Capgemini engineering

THE VIRTUAL FACTORY OF THE FUTURE

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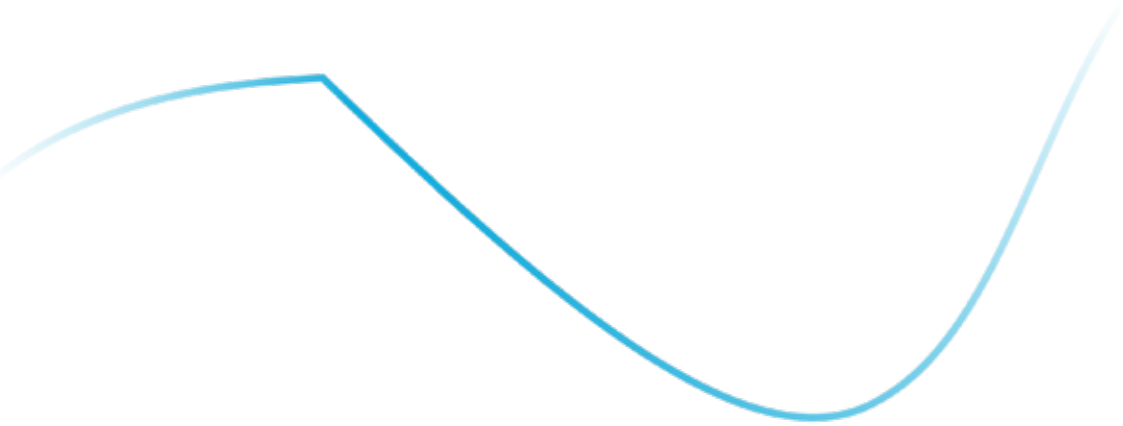


€931 billion
invested in Industry 4.0 every year

7.5 billion
connected things in the world in 2017

1 million
engineers expected to use VR or AR daily by 2020

€15 billion
estimated worldwide spending on AR and VR in 2018

98% CAGR
in AR and VR technologies spending in the next five years

What does Industry 4.0 really mean?

Although this initiative is often associated with the introduction of new technologies in factories, the fourth industrial revolution is a much broader concept that encompasses profound transformations throughout the industrial value chain.

Perhaps the best way to understand the transformation process is to review the working groups led by the founding fathers of Industry 4.0, piloted by Henning Kagermann and Siegfried Dais:

- WG 1 – The Smart Factory: Manfred Wittenstein
- WG 2 – The Real Environment: Siegfried Russwurm
- WG 3 – The Economic Environment: Stephan Fischer
- WG 4 – Human Beings and Work: Wolfgang Wahlster
- WG 5 – The Technology Factor: Heinz Derenbach

They speak of technology, of course, but also of the establishment of advanced manufacturing processes, the adoption of adaptive and smart manufacturing systems, the roll-out of new digital, virtual, and resource-efficient factories, the promotion of collaborative and mobile enterprises, and the conception of more human-centred and customer-focused manufacturing.

Deep transformations in business models and manufacturing processes are clearly necessary to enable Europe to attain such an ambitious objective: achieve maximum flexibility and customization in production to offer products at a competitive cost while maintaining the quality and commitment to society, specific to European industry.

Smart factories streamline the supply chain

In order to remain competitive, Europe proposes to combine a huge array of new technologies to conceive a new industrial fabric, one in which small or medium-sized factories are more intelligent, flexible, and interconnected, and where moderate investments allow maximum optimization of each component of the production and supply value chain.

The concept of the Smart Factory was born, based on the connectivity between people and machines, and the availability of a maximum amount of aggregated data. Thus, intelligent systems can autonomously make decisions to optimize the production and the quality of manufactured goods and to assist humans in carrying out the most tedious tasks.

Thus, in these new factories, machines, robots, and even humans will be monitored by innumerable sensors and wearables, connected to each other through the Internet of Things (IoT), supplying an enormous amount of data to autonomous intelligent systems capable of analyzing this information. Together, they can act to optimize production, reduce stock to bare essentials, streamline the distribution processes, or facilitate a more flexible and personalized production.

The Cloud, Fog, IoT, Robotics, Additive Printing, and Artificial Intelligence (AI) will be some of the key enabling technologies (KET) of this budding industrial revolution.

