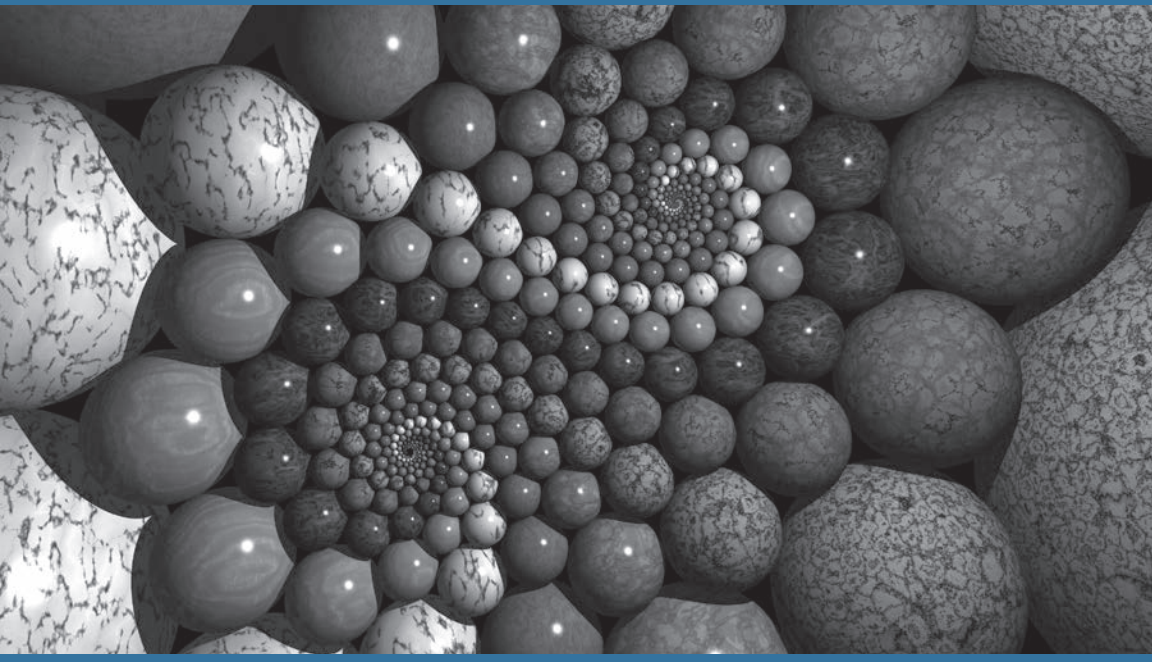
O'REILLY®

Compliments of thingworx®

Augmented Reality for the Industrial Enterprise

A Hands-On Introduction to Rapid AR Development



Leah Hunter

thingworx®

ThingWorx Studio

Create Augmented Reality Experiences for the Industrial Enterprise.

Using ThingWorx Studio, it is easier than ever for content creators to deliver purpose-built AR experiences for smart, connected products in the industrial enterprise using a drag-and-drop authoring environment and eliminating the need to write AR code.

ThingWorx Studio is scalable and delivers unmatched high-quality AR experiences. By harnessing the power of AR for the industrial enterprise, you can:

- Accelerate Product Adoption
- Reduce Service and Maintenance Costs
- Enhance Customer Loyalty and Satisfaction

Sign up for your free ThingWorx Studio trial by visiting Thingworx.com/go/ar

ptc

Augmented Reality for the Industrial Enterprise

A Hands-On Introduction to Rapid AR Development

Leah Hunter

Beijing • Boston • Farnham • Sebastopol • Tokyo O'REILLY®

Augmented Reality for the Industrial Enterprise
by Leah Hunter

Printed in the United States of America.

Published by O'Reilly Media, Inc., 1005 Gravenstein Highway North, Sebastopol, CA 95472.

O'Reilly books may be purchased for educational, business, or sales promotional use. Online editions are also available for most titles (*http://oreilly.com/safari*). For more information, contact our corporate/institutional sales department: 800-998-9938 or *corporate@oreilly.com*.

Editor: Susan Conant
Production Editor: Colleen Cole
Copyeditor: Rachel Monaghan
Interior Designer: David Futato
Cover Designer: Karen Montgomery
Illustrator: Rebecca Demarest

May 2017: First Edition

Revision History for the First Edition
2017-05-11: First Release

978-1-491-96804-8

[LSI]

Table of Contents

Preface

Industrial augmented reality can make a meaningful difference for workers.

The difference between where it is now and where it will be in 10 years is huge. What can industrial-use augmented reality (AR) do right now? It can help building contractors "see" into walls and know where to lay wiring. How about that AR in 10 years? It could enable the whole crew to walk into a holographic building and virtually lay out wiring, plumbing, lighting, and Wi-Fi systems in real time, checking for problems even before they build.

The first scenario is already in the works. The second is coming faster than you may imagine, and this book can help you get started with your own AR development.

But first, let's look at the differences between augmented reality and virtual reality (VR).

Augmented or Virtual: Depends On What You Want to Do

In theory, the distinctions between virtual and augmented reality are clear. Virtual reality takes you into the digital world. Augmented reality pulls the digital world into your reality—it weaves digital images onto and into everything.

In practice, it isn't that simple, and it would take more than a few sentences to explain. Helen Papagiannis, an expert with a PhD in augmented reality, succinctly sums up her view of the differences between AR and VR in "Designing Beyond Screens to Augment the

Full Human Sensorium," if you'd like to read more. For our purposes here, it suffices to say that the new breed of AR systems still relies on VR headsets—like the Oculus—and many of the people who play in one space play in both.

While a lot of virtual reality growth is coming from gaming, AR is starting with business. The reason makes a lot of sense: for AR to work well in business, you need a use case with clearly defined requirements.

Todd Harple, Intel experience engineer/innovation lead in Intel's New Devices Group—and the man who led several of the company's VR and AR research projects—explains:

> Over the last year or two, AR has taken a turn toward the business side of things. That's because it takes a tight vertical to make it work effectively. We purchased Recon last year, and a lot of their use cases are tight verticals. Recon Jet was about cycling—that enables you to build the device with only what is necessary for cycling. And it gives you a clear understanding of the physical and linguistic vocabulary, as opposed to "I have a telephone that can do everything on my eyes." Field service and equipment inspection are similar. You can [program the system to] have a clear understanding of what is in the walls because there's a CAD drawing somewhere.

Which is to say: you can't program a hologram to work well in a space unless you understand what is in that space, what people do there, and how it all works together.

For instance, computer vision systems are currently great at understanding that a sofa is rectangular. But they are not great at understanding that the sofa is covered with a material that should squish down when someone sits on it. And in the case of enterprise, you can only create an AR system for picking items in a warehouse when you understand exactly what is in that warehouse, how it is organized, and what is there at any given time.

"The promise of the new breed of AR systems is that they can place content into a world in the way that it seems like it's natural to that world," says perceptual neuroscientist Beau Cronin. "From my point of view, the more interesting challenge is that if you are going to put that content out into the world, you need to understand the world you're putting it into."

How This Book Is Organized

How can AR help your business? And more importantly, how can augmented reality help you?

This short book gives you answers to those questions, via a hands-on introduction to industrial AR development. It is organized as follows:

Chapter 1, Why AR and Why Now?
: Explores why now is the right time for industrial AR.

Chapter 2, AR Creators and Use Cases You Should Know
: Outlines how people are using AR to save time and money, via a few enterprise case studies.

Chapter 3, Key Technologies for Building AR Experiences (And Why They Matter)
: Gives you the opportunity to create a simple AR project with a tutorial, using ThingWorx Studio—your chance to test the technology.

Chapter 4, Your Best Strategy for AR Growth
: Brings it all together, with guidance to help you shape your own strategy for industrial enterprise AR

Appendix A, The Future of AR
: Looks even further into the future of augmented reality technology. Because if you're like me, you're curious about what's coming—and what you should be paying attention to as the category evolves.

Let's start at the beginning.

Conventions Used in This Book

The following typographical conventions are used in this book:

Italic
: Indicates new terms, URLs, email addresses, filenames, and file extensions.

`Constant width`
: Used for program listings, as well as within paragraphs to refer to program elements such as variable or function names, data-

bases, data types, environment variables, statements, and keywords.

`Constant width bold`
: Shows commands or other text that should be typed literally by the user.

O'Reilly Safari

Safari (formerly Safari Books Online) is a membership-based training and reference platform for enterprise, government, educators, and individuals.

Members have access to thousands of books, training videos, Learning Paths, interactive tutorials, and curated playlists from over 250 publishers, including O'Reilly Media, Harvard Business Review, Prentice Hall Professional, Addison-Wesley Professional, Microsoft Press, Sams, Que, Peachpit Press, Adobe, Focal Press, Cisco Press, John Wiley & Sons, Syngress, Morgan Kaufmann, IBM Redbooks, Packt, Adobe Press, FT Press, Apress, Manning, New Riders, McGraw-Hill, Jones & Bartlett, and Course Technology, among others.

For more information, please visit *http://oreilly.com/safari*.

How to Contact Us

Please address comments and questions concerning this book to the publisher:

O'Reilly Media, Inc.
1005 Gravenstein Highway North
Sebastopol, CA 95472
800-998-9938 (in the United States or Canada)
707-829-0515 (international or local)
707-829-0104 (fax)

To comment or ask technical questions about this book, send email to *bookquestions@oreilly.com*.

For more information about our books, courses, conferences, and news, see our website at *http://www.oreilly.com*.

Find us on Facebook: *http://facebook.com/oreilly*

Follow us on Twitter: *http://twitter.com/oreillymedia*

Watch us on YouTube: *http://www.youtube.com/oreillymedia*

CHAPTER 1
Why AR and Why Now?

Augmented reality (AR) is not new, but its evolution is entering a new phase—which I think of as "finally usable by a broad group of people."

We've passed the "trough of disillusionment" that comes with any new technology. Big-name companies are investing heavily in the space, as are individual investors. The hardware that drives the technology has made leaps, particularly in the past year and a half. And most importantly, thoughtful AR creators have been steadily testing and refining how to use the tech—particularly over the past 15 years. We are finally past the pilot phase. And we are now beginning to prove that the technology has business applicability—and, as importantly, the ability to really help humans.

Why should you start planning for this now? Because it can help your workers. And it can save you significant amounts of money.

Companies who are ahead of the curve are already cementing their leadership in the AR space—and creating using the tech. (Intel purchased Recon last year as a way to get into the game. PTC purchased Vuforia from QualComm. And in May, Apple snapped up German AR company Metaio.) Those who are currently following the work of Magic Leap (acquired by Google for $542 million) can expect a slow progression toward what will ultimately be a huge leap forward in technology.

All companies should be looking to augmented reality as a key tool for creating the future. And they should start looking now.

Why?

> *Someone is sitting in the shade today because someone planted a tree a long time ago.*
>
> —Warren Buffett

> *The best way to predict your future is to create it.*
>
> —Abraham Lincoln

Pokémon GO Was a Fad—And Also a Tipping Point

Industrial enterprise AR is not the same as consumer AR, but the two are interwoven in a way that pushes both of them forward. The more people—workers, kids, college students, ordinary folks—who understand and embrace a new technology, the faster it is embedded into collective consciousness. And, in turn, the easier adoption becomes. A rising tide floats all boats; in this case, the tide looks a lot like a Pokémon.

On July 10, 2016, Fortune reported that Pokémon GO was about to surpass Twitter in active daily users, and that the game had been installed on 5.6% of all Android devices in the United States. After that, those numbers spiked. There have been 10 million Android downloads. The app generated an estimated $1.6 million a day from the iOS App Store. (Each day. Just on iOS. Just in the United States.) Nintendo's market value increased an estimated $11 billion in the first five days after Pokémon GO was launched. That number went up a lot, then dropped a lot, but after all was said and done, it still made a whole lot of money (and was a massive step forward for AR).

Is and was Pokémon GO a fun, nostalgic fad? Yes, absolutely. Will some businesses look at the Pokémon model and make strategic mistakes, like trying to make people chase floating cars as AR advertising? Yes, they will. And that doesn't matter. What Pokémon did is embed—finally and clearly—in public consciousness what AR is and how it works.

Why lead with this in a book on AR for industrial enterprise? Because Pokémon created the "Ooooh, I get it!" moment. And that has a ripple effect.

Industrial Enterprise AR: The Inflection Point

People now understand that AR is about seeing digital things in and on top of the physical world. And since it's understood, it's now embedded in culture and collective consciousness. That is one of the openings AR makers have been waiting for! Fast Company wrote a piece entitled "Pokémon Go May Prove That AR Is More Mainstream Than VR." And it's true. Not only does the ubiquity of this seemingly simple game create an opportunity for small, local businesses—mom-and-pop shops that are willing to open themselves to it (or capitalize on the customers already coming)—but it also exposes a much larger, broader audience.

(Which means the social benefits are pretty great too. Go red team.)

More people who "get" AR means more people *will* get AR: in new apps, in new hardware, and in new use cases.

I do not know the people at Blue Hill Research, but they hit the nail on the head when they said, "Pokémon GO just accelerated adoption for enterprise augmented reality." They go on to say:

> Vendors such as PTC must be ecstatic about the excitement surrounding this game. As the key arms/platform dealer of augmented reality in the enterprise, PTC is in a position to translate the success of this new trend into real enterprise value through its combination of ThingWorx Studio, VuMarks [also known as ThingMarks] that can serve both as enhanced bar codes and placeholders for 3D digital representations that can be seen through a smartphone or tablet, and the professional services from the Vuforia business unit that are expert in deploying augmented reality. As odd as it sounds, ThingWorx Studio has to be seen as a leading vendor for "Pokémonifying" your business.

They have positioned themselves well at a very good time.

You Should Get Really Clear Up Front: This Is Not VR

As augmented reality has developed, it has been lumped together with virtual reality. That's happened for a lot of reasons. Some AR systems use the same eyewear and headset tech as VR. Industry analysts who wanted to make the industry look bigger (or who didn't yet know how to parse it out) did some creative things with numbers. The earliest makers of AR were people who came from the VR

world (and that's often still the case). So the conflation of the two is understandable.

But it is time for a separation.

