The Institution of Engineering and Technology

CATAPULT High Value Manufacturing

Through the looking glass

The rise of augmented reality and its role in the future of manufacturing

theiet.org

hvm.capault.org.uk

Contents

Introduction 3

The birth of AR 4

AR and manufacturing 5

Industrial applications 7

- Complex assembly 7
- Maintenance 8
- Remote expert support 8
- Training and upskilling 9
- Quality assurance 9
- Automation 10

Technical barriers to adoption 11

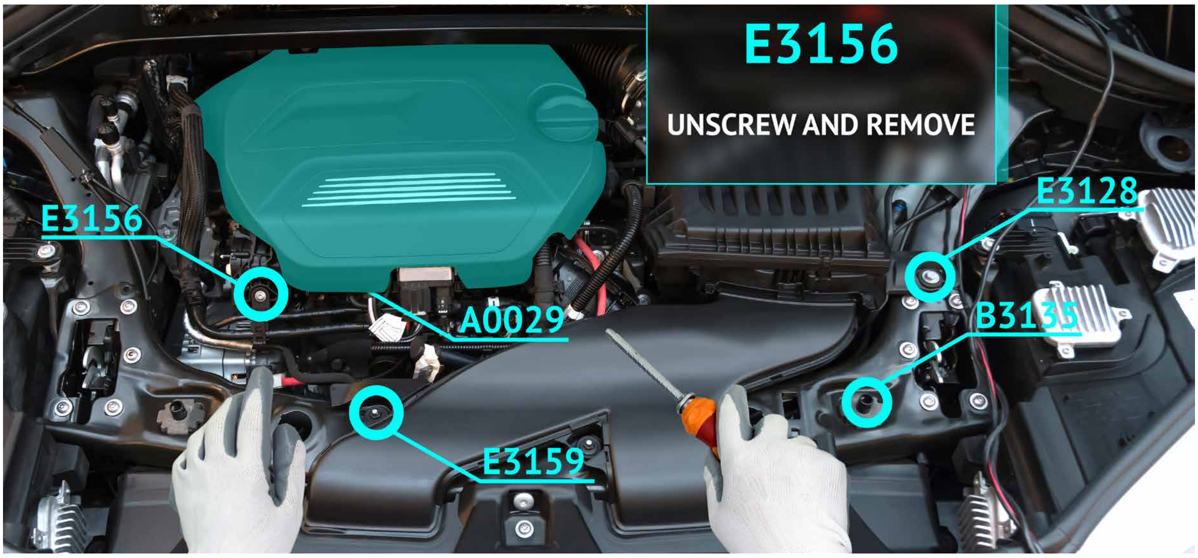
- Content generation 11
- Connectivity 14
- Power 14
- Optics 15
- Registration and mapping 15
- Latency 16
- Interaction 16
- Cyber security 17
- Lack of standards 17
- Demographics and usability 18

Insight and the future: AR utopia or dystopia? 19

About this report

This Insight Report is a joint paper from the IET and the High Value Manufacturing Catapult. The IET would like to thank the report's co-authors John Yates and Chris Freeman, and Prof. Robin W. Scott, for their efforts in compiling this report, along with Mark Sage, Paul Haimes and Jim Heley for their contributions.

Introduction



Augmented reality (AR) provides opportunities to leverage the latest innovations in mobile communications technology, big data analytics and the Internet, to develop information-rich solutions that will drive improvements in industrial productivity, performance and quality.

While much of the spectacular growth in the AR market is currently a response to consumer demand – less than a month after *Pokémon Go* was released in 2016, the AR smartphone app had attracted 100 million downloads – it is the industrial sector where the expansion of AR could be strongest, as firms seek to adopt emerging technologies to gain a competitive edge.

According to BIS Research, the existing $4 billion AR market will reach a global value of $198 billion by 2025, as software and hardware advances are exploited by major industry verticals such as manufacturing, healthcare, aerospace and defence, engineering, construction, warehousing and logistics and enterprise solutions.

Companies in these verticals are already experimenting with a range of AR devices as they discover potential new applications ranging from design and prototyping, factory layout and planning, complex assembly, machining simulation, robotics, diagnostics, facility inspection and maintenance, through to remote assistance, accelerated training and up-skilling, ergonomics and health and safety.

This Insight Report sets out to investigate the rapidly changing AR landscape; understand the technical and business challenges facing both AR providers and industry adopters; follow the contours of the market and policy environment; and identify the risks and benefits in early adoption for UK industry and advanced manufacturing in particular.

The birth of AR

Seeing the future of productivity

It is widely accepted that out of the five senses, sight is our most dominant. The value proposition for augmenting visual information focuses on productivity, performance and quality. Research by Mike Campbell of PTC shows workers are 30% more productive with AR information delivered in context. Therefore, most applications gaining traction at the moment revolve around the delivery or production of visual information.

The first AR prototypes were created by the computer graphics pioneer Ivan Sutherland and his students at Harvard University in the late 1960s and exploited a see-through display fitted to a helmet to present 3D graphics.

The *Microsoft HoloLens* is one of the latest advancements in head-worn AR technology.

But it was not until the early 1990s that the term "augmented reality" was coined when researchers at the Boeing Corporation, Tom Caudell and David Mizell, were tasked with finding an alternative to the expensive diagrams and marking devices used to guide workers assembling long bundles of wires for the new Boeing 777 aircraft.

Adopting this approach with the 777 made sense because it was the first aircraft to be fully digitally modelled before being physically assembled, which meant there were comprehensive computerised images of its complex components.

Out went the large plywood boards containing individually-designed wiring instructions for each plane and, in their place, workers were given head-mounted devices that displayed the schematics through high-tech eyeware projected onto multipurpose, reusable boards.

