



Digital Twins

A glimpse at the main patented developments

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Gartner expects half of all major industrial companies to be using digital twins by 2021. In this paper, we explore what exactly is meant by digital twins, what are their origins, and what are the associated technologies shaping digital twins applications today.

A review of all published patents in the IFI CLAIMS global database allowed us to identify the main players currently developing digital twin related technologies, to discover what the main application areas are, and to find some the most relevant inventions being claimed.

Digital twin is a concept introduced in 2003 by Dr. Grieves from the University of Michigan, referring to a digital replica of a physical object that is created in order to simulate its behavior. Digital twins have been used for various purposes but in recent years we have witnessed a growing interest due to their disruptive potential in the digitalization of businesses. Use of digital twins has grown particularly in the manufacturing sector but also in other sectors such as health where they have been shown to greatly enhance process efficiency along the entire value chain through near-real-time monitoring, communication and interaction with smart connected objects in the context of IoT and Industry 4.0.

A recent highly retweeted article by Deloitte ([“Industry 4.0 and the digital twin”](#)) states that digital twins can allow companies to have a complete digital footprint of their products from design and development through the end of the product life cycle, thus consistently improving their efficiency. Industrial companies such as Siemens are well aware of the potential of digital twins and are strategically promoting them. In a series of articles ([“Twins with potential”](#)) Siemens highlights digital twins as the epitome of digitalization and the foundation of Industry 4.0.

In this post we wanted to find out which companies are currently doing R&D and patenting new inventions related to the concept of digital twins. Because this is a broad concept, we had to use several search strategies combining keywords and patent classes to grasp the significant volume of related inventions being published worldwide.

For that, we have used the comprehensive information from IFI CLAIMS Patent Services. IFI CLAIMS compiles patent data (as well as linguistic resources, business, scientific and technical data) from different sources and aggregates and unifies this data into a common enriched format which is delivered in a relational database. Moreover, IFI CLAIMS offers a convenient web service and user interface, CLAIMS Direct 2.1, in which we can trigger searches and generate and manage reports.

We queried global patent database from IFI CLAIMS to get a workable dataset of patents claiming new inventions involving digital twins. We included keywords such as “digital twins” together with related concepts such as simulation, computer-aided design (CAD) and 3D modelling. We also took into account concepts such as “device shadow”,

“intelligent maintenance system” and “asset optimization”. More broadly, our query tried to embrace the concept of digital/virtual/cyber/physical integration, as well as the need for data, and finally, the use of sensory and connected elements. As a result, we obtained a total of 1456 patent documents, including 984 patent applications, 262 granted patents, 169 applications of utility models and 34 granted utility models.

The evolution of the patentability of digital twin technology presents a growing trend and there has been a remarkable increase from 2016 to the present.