But they will not be the only ones. In these factories of the future, a new type of operator will also be seen. This operator will be endowed with new abilities and must interact with an enormous amount of machinery, technology, and information to carry out its work at an optimum level.

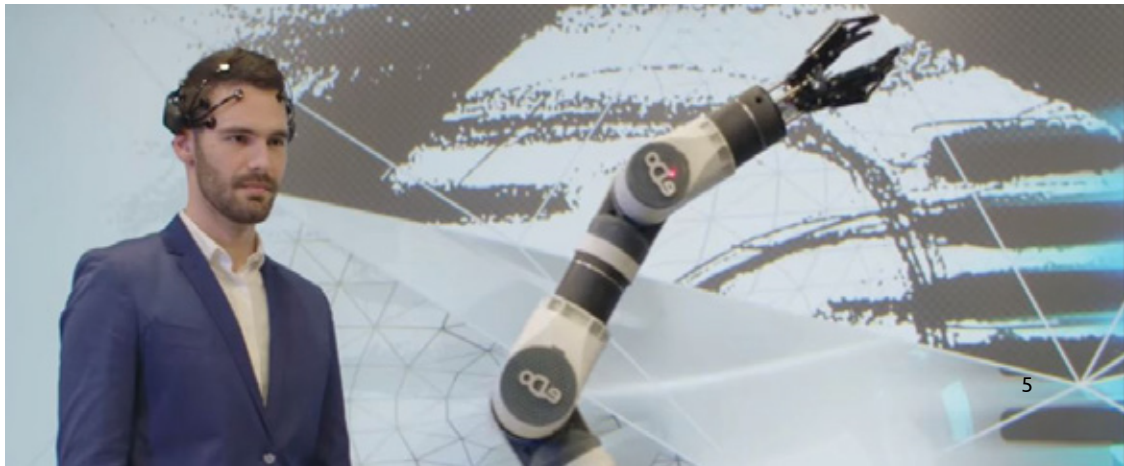
Next-generation interfaces optimize interaction with data

The introduction of increasingly intelligent systems at every step of the production value chain also requires the conception of new forms of interaction between men and machines.

The advances being made in AI, especially in the development of deep learning algorithms, will allow machines to understand orders, have conversations with operators, react to gestures, and even perceive our state of mind or health.

Overcome by advances in natural language processing and artificial vision, keyboards, mice, and joysticks will yield to voice and gestural interfaces. Their reign will be fleeting, however, because there will soon be new machine brain interfaces that will allow us to control machines through thought.

Moreover the way we access information, such as the data captured by sensors and their aggregates, processed and threshed by intelligent systems, and even the production environment itself – will also change drastically. The days of screens and consoles are also numbered.



Virtual factory

Factories of the future will not only be fully digitized and connected, but also virtualized to offer workers digital replicas of real environments, thus making the physical presence of human beings unnecessary in production environments.

Virtual factory replica optimizes production management

The concept of the connected virtual factory arises, where the production chain is controlled through digital replicas of physical environments.

Thanks to new modeling and 3D processing techniques, it is now possible to generate, in just a few weeks, a digital model of a complete factory that we can visit from anywhere on the planet using virtual reality headsets.

This virtual environment will not only be a faithful clone of the physical environment – down to the smallest detail – but will provide real-time information on the state of each production asset and make it possible to act on them with sensors and actuators installed in each of the machines connected through IoT.

So we can imagine an operator accessing any of the smart factories that will compose the new European industrial fabric while comfortably sitting in his living room.

VR goggles allow him to be immersed in each of the factories connected to his production environment to remotely inspect each asset in the production chain.

The data provided by the sensors installed in these machines will allow him to know their status in real-time. Various intelligent systems will inform him not only about the status of each asset and any failures that may occur at that time, but also use machine learning algorithms of predictive maintenance to provide an estimated time for the next repair.

This new virtual and connected operator will be able to make decisions that ensure an optimum level of production by sending orders to robots to change their work routines or altering the production schedule of the factory.

Cloud and fog computing, big data, sensors, actuators, wearables, IoT, AI, machine and deep learning, robotics, and AR/VR will all work together to create the new factories of the future.

However, the possibilities offered by virtual reality for the design of these new factories do not end with the monitoring and remote control of the production chain.

The introduction of simulators in virtualized industrial environments will help design, optimize, and secure workspaces and production lines. It will also improve the training of operators, as training can be carried out in virtual factories that faithfully reproduce real conditions, with simulated failures and risky situations. This is especially relevant when we consider the prevention of occupational hazards.