As with many of the early attempts to overlay the real world with bits of the virtual, this inaugural bright idea didn't take flight. This was largely because the head-tracking required to make the system work while people moved around wasn't responsive enough – a technical challenge that remains relevant to this day. In addition, the wearables available in 1990 lacked the computer power to perform accurately.

The advent of smartphones, tablets, and head-worn computers like Microsoft HoloLens and Google Glass – and improvements in the tracking and mapping technology that hampered Caudell and Mizell – is changing fast and opening opportunities for industry.

On the software side too, it is much easier today to develop AR applications using freely-available software toolkits (for example ARToolKit and Wikitude) that are supported by camera systems that can analyse the physical environment in real time and relate positions between objects and environment.

1bn smartphones today have AR sensors and graphics acceleration

1/10 users actually employ such applications

Source: PwC.

AR and manufacturing

There are around 1,000 immersive specialist companies in the UK employing approximately 4,500 people and generating £660 million in sales, potentially representing as much as 9% of the global market share, according to the 2018 *The Immersive Economy in the UK* Report.

A *2017 Global Digital IQ Survey* by PwC found that 10% of companies say they are currently investing in AR. 24% said they will invest in the technology within three years. Aerospace and defence, as well as software and internet/information technology companies, are among the early adopters, while those who said they will invest in the next three years include consumer banks, airlines, engineering, construction companies, retailers and wholesale and distribution firms.

For Facebook founder and CEO, Mark Zuckerberg, there is no doubt that AR is the future. "I think eventually there are going to be people who want a VR product and there are going to be people who want an AR product. I would bet the AR one will be bigger if it can get developed in a good way," he said back in 2017. But the pace of change, and the diversity of AR offers within the marketplace, means that many enterprises aren't so much falling behind as struggling to keep up with proliferating and competing proprietary technologies.

The previously secretive company Magic Leap has now joined the likes of Microsoft, Meta, ODG, Mira and DAQRI in launching AR headsets. At the same time, Apple, Google, Facebook, Snap and others are releasing platforms for smartphone-based AR.

Take the evolution of smart glasses. The HoloLens, developed by Microsoft, is a self-contained, holographic, wireless device that overlaps images on an individual's vision, such that the images appear as holograms and provide information required by the user. This, and similar devices, are finding wide application across manufacturing, construction, healthcare, automotive, aerospace and hospitality. But which device to choose?

A valuable piece of InnovateUK-funded research by University of Sheffield's Advanced Manufacturing Research Centre, as part of *The Augmented Worker* project, explores the vast range of devices on offer to industry, as part of a more forensic study into the potential impact of AR in just one sector: construction. This research shows the strengths and limitations of more than 20 devices, before drilling down into how AR can be developed to capture and visualise data in real-time, creating building information modelling (BIM) data for a site with no prior digital data.

The Augmented Worker, a Sublime project with Crossrail for Innovate UK.

175k jobs generated increasing sector growth by 3%

4.5% reduction in CO_2 emissions

Potential impact of industrial digitalisation over 10 years. (Source: Made Smarter Review).

The research shows that industry-wide adoption of digitisation through BIM and smart systems will drive a more engaging and collaborative culture within the construction sector, increasing productivity and making industrial jobs more attractive to the current and future skilled workforce. This would be fully in line with the UK government's drive to disrupt the construction industry through Industry 4.0.

The Made Smarter (previously Industrial Digitalisation) Review sets out how UK manufacturing can be transformed through the adoption of industrial digital technology (IDT). Over 10 years, industrial digitalisation could boost UK manufacturing by £455 billion, increasing sector growth up to 3% per year, and creating a net gain of 175,000 jobs whilst reducing CO_2 emissions by 4.5%. Augmented reality is identified as a key technology driving the Made Smarter ambitions.

But it also reveals that there is no easy, off-the-shelf route to getting there. Organisations like the High Value Manufacturing Catapult – of which the AMRC is a member – are integral to the adoption process. They play an essential role in developing and refining the AR technology, pushing it to its limits and de-risking its industrial application for research partners.

Industrial applications

Across the globe, larger OEMs are exploring the benefits that augmented reality can offer in an industrial environment – a trend that has nowhere to go but up, as the hardware and software for AR improves. Here we look at some of the industry trailblazers, the applications, the early results and the challenges to come.

Complex assembly

Modern manufacturing involves putting together hundreds or thousands of components in a precise sequence quickly and accurately. This is true whether you're manufacturing smartphones, motor cars or jet engines. Every new product or model requires a new set of assembly instructions.

That is why Volvo has been experimenting with AR on its assembly lines using Microsoft's HoloLens. Work instructions, along with associated technical drawings and even videos from the last person who did the procedure, are uploaded in AR glasses. This enables operatives to work hands-free and eliminates the need to walk to a workstation to check instructions. It also enables new recruits to be more rapidly inducted and develop the skills needed for production line work.

In aerospace, Lockheed Martin's engineers use AR to increase speed and accuracy in the production of the F-35 Lightning. Augmented reality is also being adopted by BAE Systems in the UK to create a guided step-by-step training solution using Microsoft's HoloLens to teach workers how to assemble green energy bus batteries.

Early evidence suggests that front line workers can be trained up in just hours at a tenth of the cost of traditional methods. This approach also enables firms to meet succession challenges and avoid potential skills shortages and gaps.

Volvo has been working with Microsoft, and its HoloLens, to develop new automotive technologies. (Source: Volvo).

Lockheed Martin's new Innovation Center in Orlando gives employees access to AR technologies. (Source: Lockheed Martin).

Maintenance

In addition to helping with the assembly of manufactured products, augmented reality can be used to assist in the maintenance of manufacturing equipment. Mitsubishi Electric's maintenance support technology uses augmented reality based on a 3D model that enables users to confirm the order of inspection on an AR display and then enter inspection results with their voice. Mitsubishi expects to extend the use of AR across a variety of maintenance work including inspections of water-treatment plants and building electrical systems.