AR is a distinct technology. While VR brings you into the digital world, augmented reality brings digital information into *your* world —and overlays it onto the physical environment around you.

People are now calling the field *mixed reality*,[1] which is an accurate term for the nature of what's happening, but one that is often used as a catchall for any new tech in this arena. It effectively still lumps AR and VR together—wrong move.

Make the distinction in your mind (and business strategies) now. *AR is distinct from VR.* Business strategies, types of development, and financial forecasts arise depending on what technology you're talking about. Digi-Capital, a Menlo Park–based industry analyst and consultancy, predicts that AR will be a $90 billion market by 2020—while the VR market will be worth $30 billion. The streams have just separated.

Is now really the time for AR? In industrial enterprise, it is.

The reason is precisely because of how long it's been developing. Picture in your mind the J-curve (hockey stick) that shows the advancement of any technology. This one had a long curve. And it's now on the upswing—and rising fast. People have been working on AR for 15 years (or 90, depending on who is counting). And all that research and thought has really paid off in the past two years or so. AR has become the beneficiary of advances in hardware, breakthroughs in computer vision technologies, and the distillation of years of thought that have gone into how to build these systems. Said more simply: the underlying technology that powers AR has finally caught up with the promise of it. As you'll discover, AR has already quietly taken hold in industry. We've begun to exit the R&D phase. Now is the time for smart companies to create strategy.

1 For more about mixed reality and why it is a term you should pay close attention to, see Appendix A.

Why Now Is the Best Time to Develop AR

Augmented reality represents a new way of seeing, and seeing into, the world. In this context, it is a powerful tool that not only "augments" the world around us, but—more importantly in a business context—enhances human abilities and provides greater insight into machines and products as well.

Imagine you just bought a new piece of machinery for your office or factory. Rather than ever reading an owner's manual, you can join your entire team in "seeing" how to properly operate, maintain, and repair the machine.

Or put yourself in the shoes of a worker on an oil rig. Augmented reality can give you complex startup, shutdown, and emergency procedures in simple visual instructions, and it can connect you with immediate remote assistance should you discover a problem.

Each of these scenarios is already happening. There are systems that allow salespeople, doctors, steelworkers, electricians, and workers of all types to "augment" themselves with smartphones, tablets, and eyewear that enable them to see *in the physical world* the information they need to do their jobs more effectively.

A number of these use cases focus on manufacturing, safety, quality, assembly, construction, inspection, and maintenance. Because of the sheer scale of manufacturing, these are some of the most striking examples of how companies have been deploying AR. Even through pilot programs, there is evidence of deeper knowledge, significant savings (think billions of dollars), and environmental crises averted. In other words, even on a small scale, you can see the possibilities this technology opens up when rolled out (and there are more rollouts coming).

AR can also be applied to areas beyond heavy industry and manufacturing. For instance, for the last few years Mercedes Benz has been putting QR codes in the B-pillars and inside the fuel door of all its new cars. The reason: so first responders at accidents can connect with an AR app to see color-coded diagrams of wiring and fuel systems. This allows them to cut through these systems at accident sites quickly and accurately—saving lives in the process. That is the power of AR used thoughtfully.

Later in this report, you'll hear about several industries—from aerospace to heavy machinery—where AR has been used in meaningful ways. Enterprise means business. And the business applications of AR are myriad.

The question is: Why is now the right time to invest in this (after all, hasn't AR been around for a long time)? The answer is: Yes, it is (and yes, it has). Not only have the base technologies underlying AR changed, but the world has also changed.

Most notably in this case, we are no longer living in a world that is paper based or centered on written instruction manuals. For a lot of things that are manufactured, we already have the digital manuals, CAD models, or videos showing how they are built and assembled —which is incredibly valuable if you are building a custom AR system from scratch. To be able to show someone how to operate or repair a machine, you first have to be able to visually, accurately, graphically show the machine. We can now do that (more or less easily), drawing from the digital world. What is more, we also have adequate knowledge about how to translate these digital images into tools that can be used in different ways for enterprise AR so we can overlay and display the important bits of it in front of us. That means we can "holographically" display and render objects accurately. And we can have exactly—and only—the bits we want, exactly when we want them.

The barrier to entry is lower than it ever has been. Computer vision systems have improved. Everyone has a tablet or smartphone. And now, for the first time, there are mature consultancies that specialize in enterprise AR (and have actually applied it), and enterprise-focused platforms that help industrial clients create and roll out AR apps and programs. The requisite systems are in place, and the tools needed to prototype a system are less expensive as well.

Knowing more about the world around you, in real time, without having to look that information up yourself is the equivalent of having x-ray vision and a genie in your pocket who makes the exact information you need appear exactly when you need it.

In his book *The Road Ahead*, Bill Gates said, "We always overestimate the change that will occur in the next two years and underestimate the change that will occur in the next ten."

AR Has Reached the Usability Phase

We've passed the imagination phase of the 1900s–1960s. We've completed the R&D phase of the 90s. Inexpensive tablets, improved computer vision systems, and people who have been playing with the technology long enough to advance it significantly have now put us squarely at the front end of the "finally usable by a broad group of humans" phase. It's still early in that era...it is dawning now. And, by doing your own research, prototyping and planning, and investing, you will put yourself in a great competitive position as this evolves. Not everyone needs to be an expert at building or authoring AR systems. But everyone *does* need to have a basic understanding of how AR systems are evolving, so you'll know how to use them to your advantage. Learning now is a smart business move.

In 2016, CB Insights presented at a 500 Startups conference called "PreMoney." The event and the presentation were designed for venture capitalists and outlined the hottest areas of investment—and AR was one of them. The crux of the presentation was very much along the same lines of what Technicolor Ventures' Mark Linao wrote in a guest post for the CB Insights blog: "Despite the dominance of gaming in media coverage of VR/AR, it's actually commercial and industrial applications that take the most deals. The number of VR/AR startups is increasing as venture capital dollars continue to flood in, with investment reaching an all-time high in 2015 of $695 million in equity funding across 126 deals, according to CB Insights data." Or course, Magic Leap made up a big chunk of that. But drilling deeper into the funding data, Linao said, "commercial and industrial applications received approximately 17% of total investments among all categories." What that means: AR is steadily —if slowly—being adopted by the enterprise. And it is being noticed by venture capitalists and big investors.

So two answers to "why now?" are because the technology has significantly advanced and because other smart people are doing it. But by looking closely for yourself at the way industry is changing, you may find even deeper business reasons.

Where AR and IoT Connect

Not only is the history of AR-enabling devices like tablets and smartphones and wearable systems important to discuss, but there's an evolution of sensors that is relevant too.

The kinds of sensors we have in modern consumer devices were once so incredibly expensive that only NASA could afford to invent (and build) them. If you look around the world today, everything is sensor-enabled or controlled. Elevators, pressurized doors in skyscrapers, and almost all factories are filled with sensors. If you walk a factory floor, you might have dozens of sensors on a single machine that are tracking everything from vibration of multiple axes to pressures to temperatures to mass flow—and you'll also have variable-frequency drives controlling the motor. In addition, there is an explosion of wireless sensors in the marketplace, all less expensive and smaller than ever. Why is that relevant?

We've entered the era of the industrial Internet of Things (IoT), which is known by a lot of different names, depending on what part of the world you are in. Some people—mostly in Germany—call it Industry 4.0. Some people refer to it as smart, connected products. People have also used the phrase Brilliant Factory, or even the 4th Industrial Revolution. But when you distill it down, what they're trying to communicate is the connection between machines, data, and people.

With industrialized, instrumented machines, you also have sensors. More sensors on these machines are pulling more data off of them. Since all of these machines have sensors, and all of them are pulling data, that's a lot of information. What you want to do is take the data and analytics and push the most meaningful information out to the workers, to give them data visualization so they can do their jobs better. Once they get that information, they act on it with the machine, and it becomes a continuous improvement cycle.

That's what AR does. AR enables the visualization and the contextualization of information. AR allows you to translate the data about your machines, within your machines, and coming from your machines in a way that's actually useful.

Glen Fields from PTC puts it this way:

> I came up through the marine industry on ships. It was important to be in the control room and to monitor the condition of the hundreds and hundreds of different machines that were all contributing to the propulsion of the ship. But if you just strictly stayed in the control room and monitored and relied on all of the gauges and the sensors, you didn't gain an appreciation for what was really happening out on the machine room floor. You might have machines that are smoking and the sensors might be bad. You want to see what's really going on.

With AR, we're trying to take the control room out of the control room.

So you have the Internet of Things and you have augmented reality. But how do the two work together? The IoT is essentially the ability to digitally talk to physical things—to monitor and to manage them. AR is all about the ability to see and experience the digital attributes of those physical things.

The ability to deliver digital information in the real world, in context with the machine, is what AR makes possible. It enhances that whole technology stack.

Right now, you have hardware. You have the software that's embedded into that physical product, and you have communications that allow you to convey what's happening digitally with that machine. The data on what's happening in the machine can be in the physical world, or it can be in the cloud in the form of databases and analytics and platforms and applications.

Because AR also enables video communication and video augmentation, it allows you to experience that hardware data in a totally different way. Brains don't just process information in two dimensions. Screens are great, but they are not the same as interacting with a physical object the way we typically do. That physical connection is one key reason augmented reality of the enterprise is gaining traction.

Workforce Transformation: AR for Knowledge Transfer (Industries Are Blending)

In addition to helping to visualize and contextualize information, AR also helps smooth a social issue facing all world economies: the

aging workforce and shortage of skilled manufacturing labor. It's an important area to consider. The latest data shared publicly on the state of global manufacturing, a joint study by Deloitte and the World Economic Forum, says that the manufacturing industry can expect a shortage of 10 million workers globally. More recent reports say that 2 million of those are in the United States. What you're seeing are baby boomers retiring, a dwindling Chinese workforce, and students coming out of school today that don't have the same skills that a 30-year veteran has. The average age for a highly skilled manufacturing worker in the United States today is 56. That's the *average* age. As these skilled workers retire, it's going to create a gap in the workforce.

Why is that relevant? Augmented reality provides an ability to transfer that knowledge, even to unskilled workers. It enables you to collect and preserve the information that lives in the heads of these highly skilled workers and digitally capture it in a few ways:

Augmented instructions
: AR can be in the form of service. By gathering information from a skilled worker, you can develop augmented work instructions about how to do a complex repair on a piece of equipment. You can easily use that in training and simulation—teaching people to do jobs before they go into the workforce.

Remote guides
: AR can also allow skilled workers to act as remote guides for less skilled workers. This creates the possibility for "retired" workers to reenter the workforce, part-time from anywhere. It also makes it possible for one highly skilled employee to have "many hands," working through less skilled workers (using AR systems and visuals as guides) to multiply value. It is now possible to be in many places at one time.

Cross-Domain Technical Skills

Industries are blending. Technology is one of the universal bridges between all of them, and AR can strengthen that bridge. A May 2016 study by the World Economic Forum, called "Manufacturing Our Future," says:

> The future of manufacturing will see an increased demand for cross-domain skills covering technology, engineering, electronics, robotics, usage of new equipment, computational thinking, coding

> and computer sciences...The typical blue- vs. white-collar job distinction does not hold anymore. While former white-collar workers have moved up into innovation, former blue-collar workers are required to perform more capability and cross-domain-based functions in manufacturing, as machines take over manual jobs.

This competitive advantage is recognized by all sorts of people. At the end of last year, Fast Company reported on a special project spearheaded by the president of Kazakhstan. He invited multiple companies, including Intel's Daqri team, to come to Kazakhstan to visit a facility called KSP Steel, to show how technology could improve their society, and to educate their new workforce. Specifically, the Daqri team showed the workers at this steel plant how to use AR to enhance production and make their jobs easier.

You can read the public version of the case study yourself. The results were remarkable. KSP Steel was able to improve the productivity of its workers by 40% and decrease downtime at the facility by 50% using digital information in context with the real world.

What Is the Business Justification for This (AKA Show Me the Numbers)?

So how much return could there be for you? How can you start to think about this if you are trying to create a business justification?

I interviewed Matt Sheridan at PTC to find an answer. What he said was brilliant:

> What we put together is a way you can think about it, and a way that you can start to have the conversation in your company. The example we [focus on] is service. There's a study that was by a partner of ours called ServiceMax. The study is called "A Diamond In the Rough: Unleashing the Power of Field Service Transformation."

The ServiceMax study talks about two aspects of service. First, that service is continuing to grow—in the sense that there's more service taking place—and various companies are looking at service as a revenue stream. Before, service was simply the add-on for selling a product. Now companies are actually selling the service itself as part of their offering. Therefore revenue is increasing.

The study says, "In 2012 there were about 5.4 million service technicians. By 2020 there will be a need for 6.2 million." That means nearly a million more technicians in the workforce. When you tie

that back to the aging workforce and add the fact that it's a challenge to find skilled labor, the conclusion is clear: this is going to be something companies really struggle with.

Sheridan also explains:

> If you look at your service department, most good service organizations have some metric that they're tracking. First-time fix, or mean time to repair, or mean time to install. If you were going to have a conversation about how AR might improve a particular area and you wanted to tie that to something, let's take a look at first-time fix and out-of-service time, what do we do?
>
> Referring back to that ServiceMax whitepaper they wrote, it talks specifically about service of two companies. Company A has a first-time fix rate of 88%—considered at the high end of the first-time fix rate range. Company B was at 10%, at the low end of the first-time fix rate. So if both companies are doing 400 service jobs a day, the first-time fix rate differentiation means Company A is able to fit in 100 more jobs a day. Multiply that by 250 days a year, that's 25,000 extra jobs. So for Company B to compete with Company A, they need roughly 25 more people to complete all those jobs. I then looked at Payscale.com and looked up the average salary of a service technician in North America and found it to be $55,000 a year. Simple math: 25 times $55,000 a year gives you $1.3 million investment for Company B to catch up with Company A. That gives you a ballpark number.

What that means: if you find what's causing the first-time fix rate problems, and what's causing increased cost, then you can tie that to how AR can help solve the problem.

"It's a little bit of A equals B, B equals C, and therefore A equals C," Sheridan concludes. "We don't have at the moment the exact company that says, 'I saved $1.3 million with AR.' But you can see where the conversations should be happening. And people like real numbers, so they'll have those conversations."

