Smith opened my mind to the use of virtual interfaces for command and control applications using virtual image projection and gestures to control remote entities.

But now these dreams and early developments have evolved and become the new tools of our age. I liken their advent to "splitting the atom" in terms of unleashing enormous power to unlock and link minds. This unlocking comes from the unprecedented shift in perspective that augmented, virtual and mixed reality gives us…like the golf pro. It is like breaking the glass of the display and going inside and being there. We can augment the real world or share and collaborate in a virtual world. Our research has shown the amazing results of doing so, especially in education and training. Somehow, "breaking the glass" unlocks spatial memory. It allows us to take the real or virtual world and superimpose or imbed artifacts in the form of graphics or images that "attach" themselves to that space…and gives us a better way to relate to those items. In a way this awakens our long-term memory. It is akin to what the Greeks called the method of loci; that is, to remember things by associating them to spatial locations. The key idea is that we often remember things better when they are spatially associated with locations in 3D spaces rather than as abstract ideas.

For many years, we have been adding artificial things to real-world things; for example, like adding the laugh tracks to TV sitcoms or showing the first down line superimposed (or embedded) on the playing field (appearing under the players) during televised football games. Why do we want to do this? Think about head-up displays in military cockpits that enable pilots to associate abstract graphical information to the real world such as navigation waypoints and landing projections. This combination of the real and virtual adds to our knowledge and understanding and helps us to do things better and more efficiently. But at the same time, we need to be careful so as not to obscure important images from the real world.

When I asked Jon Peddie what was his motivation for writing this book, he said: "I genuinely and truly believe we will all use AR and that it will alter forever our lives…." I share Jon's enthusiasm and predictions. But while I am excited about what is happening in the virtual space, I throw out the caution that we don't want to become *intoxicated* by our technology. Technology tools are not an end in themselves, but a means to an end. We should ask not only what, but so what! This means a shift in our perspective from just pushing technology because we can do it, to a mode of developing technology because it helps solve problems and provide new avenues for emergence. Let me explain this further.

I feel we need application "pulls" that we haven't had in the past. In my half-century journey in this work, I have been as guilty as others in overhyping what is possible with virtual interface technology. It is not as much an issue of developing this technology so much as the question, do we really need to do it.

Certainly we can anticipate vertical market applications in military, medicine, design, training, and education, but what good is it going to do for the everyday person not affiliated with these specialties. We are all aware of the outcome of the Google Glass experience where promoters had a substantial pushback from the social experience of people's wariness of interacting with people wearing these virtual gadgets. So

the solution is to tap the "pull"…or those applications that can benefit from having virtual augmentation. Combined, the "push" of technology and the "pull" of solving problems can propel the development and uptake of this technology. Certainly we are not finished with the hardware development of augmented reality or virtual reality or mixed reality depending on what you call it. There is a lot of work to do on the technology to make the devices comfortable, useful, and successful. Tracking and luminance are big issues when overlaying virtual images on the real world. But most importantly we need to address human factors and not just the ergonomics of comfort. We need to remember that we are deeply coupling to the human senses, and we don't want to do any harm. That should be our mantra: DO NO HARM! There is a substantial portion of this book that Jon has dedicated to these issues.

As Jon also reports in this book, the augmented reality industry is forecasted to be big…really big, far eclipsing the virtual reality industry. That is why this book is important. For some time, we have needed a definitive work on AR to parallel all that has been written about VR, such as the excellent *The VR Book*, written by Dr. Jason Jerald. Dr. Jon Peddie is a pioneer himself in digital media and graphics. From his early work, he has taken the approach to understand the trees but to elevate beyond that to view the forest in the context of the industry landscape. His current work is to guide thrusts in our industry with his substantial insights into the complex dynamics of our workplaces, especially with this new emergence of augmenting reality.

