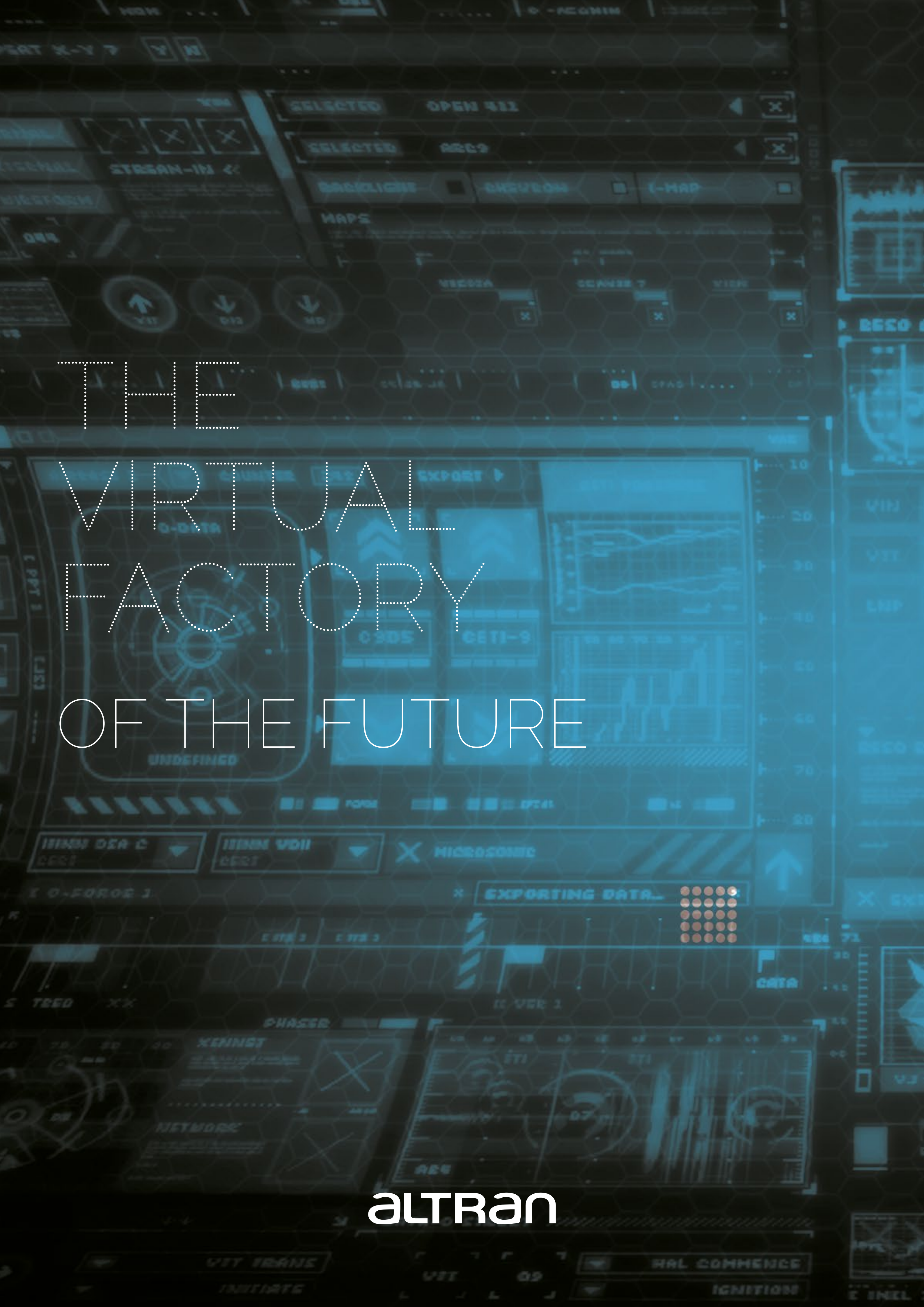

# THE VIRTUAL FACTORY OF THE FUTURE

altran

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## A BIT OF HISTORY…

**We can usually associate each of the industrial revolutions with facts, dates and concrete people.**

**In 1784, Edmund Cartwright designed the first mechanized loom, an unusable design patented the following year and revised shortly thereafter to give rise to the first industrial revolution, in which the steam engine facilitated the mechanization of production processes.**

Almost a century later, in 1870, the first conveyor belt was installed in the Cincinnati slaughterhouse. This was the beginning of the second industrial revolution, characterized by mass production over power-driven assembly lines.

Another hundred years went by before the Modicon 084, the first Controllable Logic Programmer (CLP) was created by Dick Morley of Benford Associates in 1969. This was the device that initiated the third industrial revolution marked by automation, computing and robotics.

Much more recently, coinciding with the 2011 Hannover Fair, the concept of Industry 4.0 or the Factory of the Future emerged, sponsored by the German government in an effort to revitalize European industry. It was a commendable and necessary effort to guarantee the welfare society of which Europe is so proud.

Just consider that more than 40 million people are currently employed in the European manufacturing sector and each of these jobs generates at least one additional job in the service sector. Moreover, 80% of European exports are manufactured goods, representing 16% of Europe's Gross Domestic Product (GDP).