What Else Should You Know?

After seeing how AR is developing, you might be asking the next big question: How is it successfully being applied in an industrial enterprise context?

Chapter 2, *AR Creators and Use Cases You Should Know* outlines case studies that answer just that.

CHAPTER 2

AR Creators and Use Cases You Should Know

If you're working on your strategy or budget, one of the first questions you might ask is "What is AR's place in my enterprise/operations?" The best way to answer that is to look at how it is being used, and how it will most likely be used in the future.

The Augmented Reality for Enterprise Alliance imagines use cases from warehouse picking to emergency response to aircraft cabin workflow. Some of these use cases are real. Some are hypothetical. Based on this list, the big question in my mind around enterprise AR was: Who is actually using this, and how? I found answers the best way I know: I interviewed people.

The interviewees are creators on the frontlines of industrial enterprise AR. Some run corporate AR programs, some have founded companies specifically focused on the needs of industrial AR, and some lead strategy teams. All are technologists who have been exploring, refining, and creating different ways of using, building, and piloting AR programs. Their various projects save significant time and cost, and actually *do* help people. That was part of what convinced me that *now* is indeed the time for enterprise to start thinking about testing and planning for this technology.

Each case study explores how a company is using AR, and has a specific narrative through line:

AR can save you lots of money
: Case study: Boeing

AR is being used to help humans (do things like prevent oil spills and maintain machines)
: Case study: Dotty

AR can be used by big and small companies and communities (in all sorts of ways)
: Case study: Kalypso

Big and small companies are creating AR strategies—now
: Case study: Caterpillar

AR Can Save You Money

Case Study: Boeing

Paul Davies is an electrical engineer, and an Associate Technical Fellow in the Advanced Production and Inspection group in Boeing Research & Technology. He is currently managing projects in augmented reality, machine vision, and advanced visualization techniques for manufacturing.

Davies helped design an AR study with the goal of quantifying what happens when people use AR as opposed to other methods of receiving technical information. His team partnered with Iowa State University to design a mock wing assembly—set up to mirror what is built in a factory—made of wood and consisting of 45 parts plus wiring, fasteners, nuts and bolts, and washers.

Davies brought in 48 people, primarily engineering students, who had never before built a wing. They were divided into three groups:

- Group 1 used a desktop in the corner of the room to reference IKEA-like assembly instructions—2D drawings and simple text directions.
- Group 2 had a PDF of those instructions on a tablet computer, which they could carry around with them.

- Group 3 used AR, with animated 3D content showing "parts flying into place."

The steps in each set of instructions were the same—they were simply delivered differently.

Each group was timed and graded as they completed the wing assembly twice, in two timed trials. The key metrics of the study: how long it took to build the wing, the number of errors, whether the groups were able to catch the mistakes and fix them, and how long that process took.

The results were remarkable. Group 1 both took the longest and made the most errors. Because the builders were walking back and forth to the desktop computer, they often forgot the instructions by the time they got back to the wing. Group 2, with the document on a tablet, took significantly less time to build the wing and produced higher-quality work because they made fewer errors.

The best result came from group 3, the builders using AR. During the first trial, they completed the process in less than half the time it took group 1, those reading instructions from a desktop. During the second trial, group 3 not only completed the work faster, they also did it with zero errors.

It is clear why Davies believes in AR.

Here is what he had to say in our interview about why Boeing has invested in it.

Why did Boeing start an AR program? And why is it particularly relevant now?

"In my world [it] is a technical answer. The desire to do AR has been around for a long time. But why now...it's because the two hardest parts of doing augmented reality are tracking—which is understanding things in 3D space, where things are...where a viewer is...or where you're holding a tablet or cell phone precisely—and how you do the visualization: How do you combine digital data on top of the real world? Is it on a headset, is it on a tablet? There's many ways to do it," says Davies.

Both of those two things he mentioned—tracking and visualization—are now becoming possible, whereas in the past they required

workarounds and stopgap solutions. AR has been difficult in a realistic production setting in a factory.

"We're just on the cusp of being able to do it," he says. "I think that's why now."

As to the question of why do AR at all, Davis gives a simpler answer: most companies build and design products in the virtual space using software, yet they build those products in the physical space. Any technology that connects those two worlds makes it easier for humans—nothing gets lost in translation.

In Davies's words: any *thing* we can do to bring those two spaces closer together is only going to help people understand design [and] interpret information easier or faster.

Davies says the most common way of tracking things has historically been to use markers—essentially 2D images, which look a lot like barcodes or QR codes, that let a camera identify the physical object, matching it up to the digital version that appears within the AR software. But now motion capture systems for tracking objects in 3D are very fast, and more 3D mapping, tracking, and localization technologies are available. This is to say: markers are one way to go, but they may soon be a thing of the past, particularly in large-scale factory settings. "My view has always been, nobody wants to put markers everywhere. It's time-consuming. You have to add them, they have to be positioned very precisely, and all these things," says Davies. "I know other companies and other people will tell you that they're using markers and they work great. There's different folks, different strokes. But now we're moving away from markers, and we're starting to see more things that people have used—including ourselves. We're seeing more 3D mapping and tracking and localization machines. They don't even need markers."

What is Boeing doing in industrial AR right now?

Boeing is also conducting pilots around remote support and for visualizing "stay out" zones—showing people doing aircraft assembly which areas to avoid when adding wiring bundles. This is necessary because sometimes the major components are assembled in what is essentially "reverse" order, and wiring is more difficult to move later.

"So as somebody is connecting up a harness," Davies explains, "they're visualizing the stay-out zones and they have to keep the har-

ness out of that zone to prevent any problems later when they come to install other parts of the assembly."

Davies also pointed to one of the biggest challenges in industrial enterprise AR right now: connecting everything in with legacy systems. When building an AR program and strategy it is important to consider four things:

- How you get the data from a manufacturing execution system in the first place?
- How you transmit that data over the network securely into a device?
- How you translate it from traditional instructions into an appropriate format for AR?
- And finally, how do you feed information from an AR headset or tablet on the shop floor back into a manufacturing system?

Right now, those linkages—largely—do not exist. When it comes to designing AR systems, there are a lot of people looking at tracking, visualization, and headsets. Far fewer people are looking at the bigger and very real question: How do I link this to my systems, which probably were not originally built with AR in mind?

ThingWorx Studio is a platform that is addressing this issue, and one possible AR solution for creating links between industrial systems. In Chapter 3's tutorial, we will look at how it works and test it as a tool for building an AR experience.

AR Can Help Humans

Case Study: Dotty

Dotty's Wesley McCombe, who's worked for some of the biggest names in the oil and gas industry, has been looking at ways AR can help people collaborate across long distances for things like remote coordination with workers on oil rigs and field management for gas pipelines.

At the companies he works with, when things break down, it costs in the $8–10 million range. Any large facility that handles a country's energy infrastructure works like a train system. When train ser-

vice goes down for a day, the costs are in the millions of dollars. Getting everything up and running again is paramount.

However, in the oil and the gas industry, there are a few layers of approvals—technical authorizers who need to sign off on the next steps to resolve a crisis. And, as McCombe explains, that typically means gathering a lot of information about problems, sending it out, getting emails back, receiving phone calls—and one or two days later, *maybe* getting a decision to move forward. Instead, AR can be used to create remote viewing that dials people in instantly and gives them everything they need on the spot. The result: a faster resolution, money savings, and crises averted.

How can AR fix failures that cause million-dollar delays?

McCombe says, "Let's just say a very, very basic fault occurs on an oil rig and it requires a change-out of a seal, a very basic part. An O-ring seal needs to be changed. It's taken the whole rig down, so you're on a huge delay. And for whatever reason you don't have a spare, but you have something similar. So you now need to get sign-off from higher-ups to use that. But those questions the authorities ask is: What is it? Where is it? What's the risk if it goes wrong? Is it compatible?"

McCombe continued by saying that when all of these questions come up, "you're able to dial [others in the company] in and share that information with them...they [can] give you the sign-off there and then."

That is to say: AR basically gives you eyes and ears to see and assess the problem, as if you were the one actually on the rig.

McComb—who operates from both the US and Sydney—pointed out an interesting book written by another Australian, Andrew Hopkins, called *Disastrous Decisions: The Human and Organisational Causes of the Gulf of Mexico Blowout*. Hopkins is an expert on process safety who works in corporate psychology. His book describes what's known in the oil and gas industry as the "Swiss cheese bottom," the moment when all the holes, issues, and problems line up to create a serious, life-threatening, and costly problem. The reason McComb mentioned the book is this: he thinks AR can prevent the Swiss cheese bottom from happening, and that it is a great way for an entire industry to come together to create tools that can be shared collaboratively. Once one company or consortium

builds an AR system for a particular use case, many companies could benefit.

"I find it fascinating because the amount of holes that lined up in the Swiss cheese [for the Gulf]," says McComb. "It's very rare, but when they do, you have an incident. And I believe that AR will be the key to making sure that we don't ever have that scenario, because there's too many eyes and ears watching over that thing for it to occur."

"Industries as a whole are going to need to invest money collaboratively to solve these things," he continues. "Safety is everyone's [issue]."

AR can be used as a tool that benefits society, as well as individual companies. That also points to one of the primary use cases for enterprise AR right now: connecting subject matter experts, remotely, to any other worker in the world.

Why does this matter so much right now? Because of our changing workforce.

How can AR affect our changing workforce?

As a global economy we are facing some significant challenges in and around the future of work—as the previous chapter discussed, we have an aging workforce and a shortage of labor for industries like manufacturing. A World Economic Forum study quoted in the *Wall Street Journal* said that even in China there will be a shortage of more than 200 million workers by 2050. One solution: remotely connecting more skilled workers to less skilled ones, enabling knowledge transfer—and potentially, training from one to many.

In a panel at O'Reilly's 2016 "NextEconomy" summit, Mary Gray from Microsoft Research noted that when looking at the future of work, we should be thinking more globally. Talent comes from everywhere. Age is not a barrier. With translation services, neither is language. AR can equip companies to broaden their talent pool while hiring local labor with different types of expertise.

Consider also that the next generation of workers coming into the industrial world are used to digital interfaces. They grew up on video games. Being able to give them a toolset they're comfortable with is important. And tools like Dotty's 3D exchange help to fulfill that need.

As McComb concludes: "Managing business risk at the moment is huge. To not invest in [AR] now is to potentially not have a solution. With large companies, the chance of this working out of the box is fairly unlikely. So you need to start customizing an AR solution that works for your industry and for your sector."

AR Can Be Used by Big and Small Companies and Communities

Case Study: Kalypso

Chad Markle leads the digital practice arm of Kalypso, an innovation consulting and strategy firm. He comes from a background in creating immersive video tours—a precursor to AR. Amy Kenly is the VP of marketing for their digital innovation practice.

Specifically, with regards to AR, they're focused on IoT platforms like PTC's ThingWorx and "the augmented reality solutions they have like ThingWorx Studio." What is interesting about their perspective is that they work across industries and with companies of various sizes, so they have a broad perspective about the types of people rolling out and looking at AR programs now.

My favorite case study, among those they mentioned, is about AR as a tool to eliminate the language barrier in emerging markets, and to prevent the spread of disease. It shows that AR can be used in ways we are only beginning to envision.

How is AR used to reduce complexity?

When I asked Kenly and Markle to share some examples of how AR is being embedded into products, they gave two examples. The first is from a global fork truck manufacturer. A fork truck is a more complex industrial product than you might imagine. It has more than 1,000 parts. And inside it, mechanical, electronic, hydraulic, and computing systems are all assembled in very tight spaces. There's not a gap of space in these things anywhere, and they're really difficult to service. In a lot of cases you have to take components out to get to other components. "You might have two or three layers of systems to get to something," Markle says.

Because of the complexity of the product, it is really hard to find qualified service technicians. This particular company has educated

their workforce through classroom training for many years, and they've been watching the washout rate rise dramatically year over year. The feedback they're getting from technicians who wash out is that they don't like classroom-style training and instead prefer YouTube videos. Thus, the company is trying to find different mediums to connect with this generation. That, Markle says, is the reason they are turning to augmented reality. "They're looking at augmented reality as a way to provide the information in real time, perhaps with less skilled and trained technicians," says Markle. "[They want] ways to better engage them in the process, and to be able to push engineering revisions down to the technicians more quickly."

Kenly and Markle also spoke of another case study that points out how AR can be especially useful in emerging markets. In this case, it is being rolled out to ensure accurate service of complex medical equipment—a sophisticated electromechanical faucet used in hospitals in infectious disease wards.

How can AR ensure the fix fits the problem?

"Imagine somebody who was dealing with a patient with a disease that in an unconfined state would kill people—bad, bad bugs," explains Markle. "The goal is being able to wash your hands in that situation without touching anything."

The way this faucet is designed is highly sophisticated. It is loaded with sensors so that it understands the presence of a nurse or doctor in their protective clothing. It gets the temperature right, and allows them to wash their hands or whatever else they need to wash. And then it runs a cycle where it sterilizes itself with exceptionally hot water. All of this needs to be measured; in the UK and other places, it's required that you log that the faucet completed its sterilization procedure properly.

Filling that need for more information is where industrial AR comes in. "The problem," Markle says, "is the traditional plumber is not a computer technician and doesn't deal with servos and motors and sensors and the things that are there, so they've got a real issue with making sure that it's serviced appropriately. They [can] use AR as the overlay, so they see the schematic and the diagrams."

The other reason this company is especially excited about AR: there is high demand for the product in emerging economies, whereas Markle says, "the health system is a little bit frailer, and the disease

issues are much more significant." In those markets, in addition to augmenting the technical skills needed for product repair, the company also sees AR as a way of overcoming language barriers. Reading a manual or verbally receiving information about how to complete a repair gets tricky when you're working in multiple languages. Because augmented reality is primarily visual, they think of it as a tool to help them to drive greater penetration of the product in markets that are non-English-speaking—which is to say, a lot of the world.

Just like the other interviewees, Kenly and Markle have specific preferences and recommendations about how to build enterprise AR experiences. In their case, rather than building from scratch, they prefer to use PTC's ThingWorx technology. I asked them why.