What you are going to experience as you turn the next pages of this book is an authoritative, comprehensive, and modern treatment of the subject of augmented reality. The author says that this is for the layman…that is true, but it is more than that. It also contributes to the hardware and software development community, building upon the scholarly work of many pioneers such as the seminal work by Ronald T. Azuma.[4] In this book, Jon Peddie has amassed and integrated a corpus of material that is finally in one place. This, in itself, is a grand launching platform for achieving the billions in this growing industry that has been forecasted.

Jon's book is also fun, peppered with quips and sarcasm. This is probably how the author kept himself entertained. It has brought back a lot of memories for me, but more importantly, it gets me excited again about the possibilities of this great tool of our age.

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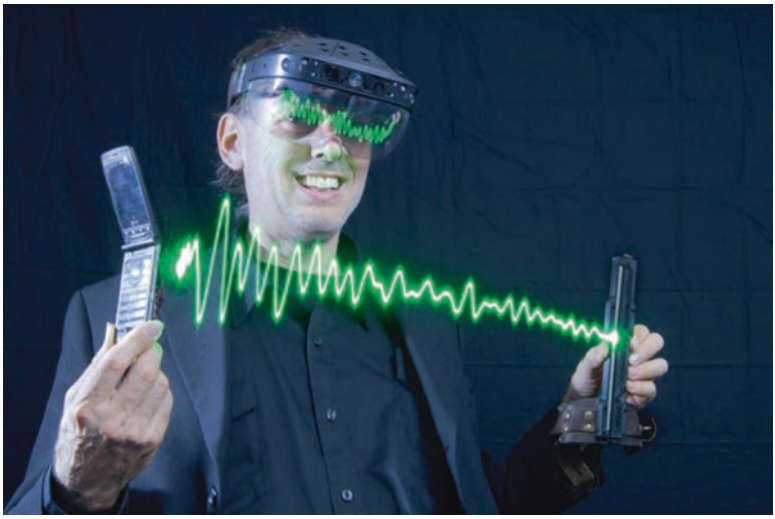
[4] See for example: http://ronaldazuma.com/publications.html

Foreword to the First Edition by Steve Mann



Real Augmented Reality: Steve Mann with SWIM (Sequential Wave Imprinting Machine) and Meta2 that visualizes electromagnetic radio waves from his modified smartphone

Since childhood, for more than 40 years, I've been living my life in a computer-mediated universe called "augmented reality" where I see otherwise invisible radio waves, sound waves, and electrical signals traveling through neurons.

In the next few years, this is the universe "where we will all live."

The father of the field of AI (artificial intelligence), Marvin Minsky, together with the world's foremost futurist, Ray Kurzweil, and myself, put forth a view that AI and machine learning are turning the world into a one-sided control system that's evolving toward total sensing of all aspects of our lives, while at the same time, it remains completely opaque to us [Minsky, Kurzweil, Mann 2013]. We argued for a different kind of intelligence, called HI (humanistic intelligence), as the fundamental basis for augmented reality.

HI is intelligence that makes itself visible and understandable to humans through something we call "sousveillance," or inverse surveillance. Rather than only having

the machines watch us, we get to also watch and understand them. HI is intelligence that keeps humans in the loop.

This very principle is what was at the heart of my childhood fascination with being able to see and lay bare the otherwise hidden world of machines and their otherwise secret world of sensory modalities.

There were three fundamental problems I solved in my childhood, through the creation of a wearable computer augmented reality device:

1. Space. The shining light of augmentation must align in space with what it represents. When your eyes focus and converge on reality, the shining light needs to appear at the same focus and convergence.
2. Time. The shining light of augmentation must align in time with what it represents. Feedback delayed is feedback denied.
3. Tonality. The light itself needs to be correct in terms of tonality (i.e., contrast), so that the shining light of augmentation matches what it is supposed to represent.

These three criteria are like a tripod that supports the experience. If one is not met, the experience falls over. And yet so many companies fail to meet all three.

And that's one of the reasons why I've been involved in the founding of a number of institutions in this space.