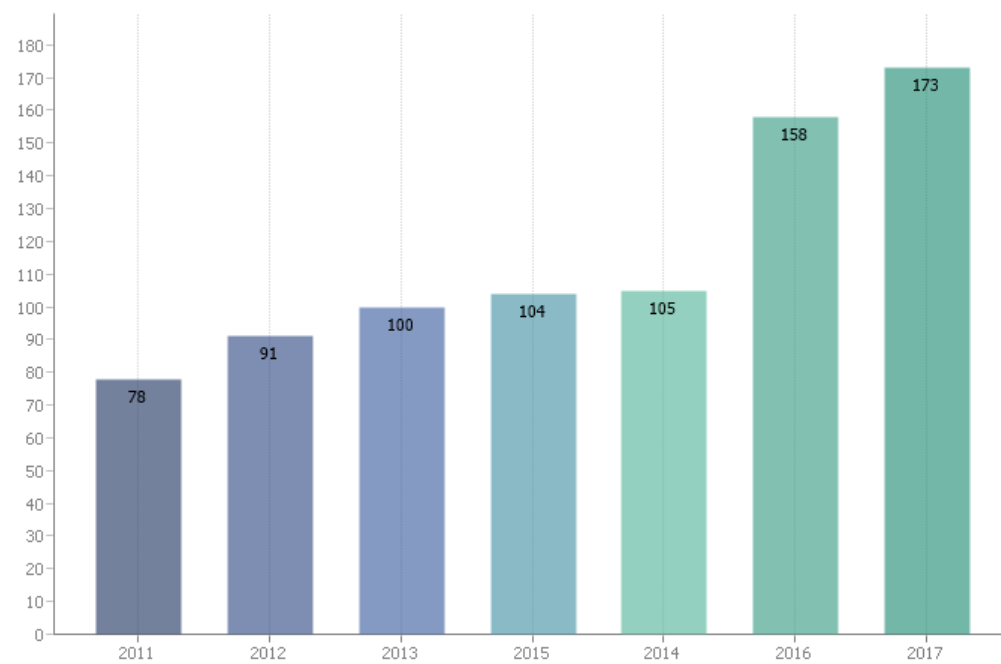


Figure 1: Evolution of the patentability of inventions related to digital twins (2011-2017)
Source: IALE Tecnologia, data from IFI CLAIMS, visualization generated with [Matheo Software](#)

Most of the patents were filed in China (39%), US (20%) and Japan (8%). Others were filed worldwide via PCT applications (7%); other designated countries for protection included South Korea (7%), European applications (4%), Germany (2%), Russia (1,7%), Canada (1,5%), Taiwan (1,4%), Great Britain (1,1%), Spain (1%) and Australia (1%).

Main players

Among the assignees owning a major number of protected inventions in this area we find companies such as **Immersion Corp**, a company specializing in touch feedback technologies. We also find some of the most innovative companies in the world such as **IBM, Microsoft, Siemens, Boeing, Honeywell, Denso** and others.

Immersion Corp	17
International Business Machines Corp	11
Honeywell International Inc	10
Siemens AG	8
Denso Corp	8
Boeing Co	7
Microsoft Corp	7
Ford Global Technologies LLC	6
Samsung Electronics Co Ltd	6
Robert Bosch GmbH	6
Eidgenoessische Technische Hochschule Zurich (ETHZ)	6
Dell Products LP	5
Lucasfilm Entertainment Co Ltd	5
Endress and Hauser Conducta Gesellschaft fur Mess und Regel	5
Airbus Operations SAS	5
Honeywell-Measurex Corp	5

Figure 2: Main assignees/applicants patenting on digital twins (2011-2017)
 Source: IALE Tecnologia, data from IFI CLAIMS, visualization generated with [Matheo Software](#)

Specialization areas

The graph in Figure 3 shows a network of main applicants and their areas of technological specialization (derived from the CPC patent classification codes). The graph visualization has been produced with the data mining and information analysis tool [Matheo Software](#).

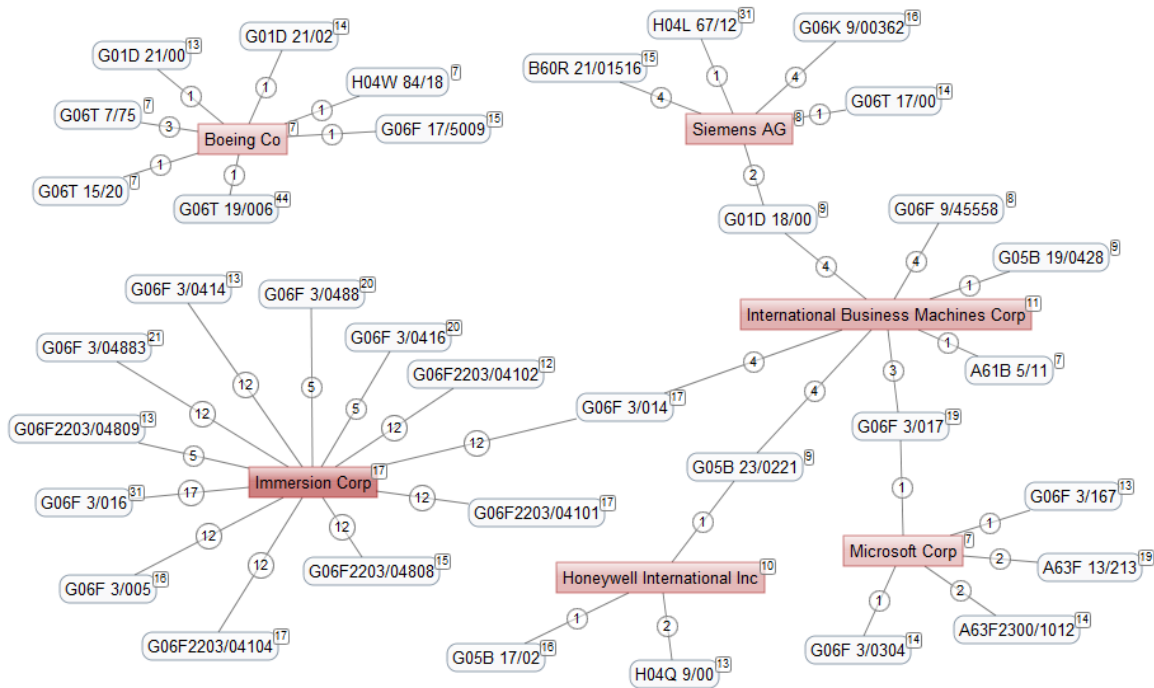


Figure 3: Diagram of the main areas of specialization of companies developing digital twin related technologies
Source: IALE Tecnologia, data from IFI CLAIMS, visualization generated with Matheo Software.