"What's powerful about PTC's platform and technology is that they have a legacy history going back to the 80s of providing CAD models, where all the products are designed and set up before they're manufactured," says Markle. "You can take the geometry and the parametrics of products that are already designed. For example, every single part of this fork truck is sitting in PTC technology, and it can be translated into augmented reality very quickly using ThingWorx Studio."

"Now you're talking about not having to rebuild any geometry. Now you're talking about animating...and deciding how you're going to make the visual experience overlay the actual physical experience."

Big and Small Companies Are Creating AR Strategies Now

Case Study: Caterpillar

Terri Lewis is Director of Digital and Technology at Caterpillar, a $47 billion company ranked number 59 on the Fortune 500 list. It operates in more than 180 countries with more than 300 products. It's a big company, and a complex one.

One might assume that because it is a 111-year-old company that makes fairly traditional products—primarily engines and heavy machinery—that it is less progressive in technology adoption. That would be a mistake. Lewis discussed the company's approach to AR, explaining that they've been looking at augmented and virtual reality

for everything from product sales to helping customers compare products and understand dimensions. The work they're doing is impressive.

How does Caterpillar use AR and VR to change the way work is done?

Lewis says their AR and VR work includes views of various pieces of equipment, allowing people to physically compare products and understand dimensions. It includes apps that make maintenance easier—which is common across all industries. It also includes virtual, visual operating instructions that replace paper manuals. As Lewis says:

> Every product that goes out the door has got an owning and operations maintenance manual...you can't normally find it. Now with AR, you can just take your cell phone and app and look around. And it shows you [everything you need to know]. Our vision too is taking the smart, connected product and putting it also on the desktop of a Caterpillar engineer, and taking a lot of data about our product and putting that in a visual context so they can see. As an example, for an engine, we're taking pressure and temperature so you can see actually how they're playing out on the engine.

Because the technology that supports enterprise AR has advanced so significantly in the last two years, Caterpillar is pretty far along in the development process. Lewis says that they've already done proof of concepts and have gotten "all of those applications working." Interestingly, they have also created a corporation-wide, cross-brand team to compare notes and best practices on all of their AR and VR work. Lewis has been leading this charge. As she says, "Late last year, we found out that there was a lot of innovation going on in the company around this space. We had a workshop. We brought everybody together, and we found that there were seven major workstreams going on in the AR/VR space—and some had been going on for over a year."

"[That was about] leveraging the innovation that's going on because people are trying to solve business problems and collaborating together to start putting that into the technology roadmap [and] to start getting that into production in the most cost-effective way across a large, very complex organization," she says.

Unifying those efforts across a massive corporation in and of itself is a huge accomplishment. And, as Lewis also admits, while it is one thing to do proof of concept and get things technically working, it's

another thing to actually put it into production. There is still work to be done.

"Everybody gets really excited about it, but the dirty, rotten secret is data is messy. That's the hard part of getting it into production. And because people didn't know about it—we've got products that have been designed for years, you've got to go back and get some of that product structure and the data structure into digital media," she concludes.

Lewis points to one reason so many divisions at Caterpillar have been interested in the technology: Caterpillar's equipment operates remotely and in hazardous environments. It can be hard to find trained technicians. With AR you can have a smart domain expert remotely troubleshoot and not have to fly them out there: "Dispatching your experts all over the world—you don't have to do that anymore. They can sit at their desks, and they can take a less skilled technician and walk them through a process and visually be there. Less travel, and then having fewer experts and increasing productivity in leveraging them, is a big value."

Another big motivation is reducing the cost, Lewis explains.

> One of the things we looked at was—we're still having a bit of a discussion—operations and maintenance manuals. If we send a gen set out, legally we send them out with an operations and maintenance manual, but you can't usually find them and that doesn't help anybody. It might make the lawyers happy, but how do we really help our customers use our equipment? How do we also reduce the cost of operations and maintenance manual? If you get consumer products anymore, the operations and maintenance manuals are really simple. It's pretty basic. If you want any more information, you go download some huge PDF off of a website. In lieu of that, we have a basic manual but then you've got an app. Digital media it's always going to make it easier to keep it more updated and relevant to the product. We're a global company, so you also have to put the manual in languages and print media.

How can incremental savings of AR scale across an enterprise?

Manuals are a seemingly small example, but this points to the scale at work across a huge multinational company, as well as the real benefit that can come from implementing a new technology. By eliminating user manuals, you eliminate printing, translation, and creation costs. Across a company, even eliminating the incremental savings of making a maintenance manual could be huge. More than

the money, though, the benefit comes from making things easier for the people in the field using the equipment.

"It could be a cost reduction," Lewis says. "But I really think the driving factor for what we're doing is trying to make it easy for our customers to use our equipment."

That is the ultimate goal of all of this: to help people. But to get there, you first need to understand the tools for making this happen —how to build AR systems and the technologies that are most useful now. These tools are the focus of the next chapter.

CHAPTER 3

Key Technologies for Building AR Experiences (and Why They Matter)

Now that we've looked at the reasons AR has entered the "usable by humans" phase in Chapter 1 and we've seen some amazing enterprise use cases in Chapter 2, it's time to make sure a couple things are clear before you plan an AR project and pick tools to create it.

The first thing to get very clear when looking at the space: AR is not eyewear. An article I recently read reported that "augmented reality will ramp up...[from] 400,000 units this year to 45.6 million units by 2020." I want to be clear that *augmented reality doesn't come in units*. The hardware is different from the technology. It is an important distinction to make, and it is an issue to keep in mind when shaping your own thinking about the space.

Here's one reason for the confusion: a lot of people have been waiting for the headset market to evolve, mature, and settle on clear winners before investing in AR. It's understandable. No one wants to be on the wrong side of a VHS vs. Betamax call. The VCR analogy is a good one here. Tape was replaced by DVD, which was replaced by streaming—all in relatively short order (this is a brilliant visual timeline of that evolution). That will also be the case with hardware.

For a lot of different reasons, analysts, journalists, and investors have woven AR and VR together up until now. Occasionally, that comes from misunderstanding the tech. Some of it stems from

inflating category potential and numbers. And sometimes it comes from an understandable reason for collapsing the two categories: until recently, AR was just too immature as a category to be considered on its own. But that has changed.

AR is distinct from VR. And AR does not necessarily mean eyewear. There is more to say about that. For now, let's say this: when you plan your AR strategy, you can do it more simply than you might imagine.

And right now your best bet is to make small investments, strategic plans, and smart tests with what is readily available: phones and tablets. When you think about it from a cost perspective, phones and tablets are ubiquitous, and cheap. Pokémon GO works on Android and iOS. It is a mobile app. People know how to build apps. And there are other resources in this book that can give you a running start.

There are certainly industries, job types, and use cases that would benefit from smartglasses and headsets—especially those technologies being designed for and targeted toward enterprise. However, if you're thinking about where and how to invest now, consider this: eyewear, visual displays, and optical headsets are likely to evolve significantly in the next three to four years. Like computers, phones, or any other technology, they will get progressively smaller, cheaper, and ultimately replaced.

If you're creating a program with broader needs, consider a broader solution.

AR is not as fancy-hardware-dependent as people think. (Pause and read that again: it is a huge point and not mentioned or considered in most stories you'll see right now; somehow it's the elephant in the room that everyone has missed.) And that is a good thing. When a technology becomes "cool" it can create a barrier to acceptance. Skepticism of sexy new tech is understandable; no CIO wants to get caught holding the receipt for sexy tech that sits on a shelf.

Sometimes the simplest tool really is best for the job—which brings us back to smartphones and tablets. Smartphone and tablet technology has advanced, particularly in the last year. GPS, gyrostabilizers, high-quality cameras, and touchscreens are all extremely functional now—at the level needed to support the technology. On June 9, 2016, Lenovo released the world's first smartphone enabled by Goo-

gle's project Tango (the Fab Pro 2). It is capable of doing all sorts of AR. The use cases shown are...marginal. But what the hardware can do is interesting.

AR Content Creation: It's a Challenge—And There Are Tools That Can Help

One of the primary problems is one of content: people just don't know how to make content for AR yet. By "content" here, I don't mean storytelling. I mean authoring—building up the digital image of the engine that looks exactly like the physical engine and can be digitally disassembled and reassembled in precisely the same way as its physical counterpart.

Many people point to the lack of content tools as missing in the space. I have heard "We have a market coming at us with hardware and no software." Or "We have a situation where anyone who wants to build either has to do it from scratch (a tough prospect) or build on top of existing platforms."

And that makes it an interesting area to explore.

Right now, AR is developed in different ways by different companies. Some hire software engineers to create proprietary software and systems. They draw on existing SDKs (software development kits) and libraries. Some leading augmented reality SDKs include:

- Inglobe Technologies ARmedia
- Layar—acquired by Blippar
- Catchoom—an award-winning image and object recognition tool
- Kudan—which works with SLAM (see the end of this chapter for why that matters so much)
- 13th Lab (acquired by Oculus)
- MobLabs, ARToolworks (acquired by DAQRI)
- Vuforia—one of the industry leaders

Exploring SDKs is an important step when you are moving into AR. To choose the right one, you'll want to look at your in-house development capabilities, familiarity with software tools, cost, how deeply the tool has been developed, and how broadly it has been adopted.

As a 2016 LinkedIn article points out, it is a choice that requires deep thought and research.

Or you can go an entirely different, simpler route. You can choose a turnkey, codeless authoring and publishing tool. And if you go that direction, it becomes a much easier decision. The only player currently in the market exclusively focused on enterprise is ThingWorx Studio. Made by PTC, the team behind the Vuforia SDK, ThingWorx Studio (formerly called Vuforia Studio Enterprise) makes sense for software engineers who want to:

- Rapidly develop AR experiences—specifically for connected products in manufacturing and industrial enterprise
- Do so with less programming—because ThingWorx takes advantage of existing 3D assets and CAD renderings PTC has been collecting since the 80s
- Create step-by-step instructions and animated sequences to make work easier and faster
- Create virtual interfaces on machinery and other connected products that provide a real-time view of data
- Visualize existing 3D data in the real world to "enhance design reviews, expedite the learning process, and improve safety"
- Build AR experiences that link into a larger, connected system—ThingWorx focuses on IoT and enabling hardware and applications to connect with each other, remotely collect data, and manage devices and sensors

It's something you can also use to begin your AR experiments. And it's a great place to start: according to PTC, ThingWorx is an IoT platform "specifically designed for the industrial internet of things." While many other AR tools come out of the gaming world, PTC's background is in manufacturing and engineering. It does make a difference. Everything they build is done with enterprise users and business needs in mind.

ThingWorx Studio can help you not only create AR experiences triggered by 2D images and 3D objects, but also weave that functionality into a larger connected-product plan.

The next section provides a tutorial using ThingWorx Studio to give you a chance to play with the technology. It is an easy, clear tutorial that allows anyone—even someone with absolutely no program-

ming background—to see how this all works and begin to understand the fundamentals of AR.

For those of you who started as technical practitioners who have been promoted out of day-to-day technical work and kind of wish you were back in it, you may enjoy an excuse to get your hands dirty. Or, you may be curious about emerging technology and want insight into how it all works by learning new software. Why would you do it as a CTO? You might not. But you might share it with your managers as a way to discover how targeting works. That is, if you want to let them have the fun. ☺

ThingWorx Studio: Blue Pump Tutorial

Originally written by the team at PTC, and reprinted here in abridged form with PTC's permission, this tutorial is designed to introduce the core components and subcomponents of ThingWorx Studio. Specifically, you'll learn how to capture, store, analyze, and visualize data—by developing an AR experience.

What You'll Need

To complete this QuickStart, you'll need the following:

- Access to ThingWorx Studio. If you don't have access to the ThingWorx Studio trial yet, go to *https://studio.thingworx.com/* and sign up for free access.
- A supported mobile device (phone or tablet) with the ThingWorx View app installed (download it from the Google Play Store, Apple Store, or Microsoft Store).
- (Optional) A printer to print your ThingMark. You can also scan the ThingMark directly on your monitor or screen.

Install and Configure ThingWorx Studio

Installation

Once you've been accepted into the trial, follow the instructions in the Getting Started Guide to download ThingWorx Studio. After your Experience Service is provisioned, your ThingWorx Studio portal account will be updated to include the link to download your

ThingMarks (2D AR codes that you scan with ThingWorx View to bring up specific Experiences). Figure 3-1 shows an example of a ThingMark.

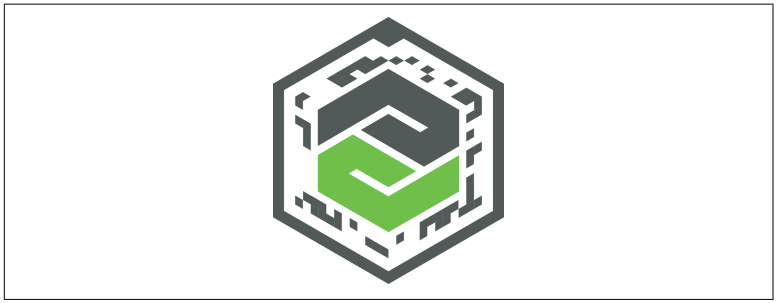


Figure 3-1. An example of a ThingMark

NOTE

Write the ThingMark number in the corner of the sheet on which you printed the ThingMark.

Configuration

Once ThingWorx Studio installs, follow the configuration steps in the Getting Started Guide mentioned earlier.

Create a Project

1. Open ThingWorx Studio.
2. Click the green plus in the upper-right corner to create a new project (Figure 3-2).

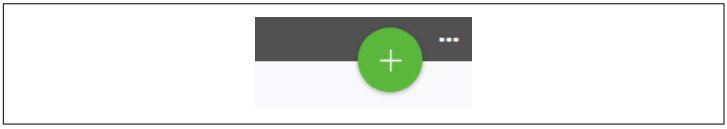


Figure 3-2. Creating a new project

3. Enter **`Pumps`** in the Project Name field.
4. Ensure that AR is selected and click Create.

5. The ThingWorx Studio development environment opens.

   - On the left side you will see the PROJECT pane, which contains individual components of your AR Experience in a tree.
   - In the center, you'll see the CANVAS pane where you'll drag and drop widgets for your Experience.
   - On the right side is the DATA pane, which includes default data listed under Application Parameters, as well as the ability to import external data. (This pane is collapsed by default. Use the Views icons, shown in Figure 3-3, to see it.)
   - On the bottom is the BINDINGS pane, which provides a list of all of the data connections. (This pane is collapsed by default. Use the Views icons, shown in Figure 3-3, to see it.)