I believe that, rather than building a carceral world of AI and machine learning, what we need to do is to build a world of HI and AR—a world in which we will live and in which we will thrive as humans.

During my lifetime of living in a computer-mediated reality, I have dreamed of the day when we can all live better, safer, healthier lives through a new form of existential technology.

Today, with the publishing of Jon's book, a large number of people will be gaining access to a deeper and broader understanding of the amazing benefits AR can offer to all industry and individuals. The book wonderfully identifies the benefits and opportunities of AR, as well as the obstacles that could delay its design and realization. The book shows how AR will make people more healthy and self-confident and not just secure but "suicure" (self-care) as well: AR is not so much a device for surveillance (security) but, more importantly, a device for sousveillance ("suicurity").

In this sense, your eyeglass will serve as your personal life recorder and record keeper, such that your most up-to-date medical record will be the one on your body. It will also be your real-time health, fitness, and wellness advisor and personal trainer/assistant.

AR is as important as electric light and may well be the most important invention over the last 5000 years, since the days when "elA"krA • n" is said to have meant "shining light."

The world of sousveillance is a world where we won't have to fear the police nor honest police fear us.

It will take many years to master all the challenges required to make a socially acceptable-looking device that meets the three fundamental criteria (space, time, tonality), but the path is clear, and we are well on our way to doing it. This book will help us on that journey.

Chief Scientist, Meta Company Steve Mann
San Mateo, CA, USA

Preface to the Second Edition

Abstract The goal of this book is to explain the many nuances of augmented reality and what augmented reality is. Often confused with virtual reality and mixed reality, it is the objective of the book to establish a clear delineation between those other technologies whose only common element is a display, but not the content, proximity, or problems.

Augmented reality holds the promise of forever altering and improving our lives. It will give us freedom from oppression, unlimited sources of information in real time, and new ways to communicate and understand one another. We will be able to help and get help for each other at great distances, and increase the quality of service, health and welfare, maintenance, design, and education. We will also have more fun. This is not science fiction, although the concepts have their roots in such fiction.

This is the second edition of this book on augmented reality. It is not meant to be a science fiction book, but it is about the future, or at least one possible future.

Philosophers, scientists, futurists, and others have speculated about the moment in time when computers will match, and quickly exceed, human processing speed, memory access, and ultimately supposition. The conceit is when machines can process data in enormous volumes, and at lightning speeds, our innate inferiority complex leads us to predict those machines will find us irrelevant, feebly competitive, and a misuse of resources. There is no analog or metaphor for such an analysis; after all, despite our irresponsible coexistence and husbandry of the environment, other animals, fowl, and aquatic species, we never deliberately, or maliciously (with a few notable exceptions), sought their genocide. Insects and viruses are another story.

So why then would super-intelligent machines, based (grown up you might suggest) on our morals, culture, and history behave any differently? Logic is the typical answer. Super-smart machines, whose basic DNA is logic, would assess, adjudicate, and execute on cold, uncompromising logic, and logic is not conducive to human behavior or vice versa. Therefore, the popular notion is the computer would simply eliminate us, or in the best case, ignore us.

Another possibility is as machines develop seemingly sentient capabilities, they will become companions and advisors. And lacking (and never able to fully obtain) imagination, will rely on us to come up with the next idea, the next goal, the next artistic expression, and the next interpretation of current events or characters' behaviors.

So how does augmented reality fit into all of that? As we are more conveniently, and comfortably, able to access information in real time, we will literally and figuratively become augmented, though not physically—at least for a while. We will have greater and faster access to information. And as we learn how to assimilate, process, and use this enhanced capability, we will become more creative, imaginative, and interesting. As we do, emerging, or even nouveau-sentient machines, will be confounded by us, always a step behind so to speak despite their astronomical processing speeds and memory access.

However, for us to be so augmented and in touch with the databases and the data analysis tools, we must have real-time, inconspicuous, localized information, information about where we are, and all the things around us and approaching us.