Finally, virtual reality will also facilitate, expedite, and cheapen the design of manufactured products, completely avoiding or at least delaying the expensive creation of prototypes in wood, metal, or other materials.

Immersive technologies remove the frontiers between real and virtual

Virtual reality has been anticipated, but it will soon be paired with its sister: augmented or mixed reality. While the former facilitates the remote control and management of intelligent factories, the latter offers similar possibilities in situ.

With the new generation of augmented reality glasses, operators can work in a physical environment enriched by the information from sensors installed in the assets of the production chain. Using new spatial mapping and position tracking algorithms, the cameras installed in these glasses will recognize the surroundings and nearby objects to superimpose information from sensors, SCADA systems, and intelligent systems that allow operators to act on them through voice or gestural interfaces.

In short, virtual and augmented reality are two complementary sister technologies that, through extensive use of new forms of communication and processing (IoT, cloud and fog computing, big data, analytics, machine learning, etc.), will become the protagonists of the longed-for Fourth Industrial Revolution.

Sci-fi?

Palmer Luckey[1] started his little revolution just a few years ago when he realized that by combining some of the smartphone's sensors (accelerometers, gyroscopes, etc.) with new graphic processors, he could create a virtual reality goggle capable of offering a satisfactory experience at a reasonable cost. This was a dream pursued by engineers since the 1970s when Sony launched the Virtual Boy[2], a product created by visionaries too far ahead of their time.

The work of this teenager soon caught the attention of John Carmack[3], the father of first-person games and creator of Doom and Quake, who urged him to withdraw his work from the public domain and create the company Oculus VR[4].

1. Wikipedia, 'Palmer Luckey', available from: https://en.wikipedia.org/wiki/Palmer_Luckey
2. Wikipedia, 'Virtual Boy', available from: https://en.wikipedia.org/wiki/Virtual_Boy
3. Wikipedia, 'John Carmack', available from: https://en.wikipedia.org/wiki/John_Carmack
4. Wikipedia, 'Oculus (brand)', available from: https://en.wikipedia.org/wiki/Oculus_(brand)

Only two years later, Facebook bought the young company for $2 billion, willing to take leadership on the development of a technology that was able to stimulate the next social networks revolution.

Since then, other actors have joined the stage, such as Valve with their HTC Vive[5], Samsung or Google itself first with its famous Cardboards VR[6] and now with its Daydream[7] helmet. Then, on October 13, 2016, Sony launched the PlayStation VR[8], a clear commitment to the potential of this technology to disrupt the entertainment market.

Thus, a market dominated by two trends has emerged. On one hand, there are virtual reality devices that take advantage of the sensors and processing capabilities of smartphones – led by Samsung and Google. On the other, there are manufacturers that use the power of computers and video game consoles to offer a virtual experience of much higher quality – dominated by Oculus, Valve, and Sony.

The augmented reality market is evolving somewhat slower, with one clear dominant player: Microsoft, which astonishes us every day with its technological prodigy HoloLens[9].

Not too far behind, other manufacturers are in pursuit with promising products such as R-9 by ODG, Metavision's[10] Meta 2, or Daqri's[11] integrated helmet that will soon be transformed into lightweight glasses weighing just 200 grams.

All these devices provide sufficient virtual or augmented immersion for markets such as entertainment, tourism, and retail, but they are too limited to be really useful for industrial sectors. However, what seemed like science fiction just a decade ago will soon become a palpable reality. And this will not take another decade. This year will witness the first advances, in just a couple of years, leading to the second generation of virtual and augmented reality glasses which will burst onto the market.

Although it is very difficult to imagine how this technology will evolve over the medium term, we already know the progress that will be made in the coming months.

5. Vive, available from: www.vive.com/eu/
6. Google Cardboard, available from: https://arvr.google.com/intl/en_in/cardboard/
7. Google Daydream, available from: www.vr.google.com/daydream/
8. PlayStation VR, available from: www.playstation.com/es-es/explore/playstation-vr/
9. Microsoft HoloLens, available from: www.microsoft.com/en-us/hololens
10. MetaVision, available from: www.metavision.com
11. Daqri, available from: www.daqri.com

First, the hardware that supports virtual reality will become much cheaper, allowing for the democratization of this technology and providing affordable, high-quality immersive experiences for the general public.