Figure 3-3. The Views icons

Add a 3D Model to the Experience

1. Drag and drop a Model widget onto the central canvas (see Figure 3-4). Now we need to specify which model to display.

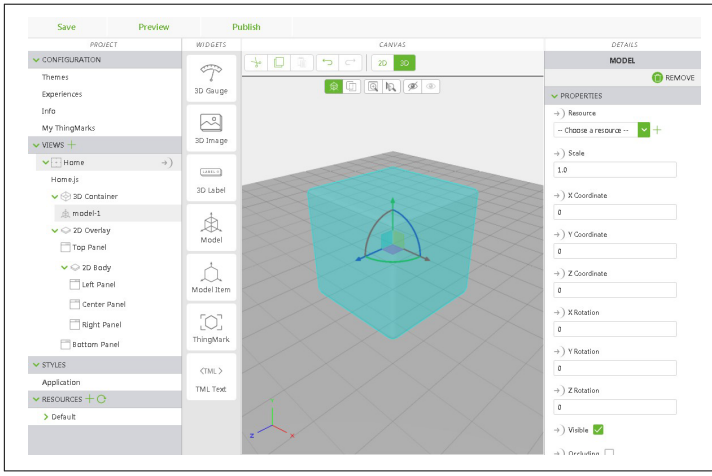


Figure 3-4. Dragging and dropping a Model widget

2. Navigate to the ThingWorx Studio Portal.
3. Under Basic Tutorials, click Blue Pump QuickStart to download the *BluePumpKit.zip* file. Extract the contents of the *.zip* file to a location on your system.
4. Navigate back to ThingWorx Studio.
5. With the model selected, click the green + sign next to the drop-down menu under Resource in the PROPERTIES pane.
6. Click Select Files on the Add Resources window.
7. Select *blue_pump.pvz* and click Open.
8. Click Add on the Add Resources window (see Figure 3-5).

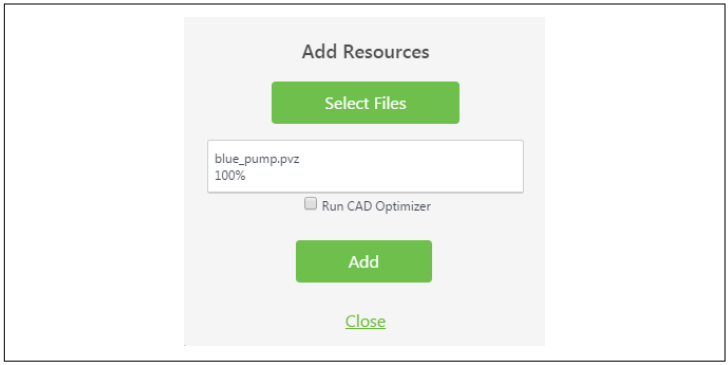


Figure 3-5. Adding a 3D resource

9. Click Close to close the Add Resources window. The 3D model of the blue pump appears on the canvas (see Figure 3-6).

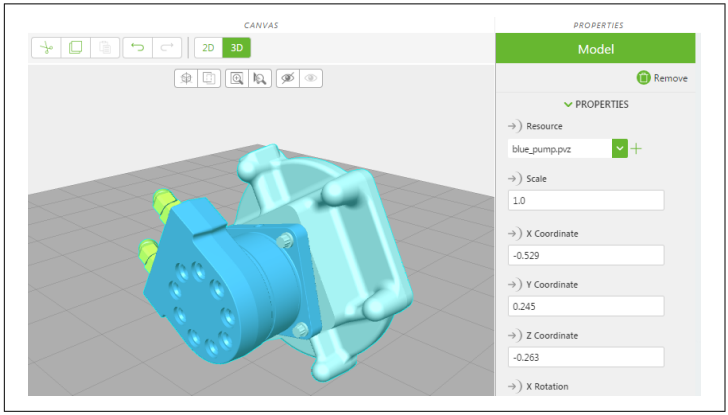


Figure 3-6. The 3D model of the blue pump

10. Once you've added the *blue_pump.pvz* file, the Sequence URL drop-down is automatically populated with the *teardown.pvi* file (see Figure 3-7). Select it to add the disassembly animation sequence to the model.

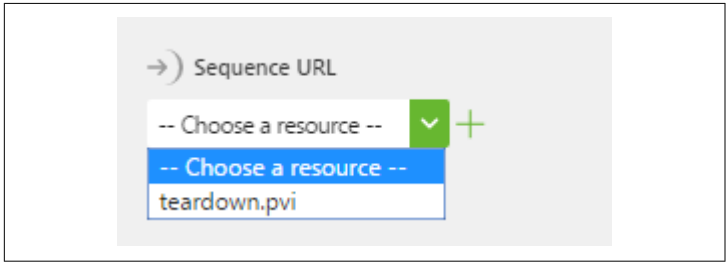


Figure 3-7. Selecting the teardown.pvi file

11. At the top-center of the canvas area, click the Transform icon (Figure 3-8).

Figure 3-8. The Transform icon

12. Click-and-drag the red arc of the Transform tool until the model is rotated 90 degrees clockwise. The X, Y, and Z coordinates are indicated by color, where Red = X, Green = Y, and Blue = Z.

> **NOTE**
>
> You can hold down the Ctrl key to rotate the model in 15-degree increments. Alternatively, you can enter **`-90 in`** the X Rotation field for the model properties.

13. With the Transform tool still selected, click and drag the arrows until the model is placed where you want it to be.
14. Click Save.

Add a ThingMark

You display Experiences in ThingWorx View by scanning a ThingMark from your device. In order for the 3D model to display in the correct location, you must place a digital ThingMark in the same location on your model as your real-world ThingMark. For example, if you want the printed ThingMark to be applied to the surface of a physical object, you must place the ThingMark accordingly in ThingWorx Studio (Figure 3-9, left). If you want the printed ThingMark to act as a tabletop for your AR Experience, you'll want to place the ThingMark underneath the model in ThingWorx Studio (Figure 3-9, right).

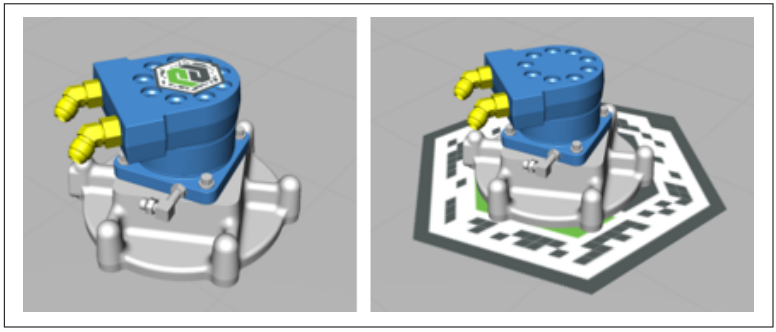


Figure 3-9. You must place a digital ThingMark in the same location on your 3D model as on your real-world ThingMark

1. Drag and drop a ThingMark widget onto the canvas.
2. Click the Mate icon (Figure 3-10).

Figure 3-10. The Mate icon

3. Drag and drop the ThingMark onto the model. The placement of the ThingMark in ThingWorx Studio directly corresponds to where the AR Experience places the model in ThingWorx View. This also corresponds to rotation.

Add a 3D Label

Let's add a 3D Label to display information from the ThingWorx platform (an IoT Development Platform).

1. Drag and drop a 3D Label widget onto the canvas.
2. While the 3D label is selected, scroll down in the PROPERTIES pane and select the checkbox for Billboard. This will cause the 3D label to rotate as you move around your AR Experience so that it is always pointed directly at you.
3. Click the Transform icon (shown earlier in Figure 3-8) and move the label to a desired location.
4. Next, we'll pull data in from the ThingWorx platform for the label to display. Navigate to the DATA pane and click the green + sign next to EXTERNAL DATA.
5. In the Search Entities field at the top-left, type in **`Car1`**. We'll use this changing RPM value to provide a changing value for the pump.
6. Click the green arrow next to Car1 (Thing). You'll now see a list of all available Services for that thing.
7. In the Filter services field, begin typing **`GetPropertyValues`**, and click the green + sign next to GetPropertyValues once filtering is complete (Figure 3-11).

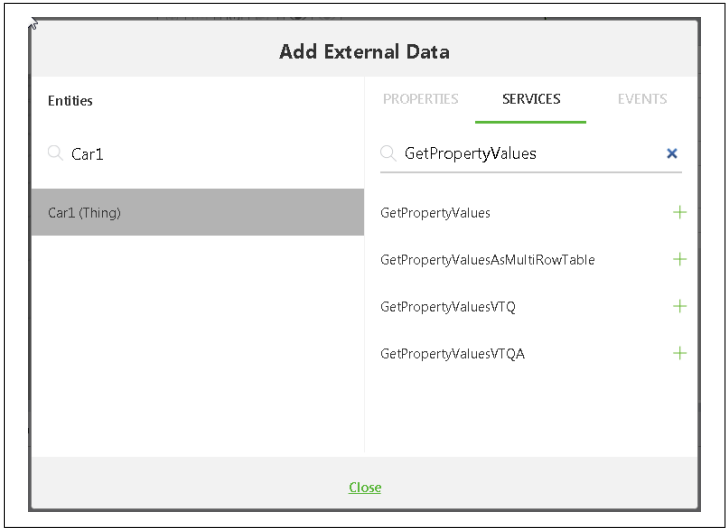


Figure 3-11. Pulling in data for Car1

8. Click the blue X to return to the canvas. You'll now see the data for Car1 appear under External Data.
9. Under Car1 → Services → GetPropertyValues, expand the Configuration section.
10. Click the checkbox next to Invoke On Startup. This will cause the Experience to pull in all of the property values as soon as the Experience is loaded in ThingWorx View.
11. Click the checkbox next to Auto-refresh, and set the Auto-refresh Rate to **3**. This will cause the values to update every 3 seconds.
12. Select the 3D Label (3DLabel-1) in the project tree.
13. Under Car1 → Services → GetPropertyValues, expand Current Selected Item to view all of the available properties being stored on the ThingWorx platform.

14. Drag the binding icon next to RPM and drop it onto the Text field in the PROPERTIES pane for the 3D Label widget (Figure 3-12).

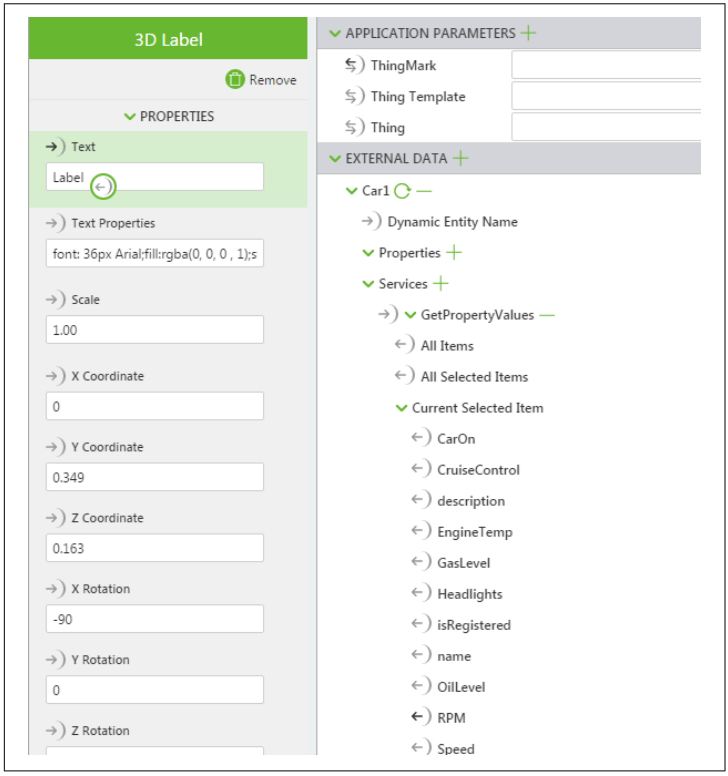


Figure 3-12. Dragging and dropping the binding icon onto the Text field in the PROPERTIES pane for the 3D Label widget

15. At this point, your canvas should look similar to Figure 3-13.

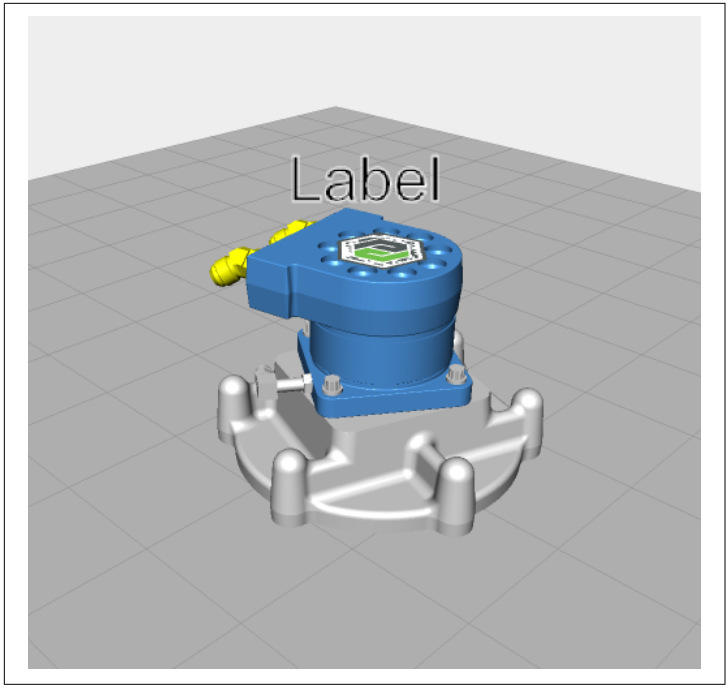


Figure 3-13. Your current canvas

Add a 2D Resource

Now that you've completed the 3D portion of your Experience, let's add some 2D elements.