Being able to see a machine's status simply by glancing at it through an augmented reality display is incredibly powerful. In 2017, elevator manufacturer ThyssenKrupp announced that its 24,000 technicians would begin using Microsoft's HoloLens technology as a tool in service operations.

Using HoloLens, the service technicians can visualise and identify problems with elevators ahead of a job, and have remote, hands-free access to technical and expert information when on site. Triaging service requests ahead of the visit, and getting hands-free remote holographic guidance when on site, has reduced the average length of ThyssenKrupp's service calls by up to four times.

As the Volvo example shows, the automotive sector has also been an early adopter of AR. Technicians responsible for servicing Volkswagen's next-generation vehicles will use an AR system known as the MARTA (Mobile Augmented Reality Technical Assistance), which lists all of the jobs to be performed along with the necessary equipment. The individual context-dependent work steps shown on the tablet gives the technician an easy-to-follow system for identifying work items more quickly and accurately.

Remote expert support

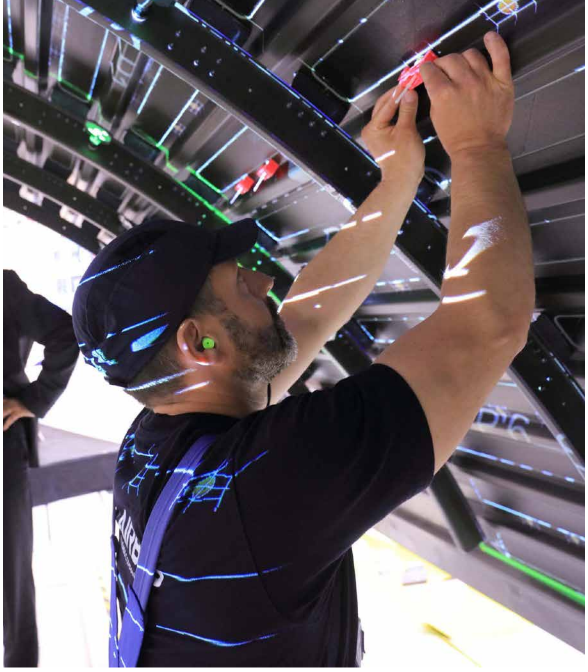
For distributed manufacturing operations, most companies have dedicated skilled inspectors and technicians for routine maintenance, but fewer trained experts to fix things when and if they go wrong.

Despatching experts to the customers' worksite is costly, time consuming and fraught with risk. 'Have you sent the right expert? Have you diagnosed the right fault?' By using AR to deliver a 'see-what-I-see' telepresence, the expert can look through the eyes of the on-site technician who's doing the maintenance.

The remote expert can also annotate on the field of view of the technician, so he can point out particular features of interest in what the technician is seeing. This enables experts to offer support and perform inspections from anywhere.

Being able to see a machine's status simply by glancing at it through an augmented reality display is incredibly powerful

At Boeing, factory trainees assembling a mock airplane wing were 30% faster and 90% more accurate using AR-animated instructions on tablets than trainees using instructions in PDF documents.



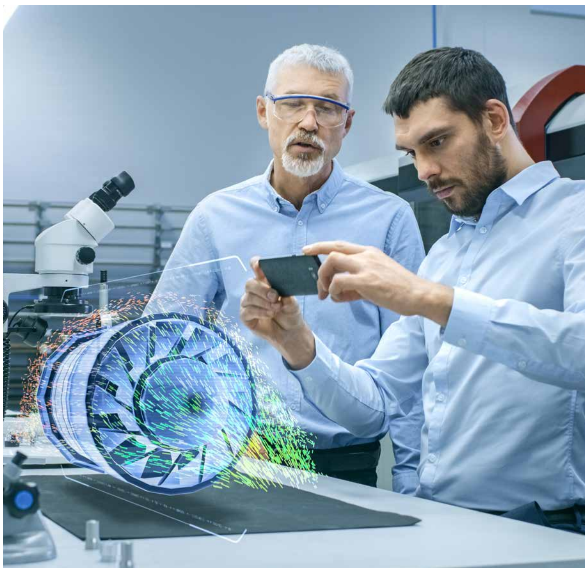
The MiRA application aiding production of an Airbus A350 XWB fuselage shell at the company's plant in Stade, Germany. (Source: Airbus).

Training and upskilling

The use of AR in complex, low-volume assembly and repair and maintenance has clear implications for the training and upskilling of staff, and for the development of effective succession planning for experienced but ageing workforces.

Rather than training every technician or machinist, companies could use AR technology to supplement their employees' existing knowledge with engineering expertise delivered digitally. Some companies are now feeding training information on top of the actual parts and assemblies – mixing the execution of the task with training, which ultimately makes the equipment easier to learn and use.

By augmenting operatives at certain skill levels with artificial intelligence via AR and the Internet of Things, the UK manufacturing industry has a clever solution to the skills agenda that not only maintains jobs but ramps up their skill sets.



Quality assurance

Quality assurance (QA) offers numerous potential applications for augmented reality. Airbus has been using a "Mixed Reality Application," or MiRA, to integrate digital mock-ups into production environments, giving assembly workers access to complete 3D models of the aircraft under production. According to Airbus, MiRA has been used on the A380 and A350 XWB production lines to check the integrity of secondary structural brackets, which hold hydraulics and other equipment in place. Using a tablet-based interface equipped with a camera for visual inspection, operators superimpose a digital mock-up over "as built" reality. At the end of the inspection, a report is automatically generated that includes details of any non-conforming parts which can be replaced or repaired quickly.