In this sense, the two major manufacturers of graphics processing units (GPUs) – NVIDIA and AMD – are embarking on a race to reduce size, increase performance, and lower the costs of their units, for the benefit of all. This all-out war has reduced the cost of computers and laptops by more than half and soon, all of them will wear the VR Ready label.

The second great leap will come when virtual reality helmets cut their umbilical cord with computers. The new generation will be presided over by standalone devices that will incorporate, in a minimum space, all the technology necessary to offer high-quality virtual immersion without relying on the processing capacity of computers, laptops, consoles, or mobiles.

Alcatel recently took that path with the launch of its virtual reality solution Vision[12], an all-in-one unit that runs for almost two hours and includes all the hardware and software necessary to enjoy high-quality virtual immersion. Next in line was Intel, which launched the Alloy project[13], a headset that, likewise, does not need a computer and enables the user to combine virtual and augmented reality to offer a mixed-reality experience. Even more impressive, if possible, is SnapDragon VR820, the offering from Qualcomm[14]. Like its predecessors, it is an integrated system, although this one exhibits surprisingly high quality. The AMOLED screen offers 1440x1440 resolution in each eye with internal cameras for eye tracking and external cameras to link with the physical world, making it the most advanced model in the field today.

Feeling in the virtual world: the expected addition of virtual senses

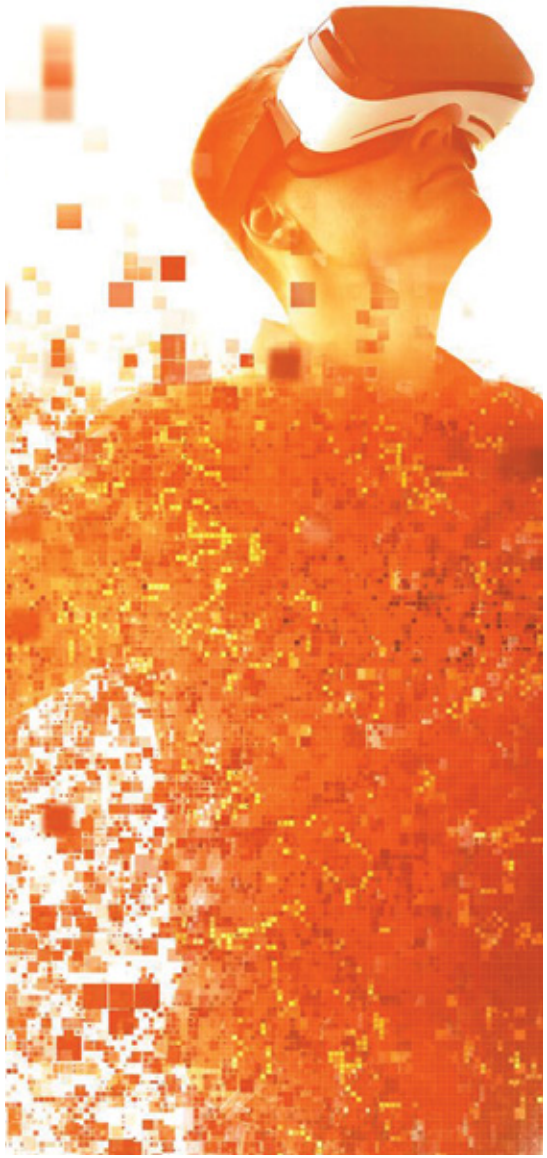
Interacting with virtual objects is another field of development. Using your own hands in virtual environments has become an everyday option thanks to devices such as Leap Motion[15]. By combining this technology with a virtual reality headset, you can see your hands and how your fingertips move so you can press buttons or push virtual objects. This capability will come integrated into most new-generation virtual reality headsets, such as the aforementioned Alloy by Intel.

12. Wwwhat´s New, 'Alcatel Presents Its Virtual Reality Solution, and Does Not Need a Mobile Phone', 2016, available from: https://wwwhatsnew.com/2016/09/01/alcatel-presenta-su-solucion-de-realidad-virtual-y-no-necesita-telefono-movil/
13. El Pais, 'Intel crea Project Alloy, un nuevo concepto de realidad virtual', 2017, available from: https://elpais.com/tecnologia/2016/08/17/actualidad/1471418568_701115.html
14. Qualcomm, available from: www.qualcomm.com
15. Ultraleap, available from: www.leapmotion.com

If you've tried this technology, you will have realized that the invention lacks something: the ability to feel objects – their texture, temperature, and weight. But it won't be too long before we can enjoy the sense of touch in virtual reality.