1. On the canvas toolbar, click 2D as shown in Figure 3-14.

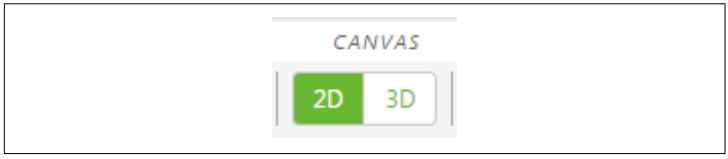


Figure 3-14. Clicking 2D on the canvas toolbar

2. In the PROJECT pane, click the green + sign next to RESOURCES. The Add Resources window appears.
3. Navigate to the location where you extracted the contents of the *BluePumpKit.zip* file.

4. Use the Ctrl key to select the following files:

   play.png
   : This will be the image we use to activate the disassembly/reassembly animation.

   info.png
   : This will be the image we use to display or hide a "card" section with Warranty information.

5. Click Open.
6. On the Add Resources window, click Add and then click Close (Figure 3-15).

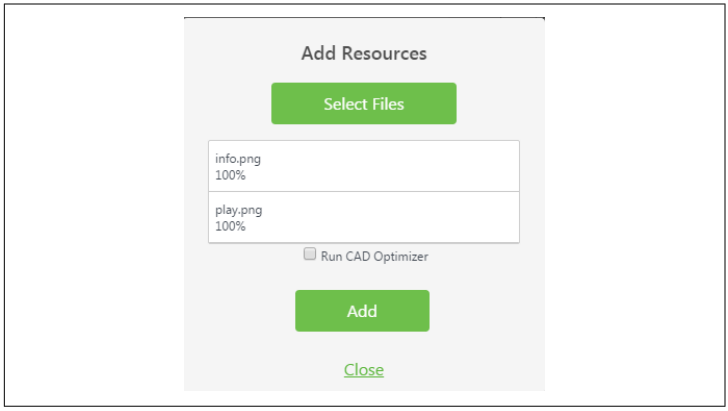


Figure 3-15. Adding a 2D resource

Add Buttons

1. Drag and drop a Grid Layout widget onto the bottom panel.

> **NOTE**
> You may need to scroll down on the canvas to view the bottom panel.

2. Click on the Grid Layout on the canvas to select it. Or, in the PROJECT pane, under VIEWS → Home → 2D Overlay → 2D Body → Bottom Panel → gridLayout-1, click row-1 to select it.
3. In the PROPERTIES pane, click on + Add Column. The bottom panel is now divided into two equal sections.
4. Select the first column on the canvas, or click column-1 in the project tree.
5. In the PROPERTIES pane, set Alignment to Center.
6. Repeat this process for column-2, setting the Alignment to Center as well.
7. Drag and drop a Toggle Button widget into the first column.

> **NOTE**
> There are both Button widgets and Toggle Button widgets; make sure you choose Toggle Button.

8. In the PROPERTIES pane, change both "Image when Pressed" and "Image when Not Pressed" to the *play.png* image using the drop-down menu under the fields.
9. Drag and drop a Toggle Button widget into the second column.
10. In the PROPERTIES pane, change both "Image when Pressed" and "Image when Not Pressed" to the *info.png* image using the drop-down menu under the fields (Figure 3-16).

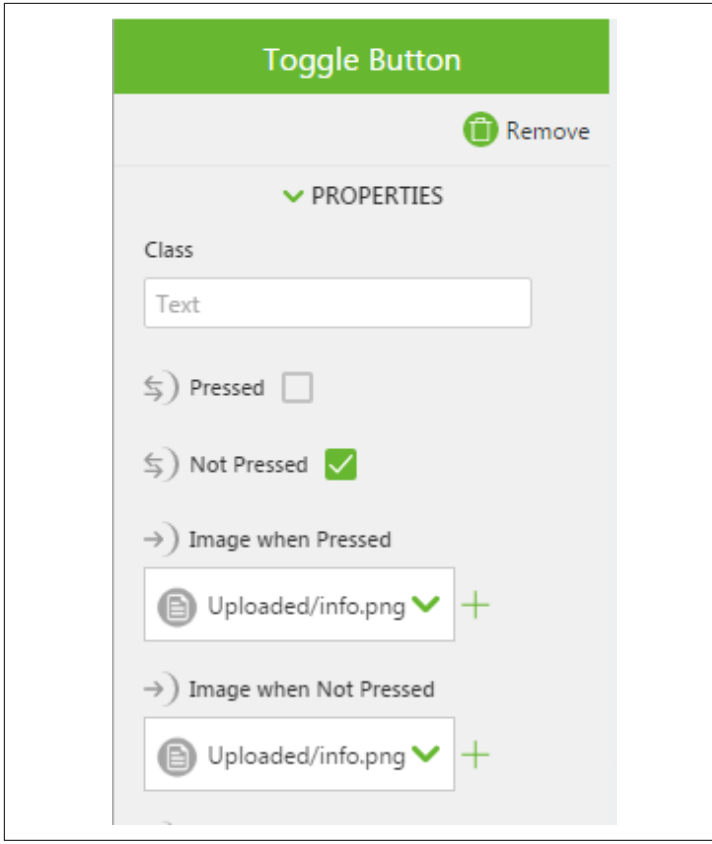


Figure 3-16. Changing "Image when Pressed" and "Image when Not Pressed" to info.png

11. In the end, your button layout should look like Figure 3-17.

Figure 3-17. The completed button layout

Bind the Toggle Buttons

1. Select the toggle button in the first column, or click toggleButton-1 (Play icon) in the project tree.
2. In the PROPERTIES pane, scroll down to the Click event, and drag and drop the binding icon next to it onto model-1 in the project tree (Figure 3-18).

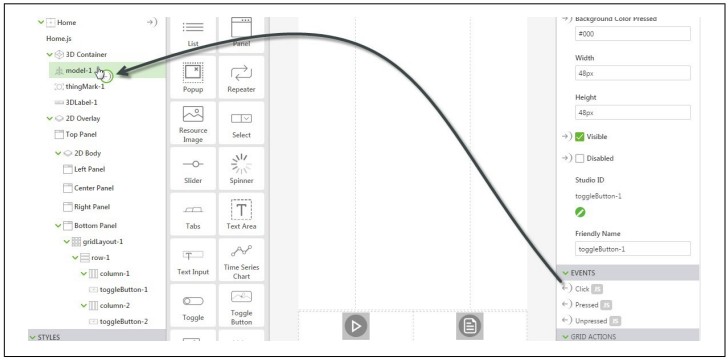


Figure 3-18. Dragging and dropping the Click event's binding icon onto model-1 in the project tree

3. On the Select Binding Target window, select Play.

   Now, whenever the Play toggle button is pressed in ThingWorx View, the Blue Pump's disassembly animation will play. If you press the Play toggle button again, the pump will reassemble.
4. On the canvas, click on the Center Panel to select it (Figure 3-19).

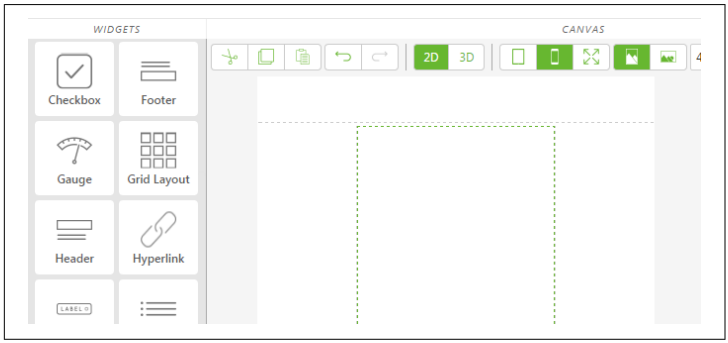


Figure 3-19. Selecting the center panel of the canvas

5. Drag and drop a Card widget into the center panel of the canvas. This will create a static area onto which we can add more widgets.
6. Drag and drop two Value Display widgets onto the Card in the center panel.
7. Click on the top Value Display to select it or select valueDisplay-1 in the project tree.
8. In the PROPERTIES pane, enter **`Owner`** in the Label field.
9. In the same manner, enter your own name in the Value field.
10. Click on the bottom Value Display to select it or select valueDisplay-2 in the project tree.
11. Enter **`Warranty Status`** in the Label field.
12. Enter **`Active`** in the Value field.
13. Since we have our Card widget, let's bind a button to it that we can use to make it visible or invisible. Select the toggle button in the second column, or click toggleButton-2 in the project tree.
14. Make sure that the checkbox beside Pressed is not selected. This will cause the toggle button to start out not pressed, so that your Warranty Info Card is not visible to begin with.
15. In the PROPERTIES pane, drag and drop the binding icon next to Pressed onto card-1 in the project tree (Figure 3-20).

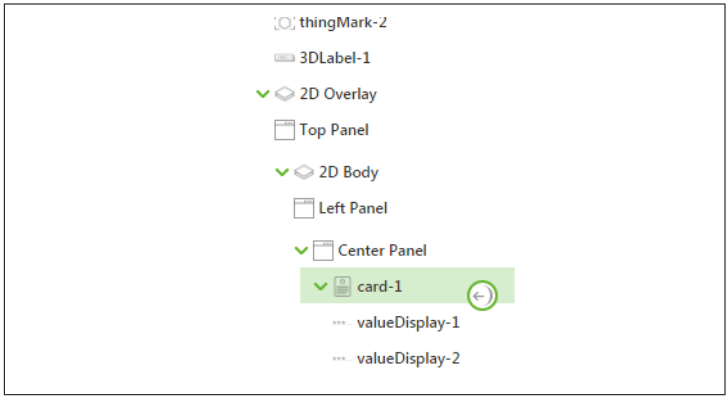


Figure 3-20. Dragging and dropping the Pressed binding icon onto card-1 in the project tree

There are two different Pressed sections under PROPERTIES. For this, we'll want to select the Pressed that is at the very top of PROPERTIES.

16. In the Select Binding Target window, select Visible.

Now, whenever the Info toggle button is pressed in ThingWorx View, the Card that you've created will become visible or invisible. This is a great way to get more information into your AR Experience without using up screen real estate.

Name the Experience

Naming your Experience will let the program know which Experience to load when a ThingMark is scanned.

1. In the PROJECT pane, under CONFIGURATION, click Experiences.
2. With the ThingMark Association set to ThingMarks, enter the ThingMark number that you want to associate to the Experience.
3. Enter **`Blue Pump Demo`** in the Title field.
4. Your Experience settings should look similar to Figure 3-21.

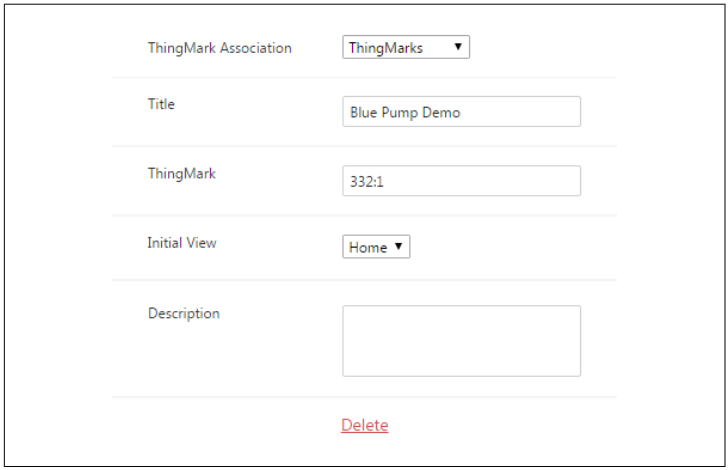


Figure 3-21. Your Experience settings

Publish the Experience

Click Publish. Publishing an Experience may take some time, as all of the elements of your Experience must be pushed to your Experience Service. Wait until the green, rotating progress indicator disappears (Figure 3-22).

Figure 3-22. The publishing progress indicator

View the Experience in ThingWorx View

Now, it's time to view the completed project!

1. Place the appropriate ThingMark on a flat surface where you can easily interact with it.
2. From your supported mobile device, open ThingWorx View and point the camera of your device at the ThingMark.
3. ThingWorx View will alert you with a sound or vibration once the ThingMark has been scanned successfully, and a list of available Experiences appears. The Experiences in the list have all been associated with the particular ThingMark that you scanned.
4. Select the Blue Pump Demo Experience you just published.
5. Wait a moment with your device still pointed at the ThingMark. Slowly move your mobile device farther away from the ThingMark so that you can view the entire Experience.

> **NOTE**
> If the model is large, a progress indicator appears. Try not to move the mobile device until this loading process completes.

6. Once the Experience loads, you should see and be able to interact with the various components of your AR Experience. You should see the Blue Pump. As you move the mobile device around (while it's still pointed at the ThingMark), you will see the pump move as well. This allows you to view the model from

different angles. You should see the 3D Label displaying the RPM value, which should also be changing every 3 seconds. In addition, the 3D Label should always be facing you, regardless of how you move around the ThingMark. If you press the Play button one time, you'll see the disassembly animation. If you press the Play button a second time, you will see the pump reassemble itself. If you press the Info button, you'll see the card appear in the middle of the screen with the information you added. If you press the Info button again, the information will disappear. If you press the i button, you'll see the 3D Label appear or disappear each time you press it.

Suggested Resource: ThingWorx Studio Documentation

Many topics are covered within the ThingWorx Studio Help Center and Getting Started Guide. You can also check out the ThingWorx Studio Community to post questions, search for answers, and chat with others. This site is monitored by PTC Support experts.

Authoring: "What Else You Should Know" Deeper Dive

This tutorial was a simple way for you to get a taste of the tech. As it shows, basic AR is simpler than you might imagine. You can get it up and running quickly. That said, if you're applying AR in an enterprise context, it can be more complicated.

Authoring AR apps is not just about choosing a platform or knowing how, technically, to create them using platforms like ThingWorx or building on engines like Unity. Even with those tools, enterprise users still face a number of challenges in organizing, presenting, and creating models for enterprise.

Giving workers guidance on how to do things via AR requires some other skills—most notably, how to create instructions or guidance for any information you want to show to a user of an augmented reality app (Figure 3-23).