Airbus reports that MiRA has reduced the time required to inspect the 60,000 – 80,000 brackets in the A380 fuselage from three weeks to three days.

Even though augmented reality and automation may compete in the short term, industry will require close cooperation between automated machines and augmented human workers in the longer term

Automation

AR is very much seen as working in a symbiotic relationship with the human operative. So what relevance can it have to automation, where the ultimate goal might be to eliminate the human element from production? One perspective is that smart glasses and head-mounted devices (HMDs) cooperate with automation as they share common protocols and standards. AR, in other words, bundles other manufacturing IT systems such as PLCs, SCADAs, Histograms, CMMSs and ERPs, making information previously constrained to the control room available on the device, wherever the worker goes.

In this way, AR enables industry to leverage 'context awareness' via the Internet of Things to gather information about the environment and then feed that to the worker. Couple this to developments in artificial intelligence, which will also augment the capabilities of the worker, and it provides a very powerful message to both the workforce and policymakers that Industry 4.0 is not a threat to jobs. It is upskilling.

The sweet spot is that, as more jobs get automated, industry will need to push more workers up the skill chain, which will make them more competitive in the market. So, even though augmented reality and automation may compete in the short term, industry will require close cooperation between automated machines and augmented human workers in the longer term.

"The term augmented reality is said to have emerged from a Boeing project in the early 1990s. However, I think that it has had a much longer history than this. The Dam Busters used projected light to assess and control their aircraft height on their approach to target because the altimeters weren't accurate enough. This is overlaying information in the real world, which is AR. Laser projection was also developed in the '90s and heavily used in the composite layup industry; again this is AR, and so the use of the technology has been around for some time.

The idea of AR being a new technology has emerged with the development of wearable computing hardware, which promises to deliver a new dimension to AR. This is still quite elusive as a robust industrial solution, but will undoubtedly grow and deliver much more in the future.

A3L have been delivering projected AR solutions into the aerospace industry since 2012. We work very closely with Delta Sigma Company in the US who have developed an AR system for projecting digital work instructions into the working environment. A major benefit of this is that information can then be dripped into the process as it is required by the worker; this does away with the need to read and digest written or pictorial instructions and then to follow what they've read.

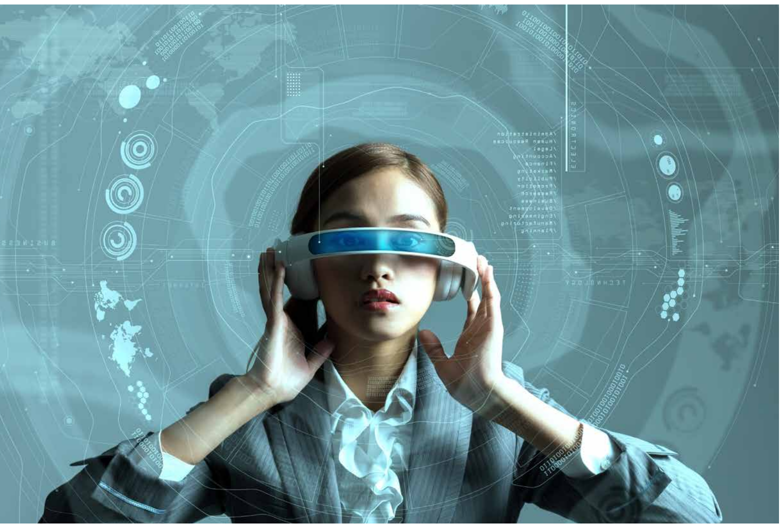
With industrial AR we find that simple tasks are only viable when there is a need to change them; for example, on a car assembly line the TAK time is usually about 90 seconds. Most people can easily remember 90 seconds of work but if there are 500 different blocks of 90 seconds because there are 500 different configurations, then the picture changes.

One of the biggest challenges to delivering AR solutions into industry is the generation and formatting of data. In aerospace especially there are many different ways that the data is formatted and constructed and so every solution needs to have bespoke filters and translators; it would be very useful to have standards to ensure that data formats remain consistent and so are easily digestible by the AR systems."

Jim Heley – Director of Advanced Aerospace Assembly Ltd (A3L)

Technical barriers to adoption

Many technical hurdles remain to be overcome, however, before AR becomes business-as-usual across diverse sectors of industry. What follows is a brief guide to these challenges. Understanding them provides insights into both the readiness of the technology and its industrial applications.



The Executive Director of AR for Enterprise Alliance (AREA), Mark Sage, told TechXLR8 in London that early AR adopters are now beginning to see and talk about the savings and performance improvements it is bringing.

"There have been some amazing savings that companies are seeing; anything from 30% through to 99%. It does of course depend on the use-case, but this is not a technology that is waiting to be developed, it is happening now," Sage said.

Content generation

The authoring of much AR device content is still a largely manual process, or has a high proportion of manual intervention. This content can include geometrical models, data models, image or video, but, whichever content it is, it is not yet seamlessly automated.

Many AR solutions use content that is already prepared for other purposes – content that includes pictures, documents, checklists, and so on. As AR authoring tools evolve, the nature of content that is best suited for AR will evolve and will lead to a future that more seamlessly merges the physical and digital realities.

Although these are early days for AR, the use-cases have been expanding. What began with simple apps that added context based on GPS data have now entered an era where 3D images are overlaid on a real-time view of the world. During this time, AR systems and associated authoring tools have evolved in three primary categories: geospatial systems, 2D systems and 3D systems.

It is the latter that is essential for AR industrial use-cases. Similar to video, 3D content is data-intensive. CAD models of a complex device or system can be very large, which requires files sizes to be reduced and encoded to allow for processing and rendering on smartglasses or other mobile devices. So providers are investing in developing proprietary encoders that optimise large files to reduce their size for use on smartglasses and mobile devices, but it is a complex process and presents challenges around not just output accuracy, but also more process-based issues such as version control and content change management.