The main areas of technological development in which these companies operate (as derived from the most frequent Cooperative Patent Classifications) include:

- **Arrangements for interaction with the human body, e.g. for user immersion in virtual reality (G06F 3/011), with force or tactile feedback as computer generated output to the user (G06F 3/016), head tracking input arrangements (G06F 3/012), using a touch-screen or digitiser, e.g. input of commands through traced gestures (G06F 3/0488) for entering handwritten data, e.g. gestures, text (G06F 3/04883), Interaction with three-dimensional environments, e.g. control of viewpoint to navigate in the environment (G06F 3/04815)**
- **Manipulating 3D models or images for computer graphics (G06T 19/00), mixed reality (G06T 19/006)**
- **Network-specific arrangements adapted for proprietary or special purpose networking environments, e.g. medical networks, sensor networks, networks in a car or remote metering networks (H04L 67/12)**
- **Eyeglasses (G02B 27/017)**

- **Videogames using inertial sensors, e.g. accelerometers or gyroscopes** (A63F 13/211)

Let's have a look at the main technologies and innovative solutions being claimed by the leading applicant companies:

- California company [Immersion Inc.](#), specializes in touch feedback technologies, also called "haptics" (G06F 3/016). They have also developed gesture response technologies (G06F 3/0488) and control and interface arrangements for touch screens (G06F 3/0416).
- **Boeing** develops technologies related to mixed reality (G06T 19/006) and CAD using simulation (G06F 17/5009).
- **Siemens** focuses its development efforts on network specific arrangements for medical applications (H04L 67/12).
- **Microsoft** primarily patents methods of hand gesture recognition and interaction (G06F 3/017), and videogames comprising photodetecting means, e.g., cameras, photodiodes or infrared cells (A63F 13/213).
- **IBM** has patented technologies on input arrangements for transferring data such as data gloves (G06F 3/014), where **Immersion Inc.** is also active. IBM also focuses on *Eyeglasses* (G02B 27/017), a field in which **Microsoft** also has obvious strategic interests.
- The multinational conglomerate company **Honeywell** focuses on electric systems involving the use of models or simulators (G05B 17/02).
- Finally, Japanese automotive multinational **Denso** has patented methods for measuring acceleration (G01P 15/124, G01P 15/125, G01P 15/134) and accessories or details specially adapted for hand carts (B62B 5).

In addition to these leading companies, many others have applied for patents in recent years in major IP offices worldwide for new inventions related to digital twins.

For example, **Bosch** has filed an application for a system and method for distortion correction in three-dimensional environment visualization (US-8892358-B2). **Samsung** is patenting methods for information acquisition of wireless sensor network data as cloud-based service and an image forming apparatus and control method (US-9547509-B2, US-

8107132-B2). [SPC](#), a US company providing voice and data-based control infrastructure installations for many sectors has patented systems for transmitting data from a bottom-hole assembly (US-8485277-B2). German provider [Hexagon](#) has patented technologies for fast image enhancement and three-dimensional depth calculation (EP-2676239-A1). Another German company, [TruPhysics GmbH](#), has developed an AR platform and is training robots to execute actions in physics-based virtual environments, using digital twins (US9671777B1). Predictive maintenance solutions provider [Fedem Tech](#) has recently filed applications claiming data transformation methods for virtual assets (EP-3348983-A1). Digital twins are also claimed by 3D printing company [Desktop Metal, Inc.](#) in additive manufacturing processes with metallic composites (WO2017151837A1). Last year, **Apple** filed worldwide and US applications for an invention for wireless communication and control of physical devices, directly or through interaction with a virtual representation (or placeholder) of the object (WO-2017136705-A1, US-20170229009-A1). **Google** worked several years ago with acquired supply chain robotics start-up **Industrial Perception Inc.** on robotic object manipulation based on received sensor data (obtaining granted protection US-9238304-B1), and registered a system for detecting an event in a physical region within a physical space this year (WO-2017091590-A1, US-20170148217-A1).