Haptic gloves, such as Avatar VR[16], that are capable of simulating the texture of objects, are already being developed. Somewhat less elegant but just as interesting is PowerClaw[17], a glove that both simulates touch and offers a range of thermal sensations. You can feel your fingers freeze when you touch an ice cube or the burn when you hold your hand to a flame. A step further is Dexmo[18], an electro-mechanical glove or exoskeleton that, as well as incorporating various tactile sensors, is capable of offering mechanical feedback to each finger so you can feel the resistance of virtual objects to the force you apply.

Sight, hearing, touch – why not smell or taste? Various masks are already being developed that will accompany us with a range of fragrances on our virtual strolls, such as those proposed by FeelReal[19] products, which are compatible with most virtual reality devices.



16. NeuroDigital, 'Avatar VR', available from: www.neurodigital.es/avatarvr
17. Road to VR, 'PowerClaw is a Haptic Glove Ready To Freeze, Burn, and Shock You (Virtually)', 2016, available from: www.roadtovr.com/powerclaw-haptic-glove-ready-freeze-burn-shock-virtually/
18. Xataka, 'Touching and feeling objects in virtual reality is the goal of this exoskeleton glove', 2016, available from: www.xataka.com/realidad-virtual-aumentada/tocar-y-sentir-objetos-en-la-realidad-virtual-es-el-objetivo-de-este-guante-exoesqueleto
19. FeelReal, available from: www.feelreal.com

The virtual factory of the future

The future will offer a greater variety of virtual reality headsets. Some will remain connected to consoles and computers while others work independently. The price of VR Ready desktops and laptops will fall dramatically. VR capability and graphics cards able to move virtual environments will eventually become standard in desktops, laptops, and mobiles.

Welcome to the factory of the future

The video quality of domestic 360° cameras will keep improving, along with their capacity for real-time streaming. This will enable us to run 360° video conferencing with virtual reality glasses.

The relevance of two of our senses will also be enhanced in virtual worlds. 3D surround sound will allow us to direct our gaze to where the action is happening and haptic and electro-mechanical gloves will let us feel the texture and temperature of virtual objects, and even their weight and resistance to the force we exert on them.

And there are more wonders to come. These include real-time 3D mapping of scenarios and avatar generation, which will offer us a much more realistic virtual immersion and the chance to interact with other virtual world inhabitants.

Virtual and augmented reality moves in a sizzling market, driven by the main technological players seeking to bring this disruptive technology to the masses in the shortest possible time. But the European industry must take advantage of this dynamic to promote the creation of new agile, flexible, and intelligent factories.

Cheaper technology and the freedom of movement offered by standalone systems will facilitate their adoption in small and medium-sized enterprises, which characterize a significant part of the European industrial fabric.

Providing haptic or electro-mechanical gloves that incorporate the sense of touch into the virtual experience will also be a critical factor in the immediate future.

Effective and agile operation of a virtual factory cannot be achieved when the operator lacks one of the most useful senses in the physical world. The ability to perceive texture, temperature, or weight of virtual objects is critical so that operators can remotely control, from anywhere in the world, virtual factories that will be connected in real-time through the Internet of Things.

Finally, the new social virtual reality will allow natural collaboration for the different actors involved in the manufacturing process. 360° video conferencing systems will facilitate real-time communication of work teams, while virtual environments and increasingly realistic avatars will ensure that such social interactions can effectively take place.

10 years ago, who would have thought that you could soon be immersed in a photorealistic virtual replica of your factory, with real-time clones of production lines, operating virtual machines connected to their sensitized sisters in the physical world through IoT? What does the future hold for factory management?

As John Lennon once said, “Reality leaves a lot to the imagination.”

Author

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Having graduated as a computer science engineer from the Polytechnic University of Madrid in 1991, Miguel Arjona began his career as a researcher in the areas of knowledge management, telepresence, artificial intelligence, and distance education, coordinating several international R&D projects and excellence centers. Today, Miguel is working in the Capgemini Engineering World Class Center in Madrid, as the R&D Director in-charge of defining strategy and coordinating research and development programs in Spain.

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