Conventional software tools such as 3D CAD authoring systems will eventually expand into AR authoring as the boundaries between AR authoring and 3D design blur and merge. This trend is reflected in the established CAD vendor PTC's acquisition of Vuforia, an AR authoring platform.

Unity, a widely used 3D gaming engine, has a plug-in to integrate the functionality of ARToolKit, a computer vision library that provides a tracking capability to make it easier to create AR applications in Unity. For AR to achieve its full potential for industry it will require the ability to rapidly create, manage, edit and deploy 3D content – that is the authoring challenge. Data handling, data translation and data optimisation.

Augmented reality is emerging as a key driver of industrial innovation for enterprises across industries. Helping front-line workers unlock the value created by digital transformation initiatives, AR technology is poised to transform the way companies design, manufacture, operate, and service products. PTC has been engaging with its customers since 2016 to reveal their current and planned use of augmented reality to drive digital transformation across their operations and products. It recently published its *The State of Industrial Augmented Reality* report that looks at the current state and future plans for the adoption of augmented reality.

The report's findings, from a survey of PTC's Vuforia and Vuforia Studio customers, revealed that customer-facing AR experiences are being developed and deployed more rapidly than ever, with 86% of respondents anticipating AR experiences going live in the next 12 months. This high pace of adoption represents both an opportunity and a disruptive threat. Furthermore, 50% of industrial enterprise respondents are keen to improve customer experiences, open up new revenue streams, and disrupt competition by leveraging the new augmented reality capabilities for product and service differentiation.

"Use case adoption and customer business goals have shown that industrial enterprises are starting augmented reality projects internally, often piloting one or two use cases within their operations or service functions to prove value before expanding AR initiatives. Companies universally recognise the importance and benefits of adopting AR for their internal use and in a business climate of razor-thin operating margins and mounting economic pressures, the race for efficiency is starting to boost the adoption of AR. PTC is helping address some of the issues that have prevented AR adoption by working with our customers to mitigate some of the challenges. We work to identify our customers' pains and business challenges and match them with PTC's unique AR solutions to identify where AR can be most useful.

With AR, organisations can improve service efficiency with step-by-step instructions, customer service with easier self-help guides, sales with virtual product demos and showrooms, and factory efficiency with augmented process plans and inspection processes."

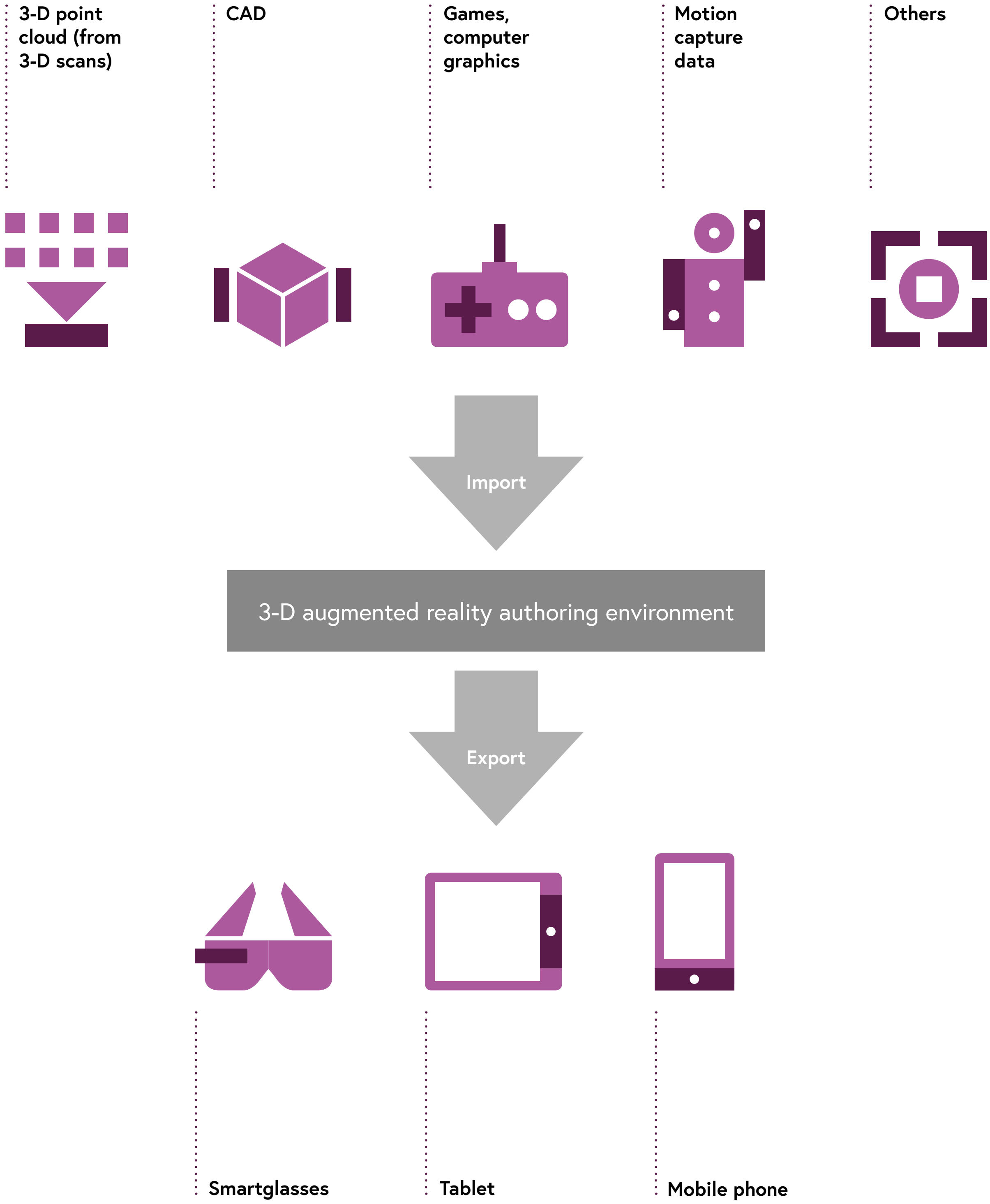
Paul Haimes – VP of Technical sales in Europe (PTC)

86% of respondents anticipate AR going live in 12 months

50% are keen to improve customer experience

Source: PTC's 'The State of Industrial Augmented Reality' report.