Application sectors

By further analysing the retrieved IFI CLAIMS patent dataset, we were able to identify examples of implementations in many sectors. The main ones are:

- Health: Digital twins are used in applications for monitoring, diagnostics, and prognostics. For example, [Virtamed AG](#), a company developing simulators for medical training and education, has obtained several granted inventions together with the prestigious Swiss University **ETHZ** (US-9142145-B2). **Dell Products** also has granted patents on systems for interpreting health sensor data (US6904391B2). **Streamline Automation** has patented medical meters (US20140275886A1). **Critical Materials LDA** has a health management system and method based on combined physical and simulated data (EP-2699881-A1). **St. Jude Medical Luxembourg Holdings II S.A.R.L** has a physical property sensor with active electronic circuit and wireless power and data transmission (US9653926B2). Drug development consultancy [Certara](#) proposes the use of digital twins for predicting and adjusting the dosage of medicines in individual patients (US20160335412A1).
- Automotive: Within the automotive sector we find applications for manufacturing and for MRO (Maintenance, Repair & Overhaul). For example,

Ford owns granted patents in the US (US-6236908-B1) related to virtual vehicle sensors based on neural networks trained using data generated by simulation models. **Denso** has patented electronic control systems (US-9346488-B2). **Continental** has applied for Hardware Independent Mapping of Multiple Sensor Configurations for Classification of Persons (US-20080140288-A1). **Texas Instruments** has co-patented with sensor producer [Sensata Technologies](#) a digital compensation circuit for calibration of sensors (US-5798692-A). We also found augmented reality applications based on a digital twin such as [PCT Inc.](#) patent US-20160328883-A1:

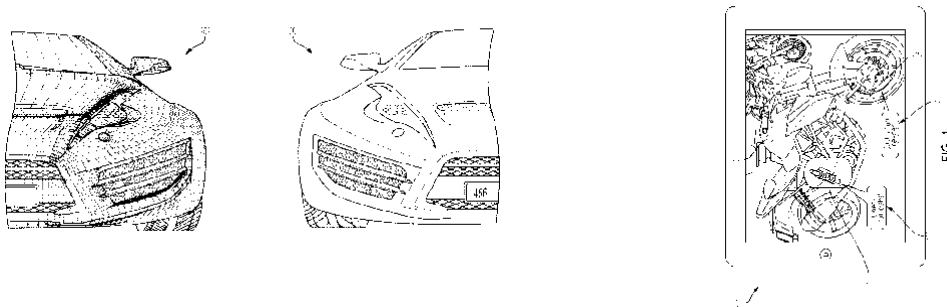


Figure 4: Mosaics from PCT Inc's Patent US-20160328883-A1 *Augmented reality system*
Source: USPTO via IFI CLAIMS

- Aerospace: **Boeing** has patented a viewpoint control of a display of a virtual product in a virtual environment (US-9355498-B2). **Honeywell** has achieved granting of technologies regarding a field device including a software configurable analog to digital converter system (US-9626335-B2) and pressure sensors with improved rate-of-change compatible data output (US-7633420-B2). **Airbus** has developed a switched flight test installation with a packet type data format (US-7203615-B2). **Korea Aerospace Research Institute** has patented signal processing devices (US-9483231-B2). **GE** claims technologies for controlling aircraft operations and aircraft engine components assignment (US20170323274A1). Drone companies such as **DJI** or **Drone Deploy** are also actively working on new visual data simulation methods (WO-2018107503-A1).
- Construction and Energy Efficiency: [Heuristic Actions](#) protects sensor modules for use in monitoring structural health (US-20180136085-A1). German

measurement instruments multinational **Endress & Hauser** has patented a system for process automation with intelligent sensors and methods for calibrating them (US-20100211832-A1). Sensor company **Lord Micro Strain** obtained in 2006 a patent protection for an orientation sensor (US7143004B2). **Siemens** has filed technologies for digital twins for energy efficient asset maintenance (US20160247129A1) and configuration and parameterization of energy control system (WO-2018111368-A1). **GE** has patented a digital twin for operating wind farms (US20160333854A1), systems and methods for monitoring coupler fatigue (US20170151965A1) and for sensing and locating delamination (US20170284974A1).