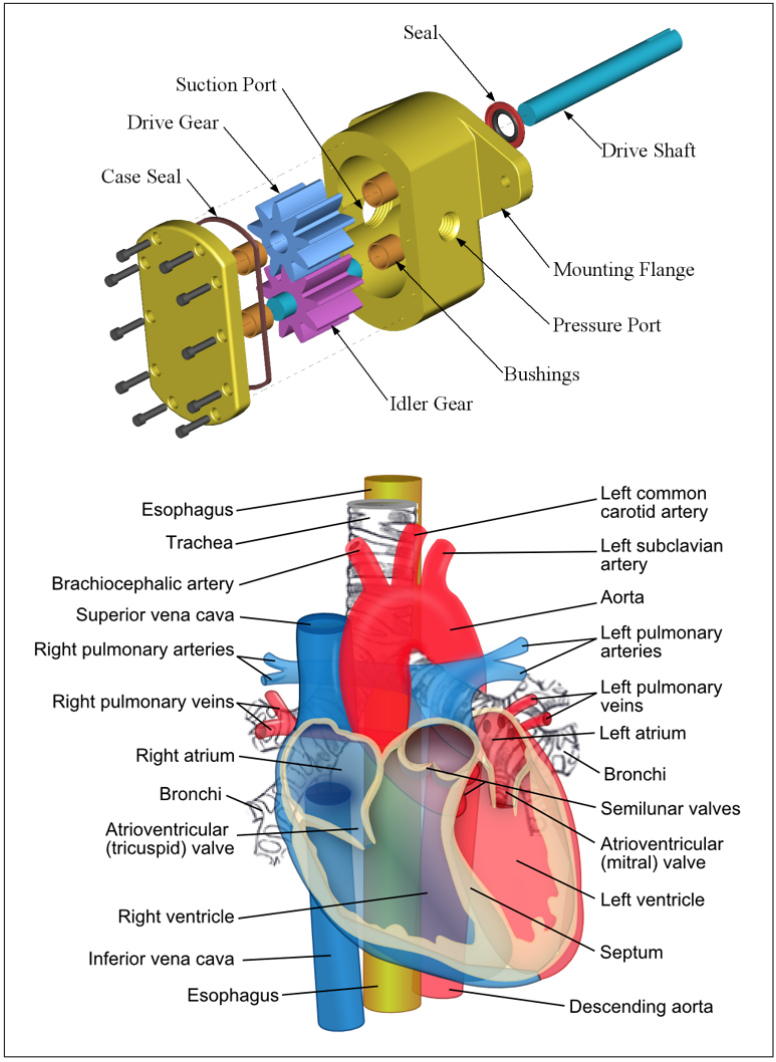


Figure 3-23. In order to build effective AR applications, you need a specialized skillset, beyond just the engineering: visual storytelling. This means labeling and describing 2D images, translating those component parts to 3D, and then showing how all of those parts come apart and go together.

For instance, if you want to show people how two pipes go together and are joined by a gasket, a seal, and bolts, you not only have to create a rendering of the pipes, the gasket, the screws, but you also have to create them in the exact way they go together, and visually show IKEA-level, simple instructions for people to follow to assemble them in that order. In this example, you'd need directional arrows or instructions that show the smaller pipe fitting inside the larger one, a diagram showing how the gasket sits inside the lip of the pipe, notes about how, exactly, to tighten the screws, and so on. You have to be able to translate instructions visually. And that is a distinct skill all on its own.

Even if you use an SDK like Vuforia as the base of your AR system, as some of the companies in Chapter 2 did, you will find it useful and necessary to build your own models (or hire one of those people to do it for you). Right now, there are only a few experts in the world who know how to do this well.

When you are creating AR instructions for enterprise users, you can use existing information and reapply it to create usable AR tutorials and instruction manuals, translated from either printed instruction manuals or video tutorials.

Why You Should Also Know About SLAM

Whether you go with an existing SDK or choose to build on top of it and create your own software, one tool you should know about is *simultaneous localization and mapping*, or SLAM. Tom Emrich, coproducer of the Augmented World Expo, called one of the "secret ingredients driving the future of a 3D enabled world." SLAM allows you to do 3D recognition and tracking in ways not thought possible before.

According to StackOverflow's definition:

> Simultaneous localization and mapping (SLAM) is a technique used by robots and autonomous vehicles to build up a map within an unknown environment (without a priori knowledge), or to update a map within a known environment (with a priori knowledge from a given map), while at the same time keeping track of their current location.

Even more precise is a post by Alejandro Silvestri from June 29, 2015:

> SLAM is not an algorithm, it's an approach, a decomposition in steps to reach the goal. Each step lets you choose one of many suitable algorithms, each of them with diverse characteristics, like performance, accuracy, and so on.

In English, SLAM is a series of mathematical computations that enable, among other things, indoor mapping—something that will be critical for enterprise AR to move beyond just individual objects...and into whole spaces and systems. It is a technology that is being explored heavily in robotics. But it is also interesting in the context of AR for enterprise: what it provides here is an underlying technology that enables augmented reality in unknown environments. Because before you can create virtual assets, you have to first understand what the space looks like (whether it's an office or a manufacturing facility). The computer has to read what's there before it can create a new object in the space that looks and feels real. Right now, that is happening largely with "markers." In the future, it may be done with SLAM.

As of June 2016, AR engine developer Kudan released an AR Engine with SLAM that works without preregistration of the environment you're tracking. That opens up the ability to visualize 3D objects virtually anywhere, whether you're walking down the street, in a park, or in a shipyard. You don't need a graphic trigger. There are no markers. It works well in low light conditions. And it works with Unity 3D.

This is a particularly interesting announcement, and one worth paying attention to—and the big boys are. Last year Facebook snapped up Swedish company 13th Lab, which had mobile SLAM technology. In 2016 Apple purchased Metaio, shortly after they announced the SLAM capability in their SDK.

In fact, Kudan is one of only a handful of SLAM-enabled AR SDKs still publicly available. According to the Augmented Reality for Enterprise Association site: "SLAM libraries for AR are available from Flyby Media and Imperial College London. The OpenSlam site provides more information on sources of SLAM technology."

There are, of course, other SDKs and various comparisons of them —Vuforia being one of the most robust and, backed by the team at

PTC who specializes in industrial application, one of the best suited for industry (that's where they're aiming).

The gist of all of this: authoring is something you should look at closely and at the outset. And looking more deeply at image recognition technologies matters because that is one of the areas that will most profoundly drive the development of the space. You should know what's driving your engine.

Next, in the final chapter I'll give you my thoughts on best strategies for AR growth.

CHAPTER 4

Your Best Strategy for AR Growth

AR for Enterprise: What Else Is Happening

We've looked at why now is the right time for industrial enterprise AR. And, as we've discussed, many of the people building AR are using the technology for heavy industrial work, training, and manufacturing. However, there are other categories of business that represent the future of where enterprise AR is headed. This chapter explores how else it can be used, and what you should know about as you plan your strategy for AR development.

According to the investment bankers at Goldman Sachs, VR and AR technologies will generate $80 billion in revenue by 2025, $35 billion of that from software. We've already discussed the fact that VR and AR are separate categories—and are now ready to be separated in all ways, including financial projections. We've also looked at professional sectors like healthcare—projected at $5.1 billion—followed by engineering ($4.7 billion). But what about the other areas?

I dug deep to find great examples across industry. And what I found? There's a lot of hype.

First, there are a lot of use cases out without a clear reason for being. In 2016, we saw:

- Augmented reality car showrooms that are somewhat useful—but still a stretch
- Lowes and Walgreens are making attempts that are closer

- Hyundai cars with new augmented reality owners manuals

This is a challenging space. And these companies are trying. What's still missing is the use case that makes retail AR deeply valuable.

That said, if you look closely there are gems in the space. There are great examples of AR being used in ways that are useful, and even beautiful, while also making lives easier, such as these noteworthy cases from Christina Chang at French AR platform company Augment:

- L'Oréal Professional gave its European sales team AR capabilities to show hair salon owners where and how their merchandising displays will fit, and how they'll look in the space.
- Coca-Cola Germany linked Augment's system to Salesforce to allow sales reps to show customers 3D images of coolers, upload visuals of those configurations directly into Salesforce, and track the conversations and promised designs.
- Augment worked with retail packaging and display company Dusobox to create AR models of displays to give a sense of scale in the store (the coolest parlor trick of headset-based AR is that you can show models that are life-sized).

In addition, the companies within the Augmented Reality for Enterprise alliance are also using and approaching the technology in valuable ways:

- DAQRI is using AR to give 4D work instructions.
- Atheer is helping utility engineers and the workers on power lines stay safer.
- Chinese smartphone manufacturer Huawei (which had revenues of $61 billion last year—slightly more than what Apple makes in a quarter) is also thinking about AR and immersive storytelling in some very smart ways.

There are also some ideas that need more time to develop before they become truly useful. Goldman Sachs predicts that augmented reality in real estate will generate $2.6 billion. AR in retail will be at $1.6 billion, and education is projected at $700 million. But what do these three areas look like now?

Enterprise AR in Real Estate, Education, and Retail: What You Should Know (and Question)

Real Estate

Real estate is one example of the predictions being driven more by venture interests and investment banking projections than by actual industry demand, interest, or usage. It *is* the perfect use case on paper. And there are a few amazing examples of how it could be implemented.

Coeur d'Orly Arforia is a good example of AR being used for real estate—in this case a retail, office, and hotel space connected to an airport in France. They use AR to let you look through the complex and see entirely how it will look inside.

Global engineering design firm AECOM is using Microsoft HoloLens to display 3D engineering models as holograms and collectively do design reviews. But that's more in the engineering space than real estate. In digging for actual examples of real estate AR applications, I found some. But mostly they're examples of marketers or technologists trying to educate people about the value of the technology, or of AR app builders who are creating tools specifically for architecture. Some are very cool, and they are well versed and deeply immersed in the space.

Real estate AR is an area of potential—without much action to back it up yet. But in the future, that will change. And whatever quiet conversations are happening behind closed doors at global, mega–real estate developers like Dailan Wanda and Cushman & Wakefield will determine how this area grows.

Education

Education is a similar situation to real estate. There are higher learning institutions adopting and using AR technology as well as VR headsets. It is easy to imagine trade schools, art schools, and engineering-focused universities diving deep in the space.

However, right now there are few powerful, public examples of AR being used in higher education, and even fewer in primary and secondary school education. Some examples include:

- Michigan State University's School of Packaging is using the Augment augmented reality app for a course in technology design.
- Sixth-grade students at Blake Middle School in Medfield, Massachusetts, used AR to augment posters and make 3D models of Saturn, including its rings.
- Dr. David Feifer used AR to help students understand the structure and vasculature of the heart.
- A company called Eon Reality offers examples of how AR can be used to help aerospace and history students, with the goal of changing how teachers use technology in the classroom. However, a lot of that is hypothetical.
- A few apps like SkyView, AR Circuits, and HoloStudy—a HoloLens app that attempted crowdfunding in Russia—have been designed for or tested in classrooms.

These are good examples that show effort and potential. *But* they are few—which is emblematic of what is happening in the space. Great examples of AR in education are still few and far between. The Goldman financial projections predict massive growth. In order to get there, something has to shift.

Retail

Retail is one area where it looks like Goldman really got it right. In the consumer-facing realm of retail, companies are working on the ideal use cases for AR: testing, sampling, and decorating.

- Since 2013 IKEA has been letting customers test-drive furniture with an app (that could probably use a refresher—it got panned on the Google Play store).
- Taobao.com (the Chinese equivalent of Amazon.com) has AR cosmetics testing baked into their app.
- Japanese beauty retailer Shiseido uses digital "cosmetic mirrors" in a similar way, to allow customers to sample makeup as well as receive beauty advice, product recommendations, and shopping lists.
- Mothercare has an interesting AR app for envisioning what maternity and baby clothes actually look like on live bodies.

- In the behind-the-scenes retail world, there are some good "non-gimmicky" examples from UK grocery chain Tesco and Chinese online grocer Yihaodian.

My assessment: there hasn't been a compelling enough use case for consumer-facing AR in retail. But it is the perfect time for AR in the backend of retail—in enterprise, sales, and design.

How Can You Cash In Financially and Ethically from AR Over the Next Five Years?

When you are planning strategy, you should look at which types of AR categories will continue to grow. It is also important to focus on how advances, investments, and ideas will create winners in the space. Following are four ways I predict that enterprises playing in AR can succeed in the future.

Play with Different Interfaces

Phones and tablets work for AR. They are *absolutely and without question* the best solution for most use cases right now. Still, they are not ideal from a user interface standpoint. Walking around with a phone in front of your face can present a safety hazard. VR headsets are also still developing. The interface is too delicate for heavy construction sites. The systems make some people motion sick—and it particularly affects women, possibly because of differences in the way depth perception works.

This interface issue is one reason Magic Leap is poised to jump ahead of everyone in the consumer AR world. They *are* different because they're playing with light and how it bends, as well as the best display systems that exist—biological ones.

Sure, there will be some sort of hardware interface, but it will not look like a mask. And, while Magic Leap's development time may be far longer than race-to-market hardware companies, when they perfect what they are working on, they will win. Because while everyone else is playing in hardware, they're playing with the fundamental building block of life: light.

Magic Leap is owned by Google. Under the name Verily Life Sciences, Google applied to patent a contact lens that embeds in the eye and acts as a heads-up display (Verily is the science company that

emerged when Google restructured and divided last year, and was rolled under the umbrella company Alphabet).

Sony also applied for a patent for a smart contact lens that can record video. A recent *Computerworld* article describes it as "Google Glass Without Google Glass."

If e-skin can already turn your hand into an electronic display, how long before it can turn skin into an electronic projector (i.e., point your arm at a wall and a virtual display appears)?

The people who will win are the ones who approach the idea of interfaces differently, or significantly improve the ones already available.

Capitalize On (and Create) the Best Inputs and Outputs

Inputs and output include a few different technologies, and both mean we need more accurate trackers and sensors. For *visual registration*—which means accurately aligning virtual objects in AR displays with those objects in the real world—your registration is only as accurate as your sensors. According to "A Survey of Augmented Reality," an excellent journal article discussing teleoperators and virtual environments, "the AR system needs trackers that are accurate to around one millimeter and a tiny fraction of a degree, across the entire working range of the tracker." Currently, very few trackers meet this standard, though people are looking at new ways to approach the problem.