Authoring tools for 3D AR can import 3D information from a variety of 3D content domains and export content for use on different AR devices.



Connectivity

In many industrial environments, and on many devices, connectivity is a challenge. If the content is deployed onto the device at the start of a session rather than being updated through real-time connection, then version control can be an additional problem. The industry believes that the advent of 5G will bring more stability to the mobile AR experience and allow access to more and better quality content. But how long before this is overloaded?

Having the infrastructure to support AR will certainly elevate the application and use of these technologies in industry. This will go a long way to fulfilling the promise of the Internet of Things to make our world smarter by ensuring the right information is provided at the right time. With ubiquitous connectivity, AR can be used to visualise data from hundreds of sensors simultaneously, overlaying relevant and actionable information through a headset.

Caterpillar is using AR for predictive maintenance, enabling a user to look at a machine and instantly see a visual overlay that states when various components need to be replaced, how much fuel has been used, and how much weight a backhoe is carrying.

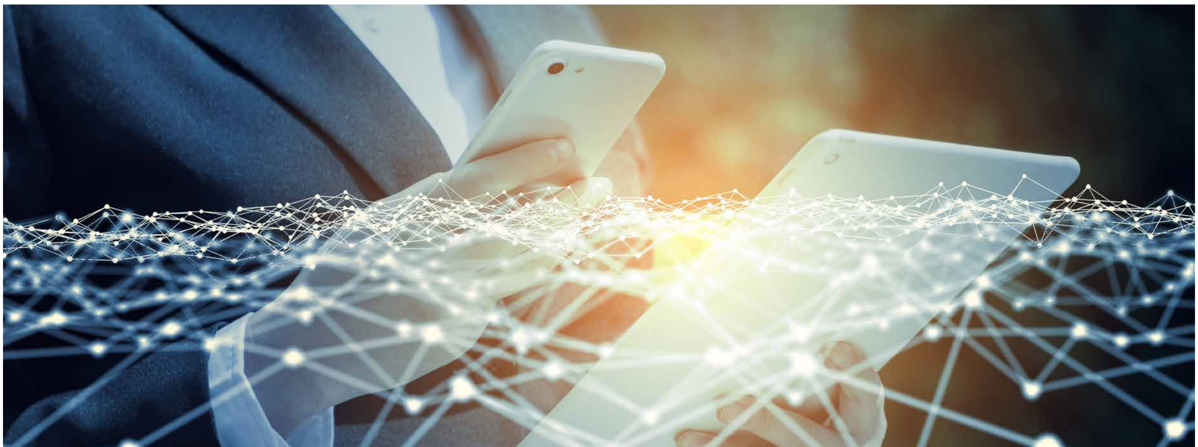
Power

As one of the main benefits of most AR devices is the fact that they are untethered, the downside is that of power and a reliance on batteries. Most devices are designed to be lightweight and portable and thus, much like mobile computing, processing power and battery size (and hence life) is a challenge.

Mobile computing has advanced rapidly over a relatively short period of time, with mobile CPUs more capable than they've ever been, however there is still a shortfall in the power required to deliver rich AR experiences. This may yet be solved through the continued development of mobile based GPUs, matching the trend seen in desktop computing, or the development of web-based experiences enabling content to be streamed.

Whatever the solution, the power requirements will put an ever-greater strain on battery life. Mobile computing providers are investing heavily in battery technology but optimal solutions are still some time away. So in the short term, either devices have to have swappable power supplies, or to have charging built in; either solution, however, restricts usability.

The industry believes that the advent of 5G will bring more stability to the mobile AR experience and allow access to more and better quality content



Optics

While digital imaging and video capture are sophisticated and useful in AR, the challenge in optics is the display of information. For instance, field of view today is typically only 25 to 40 degrees horizontal and vertical, compared to the 190 degrees horizontal and 120 degrees vertical for normal human vision. Limited optical capabilities reduce the variety of use-cases and the potential of AR.

Add to this the need to reduce the size and weight of headsets to make them more user- friendly and it is clear that optical designers will have to pursue more extreme freeform shapes to achieve thinner, lighter prisms. They are also experimenting with lighter, higher-index materials, and optical components like holographic lenses.

Optical designers will have to pursue more extreme freeform shapes to achieve thinner, lighter prisms

Registration and mapping

One of the key benefits of AR is the ability to overlay computer-generated (or compiled) data onto the real world. To do this the device must be able to understand its physical context (location, direction, height, pitch, yaw, roll). This may be done through the use of markers (fiducial markers / QR codes etc), tracking technologies (RFID, Wi-Fi triangulation, IR tracking of markers), recognition technologies (edge and object-based detection) or through more macro-sized systems (GPS).

Whichever is used, there are challenges related to the latency of location update (see below) and the dislocation of the computer-generated data set and the physical area of interest. For some applications, such as a head-up display that shows an instrument gauge in a car, the exact position of the projected image in the real world is not critical. For other AR applications, the position of the projected image must be precisely controlled. This is often done by adding a depth camera to the headset that images and analyses the world to determine where the projected image should appear. This technology is called simultaneous localisation and mapping (SLAM) and is the method of constructing or updating a map of your surrounding environment whilst simultaneously recording your precise location within it. As a technology it is central to many autonomous applications such as UAVs and self-driving cars.