To be in touch with the databases and analytical tools requires wireless communications and real-time updating. To have inconspicuous capture of localized information in real time, we will have smart contact lenses, and ultimately implants.

So the science fiction scenario is we will have augmented reality contact lenses while the computers approach or perhaps reach sentience, and rather than dismiss or kill us because we would be irrelevant and unnecessary resource usages, they will rely on us for insight, imagination, and challenges, cynically perhaps as a necessary evil. And of course, they will need some of us to keep them running.

This book will provide insight for technologists, marketing and management people, educators, academics, and the public who are interested in the field of augmented reality concepts, history, and practice and the visual and sensory science behind the improvements in advanced display systems. From the explanation of the human-machine interaction issues, through the detailing of visual display and informational access systems, this book provides the reader an understanding of the issues related to defining, building, and using (with respect to our senses) our perception of what is represented and, ultimately, how we assimilate and react to this information (Fig. 1).

The artist Zenka, who is an artist and curator-historian of augmented and virtual reality headsets, says, "augmented reality catapults us from the information age to the knowledge age."[5]

[5] http://www.zenka.org/

Fig. 1 Renowned AR artist Zenka's depiction of the joy of augmented reality. (Image courtesy of the artist)

What Are We Doing Here?

Augmented reality is such a complex, wide ranging topic, it's difficult to organize all it encompasses in a logical outlined way. But one has no choice, so this book is organized into ten sections: The beginning chapter introduces the benefits and potential dangers of augmented reality, an overview of the applications, some proposed rules or law for augmented reality, the definitions, and augmented reality's place in the metaverse. In the second chapter, a taxonomy is presented, and the ways in which augmented reality can be delivered is given. That is followed with an overview of how augmented reality has the potential to make all of us experts with information at our eyeballs.

In the next chapter, some of the technical aspects of seeing things in augmented reality are discussed, as well as the challenges of describing technology. That is followed with a brief historical overview of when augmented reality started (earlier than most people think).

Next some of the applications are examined and a distinction is made between commercial and consumer—although there is overlap (e.g., is a real estate user of augmented reality a commercial (the real estate agent) or a consumer (the house buyer) application)? That chapter is one of the largest and still it can't cover all of the existing or future applications of augmented reality—augmented reality isn't going to be a big thing, it's going to be everything.

The following chapter gets technical and delves into the physiology of the eye, on to the types and technology of displays, and ends with brain waves and implants—you've been warned.

Finally, there is a brief discussion on some of the suppliers, take note—there are too many and then there are conclusions and a very brief vision of the future.

Augmented reality will touch all parts of our lives, our society, and the subsequent rules we live by. As we adapt to the new capabilities, and power that augmented reality bestows on us, we will have to think about things differently and give up some cherished ideas and fantasies. It will change social mores and rules and challenge those who hold power arbitrarily.

Studying augmented reality is like spiraling down a Mandelbrot that reveals progressively ever-finer recursive detail. Down and down I go into the never-ending rabbit hole, finding one thing, only to learn about three others and on and on it goes.

Tiburon, CA, USA Jon Peddie

Acknowledgments

No book was ever written in isolation or without help. A book is a joint effort, a team effort, a massive body of work contributed to, edited by, and at times painfully read by friends, colleagues, relatives, and underpaid editors. Listing all their names alone would fill pages; their contributions would require even more pages, and it would appear as the credits of a major movie.

And yet I try, for to do otherwise would at the least be rude, and at the most make me the most unappreciative person to walk the earth. (Egotistical and selfish also come to mind.)

The second problem is how to list? By order of appearance, by number of hours invested, alphabetically, topically? I took the easy route—alphabetically. I did that for two reasons: A—so they could find themselves and make sure I didn't forget them (as I have sadly done in other books), and B—so I could easily add them when their contribution was realized.

So here are some of the folks who helped make this book possible. If you know any of them, give them a pat on the back, and tell them, Jon thanks you.

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