Creating better inputs also means adding camera arrays; more cameras are great for AR. And that's coming. Amazon's Firephone, which had multiple cameras, was a flop. However, it showed that they are thinking in that direction. GoPro is currently building a 360-degree camera array with 16 cameras that work together as one —with features like multicamera control and camera syncing. And the iPhone 7 also has dual cameras. It's only two, but that's a big step toward enabling and advancing AR, in that it allows you to take images at different depths so they can be overlaid or separated in new ways (check out some possible special effects it creates, and you'll understand more).

Finally, as Dieter Schmalstieg and Eino-Ville Aleksi Talvala (the author of a brilliant dissertation on computational photography) suggest, we would all benefit from the creation and spread of pro-

grammable cameras to improve all real-time computer vision. This is one of the core technologies that can help video-based AR systems analyze and correctly identify objects in the environment around them. They can help you understand and sense things like depth—how far an object is away from you. As Talvala says, they can "fuse together several images to create a more interesting one."

Play at the Intersections Between Industries

The potential of AR in enterprise is to do things like see through walls to determine where repairs are needed, figure out where to lay pipes in roads, or work with sensors or infrared to find people trapped in a burning building.

Here AR has the potential to broadly and greatly improve the lives of service technicians, repair people, construction teams, mechanics, rescuers, and builders of all types—outside of factories. Independent and small businesses, regional manufacturers, companies with a single factory and $20 million can all benefit from AR as much as multinational, billion-dollar corporations.

So why is no enterprising startup currently in the business of taking CAD drawings of businesses and giving them to electricians? Why is no one turning IKEA instructions into AR? Why isn't someone turning all fancy coffeemaker instructions into AR tutorials for baristas around the world?

It's hard from a business model standpoint. You not only have to create hardware and software for AR, but also fold it in with other companies and industries. To accomplish this, you'd have to interface with real estate companies and construction companies and retail companies. You'd have to get difficult permissions. And then you have to work out the legalities for all of that. This is a moment where Thomas Edison's quote applies: "Opportunity is missed by most people because it is dressed in overalls and looks like work."

But someone can do this. The person who both takes on this challenge and nails it will win big.

Look at How to Link This to Existing/New Systems—From the Beginning

When I asked Paul Davies from Boeing "if you were giving someone advice about a smart way to plan AR strategy, what would you say?" This is what he said:

> One of the biggest parts of this is having to connect the AR tool or technology to the existing backend systems. That is a difficult thing to do and it's something that not many people want to focus on. Everyone wants to say, 'Look what you can do with AR. It looks really great, you can show all this content, it's 3D, it looks amazing!" But they are legacy systems that Boeing has. There are many people who are looking at the tracking, the visualization, the headsets, all of that stuff. Many fewer people are looking at the reality of, how do I link this to my systems? That's the part where a lot of work needs to be done.

It is true of enterprise, and it is true everywhere. It's a big issue. It's what's slowed IoT so far. And it's a hurdle for AR. That said, it's a solvable challenge, and it *will* be solved—even before machines age out—by many developers using SDKs and platforms such as the ones listed under "AR Content Creation: It's a Challenge—And There Are Tools That Can Help" in Chapter 3.

It will take deep thought and planning up front. As this report has shown, with industrial enterprise AR, as with anything, you don't have to have all the answers at the outset. But you do need to begin with your endpoint in mind.

Start clearly and powerfully—the same way you intend to continue.

APPENDIX A

The Future of AR

The earlier parts of this short book look at the present state of industrial enterprise AR. If you enjoy emerging tech and ideas like me, though, what's coming in the future may be even more intriguing.

Specifically, this appendix focuses on two things: developing areas you should pay attention to, and why the way "mixed reality" evolves (as a term and as a set of technologies) matters so deeply. Both of these will shape where this category goes.

This is a look at what's just beginning to emerge—with research minds and investment dollars indicating it will gain traction. It also gives insight into the kinds of ideas that will make AR more useful and exciting.

Durable Reality: Things That Stay in Space

One emerging space that will grow is *durable reality*—things that are durable and persistent, that stay in space. There are a few systems already created where you can leave notes, images, and objects in space just as you'd leave a sticky note in the physical world. For instance, you can leave a digital note on a machine for when a tech comes by; it pings him and tags a specific location telling him "it needs you here." A few people featured in this short book have built basic systems of that sort. But there are a million other uses for durable reality as well.

- Fashion designers can draw textured leather jackets and jeans, and then walk around "inside" their creation to see how it really looks and feels.
- Artists can create and instantly change 3D sculptures and paintings that you can walk around inside, as they're already beginning to do by experimenting with the new Tiltbrush.
- You can leave your partner love notes on the mirror or windshield that the kids will never see because they are encoded just for his or her phone/app. :)

Imagine walking through the physical world and finding Easter eggs left there just for or by you.

Diminished Reality

There is another emerging category for AR: *diminished reality*. This idea has been discussed since 2011. Now, though few people have noticed, it's starting to quietly and powerfully gain traction. How it works: rather than adding things into the space, you take them out. The possibilities for uses are as broad as you can imagine.

- Use it to filter out overwhelming sounds and stimulus for people with autism (or in open office floorplans!)
- Use it to block your home from Google search (Harry Potter train station–style: you only know it's there if you know it's there).
- Use it to remove graffiti from a street view, if you don't want to see it. Use it to "hide" AR markers in the real world.

It's the "real-life" version of photo retouching, and you can watch here and see how effective it is. You can use it to make things disappear. Really.

But we are not there yet.

This begins to get into the fuzzy parts of reality (mixed, augmented, virtual, and physical) as well as some deep questions of privacy, ethics, and physics that we all need to consider. For now, though let's focus on the more immediate changes in the AR world.

Gestural Control

Gestural control is all about using hands to take actions in the physical world that show up in the virtual world. Everyone loves the *Minority Report* user interface. They actually made it at MIT using a Leap Motion Orion. *Minority Report*'s science advisor John Underkoffler demoed it at a 2010 TED conference. He called it a "spatial open environment" interface, and his talk is brilliant and worth watching to see how far we have come, even in six years.

Since then, people have built on the idea of controlling and displaying objects in space in various ways—some mimicking his approach, some adapting it. Obscura Digital has created some amazing and useful gesture-controlled systems, and companies like Navdy are playing in a similar realm with their heads-up displays for cars (this is real; thankfully, Sugarbeef is not).

Enhanced Reality: Multisensory Experiences

Imagine using electrostatic energy, the way Disney Research did, to run your finger over a screen and feel the bark of the tree. Or mimicking touch: with a UK-based tool called Shoogleit, you can scrunch up fabric and see how it folds. (Fashion company buyers could use things like that.) Or imagine modernized and improved versions of way-too-early technologies like Audio Perfume using ultrasonic frequencies and sounds to augment your world.[1]

Experiences that play with touch, taste, sound, subtle energies, and smell will only add to an environment that is created by augmented reality. If you're remotely repairing a car, you may not wish to hear all the sounds of the highway. But hearing the isolated sound of the key in the ignition can help you learn whether the issue is the alternator or battery.

Noise-cancelling and enhancing technologies, haptics and touchless haptics, new uses for music and color, and other types of multisensory experience make the "overlays" and augmentations to our physical world more interesting.

1 Hat tip to my friend Todd Harple for these examples.

Google Nose was announced a few years ago as a funny April Fool's joke. But remember: Pokémon GO started as a Google April Fool's joke as well. We may not have smell-o-vision anytime soon; it's still a problem in search of a real use case (what BMW is doing with AirTouch is interesting...but not necessary). And it is an area that will continue to develop.

Max Maxfield points out one "simple haptic example, one of the free applications that comes with the Oculus Rift is the *Oculus Dreamdeck*, which allows you to sample a suite of virtual experiences (just listen to the commentator's excitement when he reaches the 3:20 mark in this video)."

Creating a more realistic virtual world will require engaging senses other than sight. We've already started down that path.

Language and Lightfields Will Shape What AR Becomes

As technology evolves, so does the language that describes it. It's chicken and egg; one informs and helps shape the other. There is one term you should really pay attention to here: mixed reality.

If you're a CTO or a research geek like me, you'll want to follow the way that phrase is beginning to emerge and evolve, because it represents very different streams of thought in the industry, and because it is being used in radically different ways by different people.

What does mixed reality mean right now? It depends on the person talking. Here are two current, common working definitions. The first refers to a blending of AR and VR. The second refers to blending digital assets into the fabric of the world around us—what we currently view as "reality" itself.

Mixed Reality: Blending of AR and VR

Vuforia's Product Manager, Manish Sirdeshmukh, subscribes to the first definition. In a July 5 presentation at Unite Europe '16, he calls mixed reality a hybrid of virtual and augmented reality technologies involving headsets and AR triggers. Here's what else he says about it—and how you can create mixed reality experiences with Vuforia (something that's not currently possible in Unity):

> A lot of people have been talking about mixed reality, augmented reality in the same fashion. But what I really mean is...when I talk about virtual reality, if you are immersed in an environment which is completely 3D. It's a completely virtual environment. Augmented reality is when I see things through the camera or directly through my eyes, and when I'm augmenting a virtual object into the real world. And then if I am switching between augmented reality and virtual reality or using the data from the real world that is captured through the computer vision algorithms and using that as a reference within my virtual reality application, that's what I call mixed reality.
>
> A few examples: if you're developing an application in Unity, you have two paths – do you want to create an augmented reality application or do you want to create a virtual reality application? Right now, you can't create a single application that does both. That's what mixed reality can do.
>
> What it is: a transition between both experiences. For instance, if you want to trigger based on an image an augmented reality experience and from there, you're switching to a virtual reality experience —that's one definition.

How does Vuforia support mixed reality? In three ways:

Improved rendering
: The first is through stereo rendering—left eye and right eye view. This also includes distortion correction for the lens. A lens is never straight—it is always concave—so they compensate for the curvature of the lens. Those are the rendering parts of the features they added.

Rotational device tracking
: This is also referred to as "3 doff." When you're not looking at an image or when you're in a completely immersive environment of a VR experience, you don't want to be restricted by looking at an image target. Even if the target is out of sight, you still need that extended tracking. That is baked in as a feature in Vuforia.

Mixed reality controller API
: That is basically an API that lets you control for how you transition between the virtual and the augmented world.

This definition of mixed reality is the dominant hardware-driven one right now. It is simply and beautifully described in this article from the Next Web that also discusses how artificial intelligence is

connected to AR development. However, other people define mixed reality differently.

Mixed Reality: Blending Digital Assets into the Fabric of the World Around Us

In a talk called "The Dawn of Mixed Reality" at the WIRED Business Conference in 2016, Rony Abovitz—founder, president, and CEO of Magic Leap—calls what they do "a mixed reality lightfield." The way he thinks of it is not based on a blend of virtual reality and augmented reality the way we think of it today. It is not headsets and graphics.

It means walking through the world without any technology (except, perhaps, what's embedded) using our visual cortex—and the power of our minds—as the display system. Abovitz is talking about our reality itself.

Here are some excerpts from that talk that give you insight into his current thinking about mixed reality, and how he plans to shape what it becomes:

> Thinking about how we experience the world visually, without any technology, the idea was there's this amazing display that we have in our brain already and it's processed by our visual cortex. And I thought we would never build a better display than that, so how can we get into that. And that led to the studying of how the visual world outside of us, which we call an analog lightfield, how that interfaces with your brain—the sort of physics and neurobiology interface—and allows that display in your brain to create all the amazing imagery that we're doing right now. And our digital lightfield is basically mimicking that process. It's allowing the brain to be a display and not replacing the display you already have with something inferior. It's trying to use what's there.
>
> *So how does it work?* The heavy lifting piece of what we do, we have to think nature and biology. I mean, we evolved this incredible brain that has a hundred trillion connections, hundred of billions of neurons—somewhere around 40%+ is all about visual processing and perception. What we're doing is we create a digital lightfield signal that is a biomimetic signal that is very similar to the analog lightfield that's coming in. And our signal blends with that one.
>
> So really you have this one integrated signal coming from your eye retina system into the visual cortex and you don't have something on top of the world. You don't have like a cellphone display in front of your eye like what people think of with VR. You just have some-

> thing that feels like an integrated natural blending of digital and physical, and that's what we call mixed reality lightfield. All of the details of how those hundred trillion neural connections work—we'll be here for probably 10 years—but it is a blend of how the brain works plus our intense effort to mimic a signal very naturally into your eyebrain system.

In a July 12 tweet, Abovitz also said this: "Mixed Reality adoption will be a journey—think first iPod through the iPhone—but will be fun all along the way :)"

It will be.

It is still early days in the new AR frontier. "Reality" is changing. The digital and physical worlds have already merged. Dipping a relatively low-investment toe into AR technology makes sense if you're in enterprise (remember: that doesn't necessarily mean getting smart glasses—start with what you have). Begin learning how AR works and how to use it as a tool. Don't roll it out to consumers. Use it to help your design, manufacturing, sales, and ops teams. Augment the people behind the scenes, to make their lives easier (and time more efficient).

What we're augmenting (especially in enterprise) is not reality, but the ability of humans. The digital and physical worlds have already blended.

Now, it's just a matter of proportion.

About the Author

Leah Hunter writes about the human side of tech for Fast Company, entrepreneurial women for Forbes, and innovation for O'Reilly. She speaks on "How To See The Future" via The Lavin Agency. Formerly an editor at MISC Magazine and AVP of Innovation at Idea Couture, she has spent her career exploring the intersection of technology, culture, and design. She has created brand strategies and new products for everyone from Apple to Target to Sephora.

When she's not writing or producing, you can find Hunter: leading IDEATE, a camp of entrepreneurs and world-changers at Burning Man; judging for orgs like the SXSW Accelerator and the Roddenberry Foundation Prize; doing on-air journalism and emceeing events; modeling; or teaching MBA courses and workshops on wearables and ethnography/deep observation at California College of the Arts, CEDIM— Mexico, University of California Berkeley, and The Stephen M. Ross School of Business at the University of Michigan.

This year, she founded a company and she is co-producing a television show.