In all cases, both the projected image and the real-world image must be crisp and undistorted. Optical-design software packages must allow the designer to simultaneously evaluate the system performance for both paths and to consider both paths during an optimisation.

Latency

A key performance and usability measure of AR is that of latency. This is sometimes referred to as motion-to-photon and is a measurement of the time it takes for light to enter a camera, get processed by a computer vision algorithm, generate a pose, render digital content, and display it as augmented reality so that it can be seen by the eye. If the latency is too high, the content won't match up.

This challenge is at two levels. This first is related to updating location (see above) the second is to the updating of data. On a disconnected device, a static data set can be delivered with less latency, but with less flexibility in terms of data or content update. On a connected device, this updating can be done on the fly, but latency of location and content can be higher.

The very low latencies required for AR's industrial applications will require efficiencies in four main areas: sensors (camera and IMU); tracking (motion estimation); rendering (image generation); and display (image presentation).

Interaction

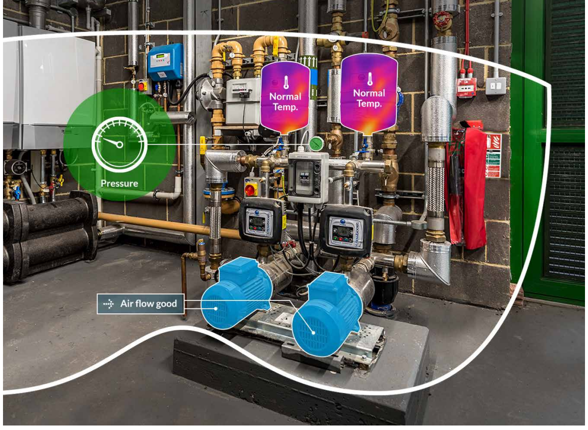
Augmented reality presents myriad challenges for how humans interact with it, requiring technology to stitch together various realities into a cohesive and seamless experience. No single technology, both contact and non-contact – voice, gesture, tapping or swiping – is likely to achieve this cohesiveness on its own, and the future of AR will likely revolve around a collection of these technologies coming to prominence together.

Approaches that span gesture tracking, motion tracking, eye tracking, and speech are evolving in their capabilities and accuracy. While the relative mix of these solutions is unclear, the approaches all complement each other, as different interface technologies are bound to work better in different environments.

For example, speech is unlikely to work well in a loud factory, and many tracking systems – gesture or eye – currently have problems working in bright environments, such as outside on a sunny day.

Today, the interaction technologies are largely isolated components, and innovators are still learning to build with them. In the future, those components could converge in a common interaction fabric that developers take advantage of and that allow users to intuitively interact with physical items and digital items in the physical spaces where they work.

The very low latencies required for AR's industrial applications will require efficiencies in four main areas: sensors, tracking, rendering and display



Cyber security

The growth of the digital economy and the emergence of new technologies such as AR has led to particular skills shortages in areas such as cyber security, with companies and public sector organisations increasingly prioritising the protection of their data against malicious threats or accidental loss.

According to CWJobs' 2017 UK Skills Gap Survey, 31% of tech companies in the UK believe that they face a major skills gap in cyber security with 80% currently struggling to fill cyber security roles. Only half of workers (51%) said that their training included cyber security and 23% felt that they were not confident in handling a cyber security attack. 50% thought that their company was unprepared for a cyber-attack or were unsure on their position.

Augmented reality is about overlaying graphics and information onto the real world. If hackers compromise an application and start showing fake information and graphical objects on an AR display or glasses, they can potentially cause harm. Imagine a doctor checking a patients' vital signs through an AR display, only to be presented with the wrong numbers and failing to diagnose a condition that requires immediate medical attention. Or a processing plant where the maintenance is being carried out using AR, but the data has been hacked and shows safety-critical components that require replacement to be functioning well.

Lack of standards

Standards are a challenge. For AR to maximise its potential, there are many aspects that will require the further development of standards. Fortunately, for AR developers many of these fall under the broader narrative of digital transformation and are not exclusively an AR challenge. There are also a number of standards in place that are transferable from other technologies which form part of the AR ecosystem, such as communication protocols.

Within the digital transformation narrative would fall the requirement for *single source of truth* data, and specifically in relation to AR, how to ensure we are accessing the correct information, at the correct time, and in the correct place. How to deal with system integration and control the distribution of proprietary information is particularly pertinent when we consider the previously discussed authoring challenge.

The industry has in the past attempted to implement standards around content translation and optimisation, however the generation of 3D engineering content is such a nuanced process, with variance seen not only cross-sectoral, but also at a business and user level. Applying catch-all standards to govern the translation and optimisation is very difficult.

Further complexity is added when we consider the storage, management and certification of this duplicate data in relation to the *single source of truth* narrative. Such challenges are the reason we see either different flavours of standard formed, or the creation of standards within a standard. The result is a series of best practice guidelines – while being useful as a resource, they do not offer the governance required around many of the universal formats that exist today.

Demographics and usability

As industry approaches an era with mixed demographics on the shop floor, it will encounter a number of challenges around AR in the workplace. With technology playing an ever-greater role in society, it's recognised that the next generation of engineers will not only be 'tech-savvy' but also technology-fluid. Having grown up with a stream of innovations, in particular around mobile technology, and the influence this has on their day-to-day lives, they are generally more receptive to technology change.