However, although industrial production remains the main driver for innovation, growth and job creation in Europe, and the continent's position in this sector is constantly challenged by Asia and America.

## 1 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 FISCHE
→ 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 rollout 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.

## 2 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 is 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**, 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, The Fog, the Internet of Things, Robotics, Additive Printing and Artificial Intelligence 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.

## 3 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 Artificial Intelligence, and especially in the development of **Deep Learning** algorithms, will allow machines to understand our orders and even to have conversations with operators, to react to our gestures and even to 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--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.

## 4 VIRTUAL FACTORY REPLICA OPTIMIZES PRODUCTION MANAGEMENT

**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 physical presence of human beings unnecessary in production environments.**

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 thanks to 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 of the production assets and make it possible to act on them thanks to the **sensors and actuators** installed in each of the machines connected through the **Internet of Things**.

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.

Virtual Reality 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 the any failures that may occur at that time but also, through machine learning algorithms of predictive maintenance, the systems will provide estimated time for the next repair.

Thus, this new virtual and connected operator will be able to make decisions to ensure the 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, Internet of Things, Artificial Intelligence, Machine and Deep Learning, Robotics and Virtual & Augmented Reality will all work together to create the new factories of the future.

However, the possibilities offered by the 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 **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.

## 5 IMMERSIVE TECHNOLOGIES REMOVE THE FRONTIERS BETWEEN REAL AND VIRTUAL

**Virtual Reality has anticipated, but soon will 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 on them 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, BigData, Analytics, Machine Learning) will become the protagonists of the longed-for Fourth Industrial Revolution.

## 6 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 the 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].

Only two years after, Facebook bought the young company for $2 billion willing to take leadership on the development of a technology 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 Play Station VR [8], a clear commitment to the potential of this technology to disrupt the entertainment market.

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[1] https://en.wikipedia.org/wiki/Palmer_Luckey
[2] https://en.wikipedia.org/wiki/Virtual_Boy
[3] https://en.wikipedia.org/wiki/John_Carmack
[4] https://en.wikipedia.org/wiki/Oculus_VR
[5] https://www.vive.com/eu/
[6] https://vr.google.com/cardboard/
[7] https://vr.google.com/daydream/
[8] https://www.playstation.com/es-es/explore/playstation-vr/

Thus a market dominated by two trends has emerged. On the 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 hand, those 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 more slowly, with one clear dominant player: **Microsoft**, which astonishes us every day with its technological prodigy, Microsoft Hololens [9].

Not too far behind, other manufacturers are in pursuit with promising products such as R-9 by ODG, Metavision's [10] Meta2 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 or 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 leading, in just a couple of years, to the second generation of virtual and augmented reality glasses which will burst onto the market.

[9] https://www.microsoft.com/en-us/hololens
[10] https://www.metavision.com/
[11] https://daqri.com/

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.

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 processors (better known as GPU--Graphical Process Unit), **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 Stand-Alone 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 VISION [12], its virtual reality solution, 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 has 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 1440 x 1440 resolution in each eye and has internal cameras for eye tracking and external cameras to link with the physical world, making it **the most advanced model currently in the field**.

[12] http://wwwhatsnew.com/2016/09/01/alcatel-presenta-su-solucion-de-realidad-virtual-y-no-necesita-telefono-movil/

[13] http://tecnologia.elpais.com/tecnologia/2016/08/17/actualidad/1471418568_701115.html

[14] https://www.qualcomm.com/

## 7 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]. 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.**


If you've tried this technology, you will have realised 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.

[15] https://www.leapmotion.com/
[16] https://www.neurodigital.es/avatarvr/
[17] http://www.roadtovr.com/powerclaw-haptic-glove-ready-freeze-burn-shock-virtually/
[18] https://www.xataka.com/realidad-virtual-aumentada/tocar-y-sentir-objetos-en-la-realidad-virtual-es-el-objetivo-de-este-guante-exoesqueleto
[19] http://feelreal.com/

## 8 WELCOME TO THE 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. We will also see the price of VR Ready desktops and laptops fall dramatically. VR capability and graphics cards able to move virtual environments will eventually become standard in desktops, laptops and mobiles.**

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 real-time 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 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 stand-alone systems will facilitate their adoption in small and medium-sized enterprises, which characterize a significant part of the European industrial fabric.

Providing haptic or electromechanical 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 the 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. Video Conferencing 360 systems will facilitate real-time communication of work teams, while virtual environments and increasingly realistic avatars will ensure that such social interaction 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 connnected to their sensitized sisters in the physical world through IoT ? What does the future holds for factory management ? As John Lennon once said «Reality leaves a lot to the Imagination...

## ABOUT THE AUTHOR

Having graduated as an Computer Science Engineer from Polytechnic University of Madrid in 1991, Miguel Arjona began his career as a researcher in the areas of knowledge management, tele-presence, artificial intelligence and distance education, coordinating several international R&D projects and excellence centers.
Today Miguel is working in Altran World Class Center in Madrid, as R&D Director in charge of defining the strategy and coordinating the research & development programs of the company in Spain.

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