There is however a wealth of knowledge and experience in the existing workforce that needs to be included as part of a digital transformation narrative. Understanding how to manage a deployment and ensuring end-user buy-in will be critical for AR. For instance, there is a quest for a 'Goldilocks' amount of information (not too much, not too little), delivered to the right user in the right way. As yet systems do not commonly have the 'intelligence' to recognise the capability or preference of the user to author the content on the fly, and deliver to the users' preferred device. A 50-year-old worker will have different preferences, aptitudes and skills to an 18-year-old.

35% **time saving to train new staff**

The result of Boeing using AR for training.

96% **reduction in inspection time**

Reported by Newport News Shipbuilding since it started using AR.

"The enterprise AR ecosystem has evolved from being irregular – with the technology not quite being ready, best use-cases still being developed and efficiencies being difficult to achieve – into a developing ecosystem. This means is we are seeing greater clarity on best practice, the best tools for purpose are being identified, AR language is being shared between providers and buyers and there are clear efficiency impacts being realised.

This is being backed up by real-life examples of performance improvements. Companies like Boeing, by using AR for training, have made a 35% time saving to train new staff. Another AREA member, Newport News Shipbuilding, have made an amazing 96% reduction in inspection time (36 hours to 90mins).

They now use AR for maintenance, enabling every sailor to become a quick expert on complex systems; safety, highlighting safety information in a challenging environment; and operations, bringing the ship to life in a new way by revealing data while it is in context.

In summary, the AR ecosystem is now seeing a positive ROI and tangible bottom-line benefits. The AREA members continue to develop the ecosystem by working on initiatives to overcome the barriers to AR adoption (including business issues such as security, safety and creating a single global set of requirements). Through its research and promotion, it will continue to help the ecosystem, allowing us all to develop mature, long lasting and beneficial AR solutions."

Mark Sage – Executive Director of AR for Enterprise Alliance (AREA)

Insight and the future: AR utopia or dystopia?

So what does the future hold for augmented reality? A good person to ask would be the CEO of Siemens UK, Jürgen Maier, who identified AR as one of the five key digital technologies shaping industry.

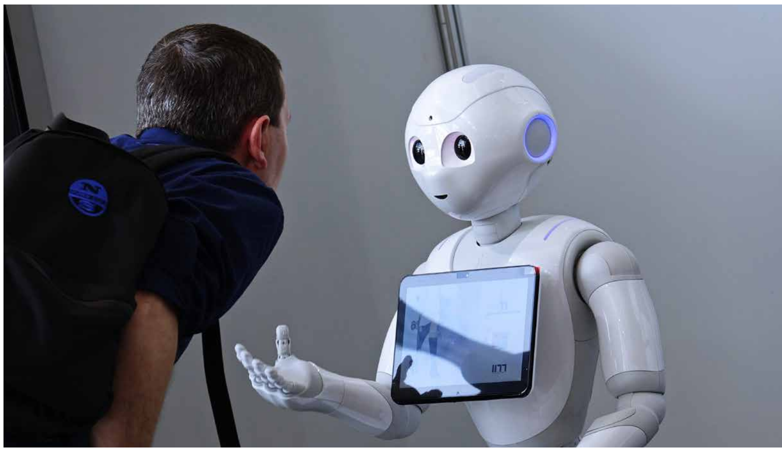
Author of the government-commissioned *Made Smarter Review*, Maier argues that the fourth industrial revolution will be a digital revolution: a revolution founded on virtual reality and augmented reality; on robots and cobots; on artificial intelligence and machine learning; on harnessing data and using it to better manage assets and processes; and on the Internet of Things.

Done well, with real leadership and significant investment from government, this bundle of digital technologies could boost UK manufacturing by a staggering £455bn over the next decade, according to Maier and a group of leading UK industrialists. As Maier suggests, AR on its own will not do it. But when it is combined with advanced sensor technologies, data analytics and artificial intelligence, augmented reality and other emerging immersive technologies could hit industry and society like a tidal wave of overlays and holograms.

If you can't picture a future like this take a peek through the lens of Denis Villeneuve, the director of *Blade Runner 2049*. The star of that film is not so much Ryan Gosling or Robin Wright, but augmented reality. From Gosling's pixelating companion who overlays herself – with perfect latency and location – atop another woman, to cityscapes bathed in advertising and public information messages, the cyberpunk city will be dystopia to some, utopia to others.

Whether this is the future made visible through augmented reality remains to be seen. What both the film and the technology express is the potency that comes with the combination of human creativity and scientific/engineering curiosity.

At the moment we have visual AR (projected, screen-based, headset-based) but what about the other senses? Haptics already exist in VR, so why not in AR?



How long before IKEA can let its customers *feel* that new piece of furniture that IKEA Place allows them to visualise in the context of their own homes?

And how long before visitors to the historical re-enactment of old Viking York (Yorvik) smell the scene as they drive around it in their driverless car with augmented windows (this might be easier to imagine, as Smell-o-vision, AromaRama, Odorama, and Aroma-Scope all came out in the 1960s).

Could those very same scenes of Yorvik be augmented with the sounds of what the visitor is seeing? Technologies already exist that allow us to do these things independently, so perhaps that is where the challenges lie for the future – integrating all these technologies together. Maybe in the not-too-distant future the act of seeing – and hearing, and feeling and tasting and smelling with augmented reality – won't ever be the same as believing?

The Institution of
Engineering and Technology

Our offices

London, UK
T +44 (0)20 7344 8460
E faradaycentre@ietvenues.co.uk

Stevenage, UK
T +44 (0)1438 313311
E postmaster@theiet.org

Beijing, China
T +86 10 6566 4687
E china@theiet.org
W theiet.org.cn

Hong Kong
T +852 2521 2140
E adminap@theiet.org

Bangalore, India
T +91 80 4089 2222
E india@theiet.in
W theiet.in

New Jersey, USA
T +1 (732) 321 5575
E ietusa@theiet.org

@TheIET

theiet.org