- Games, Media & Entertainment: **Lucas Film** obtained grants in 2015 and 2016 in the US and Australia for a patent for a visual and physical motion sensing for three-dimensional motion capture (US-9401025-B2, US-9142024-B2, AU-2009251176-B2). **Disney** claimed a haptic interface for population of a three-dimensional virtual environment in 2014 (US-20170322700-A1 | US-9733790-B2). Icelandic video game company **CCP hf** patented methods and systems for providing virtual display of a physical environment in Europe, Australia and Canada (EP-3250985-A1). Other active companies that have developed digital twin related inventions in the gaming field include **Intellisys Group LLC** (US-20160332064-A1), **Ncam Tech**, **Elwha LLC**, **CPA Global Limited**, **ClearWorld Media**, **Gravitx Ltd**, **Anthrotronix Inc.** and the **University of Maryland**, Japanese **Semiconductor Energy Lab**, French **Spraed**, Bulgarian **BG Serviz ood**, Korean **Kyung Hee University Ind Coop Group** and Chinese companies such as **Shenzhen Yikangda Information Tech Co. Ltd.**, **Beijing Vofrid Culture Transmission Co. Ltd.** and **Anhui Huan Intelligent Information Science and Technology Stock Co. Ltd.**

Companies specifically using the concept of digital twin in the title, abstract or description text of their patents include:

- **General Electric**: “DIGITAL TWIN OF TWINNED PHYSICAL SYSTEM”: (US-20170286572-A1)
- **Siemens**: “EXAMINING A CONSISTENCY BETWEEN REFERENCE DATA OF A PRODUCTION OBJECT AND DATA OF A DIGITAL TWIN OF THE PRODUCTION OBJECT” (WO-2017045789-A1)

- [PCT Inc.](#): company providing industrial control automation services, has filed a patent for an augmented reality system for automation generated from a digital twin (US-20160328883-A1)

Highly cited patents

Amongst the most cited patents in this field, we found foundational patents being registered back in the late nineties, such as Ford’s 1997 patent US-6236908-B1: “Virtual vehicle sensors based on neural networks trained using data generated by simulation models” and US-6697879-B1: “Computer implemented virtual sensor object and tangible medium utilizing same” by inventor [Robert Tufty](#) from Sensiview Corp in 1996.

Other more recent, highly cited patents that we have been able to identify through IFI CLAIMS’ convenient “forward citations” metadata patent field are patents such as “Touch interface device and method for applying lateral forces on a human appendage” (US-10007341-B2) granted in 2011 to **Northwestern University** and **Immersion Corp’s** patents “Systems and methods for transmitting haptic messages” (US9785238B2), granted in 2009 in the US and “Friction augmented controls and method to convert buttons of touch control panels to friction augmented controls” (US20150185848A1), applied for in 2015.

Touch interface device and method for applying lateral forces on a human appendage

Friction augmented controls and method to convert buttons of touch control panels to friction augmented controls

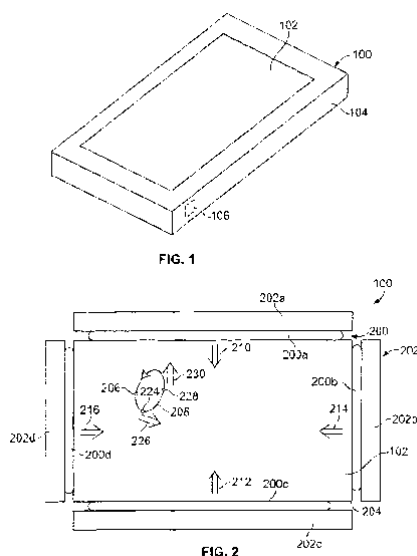


Figure 5: Mosaics from Northwestern University’s Patent US-10007341-B2 (left) and Immersion Corp’s Patent US20150185848A1 (right)

Source: USPTO via IFI CLAIMS

Some final remarks

This short report is a non-exhaustive glimpse at some of the most relevant developments in worldwide patented publications. As we have seen, digital twin is a broad concept that embraces several technology fields and focalized approaches (namely virtual and augmented reality, 3D imaging, sensing, IoT and smart connected objects, means of human interaction, machine learning and data processing, etc.) as well as differentiated application areas such as manufacturing industries, health, entertainment, education, etc. Further studies may be undertaken focusing on each of these.

References:

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- GE Digital Twin Prediz <https://www.ge.com/digital/predix/digital-twin>



- Hannover Messe – Digital Twin <http://www.hannovermesse.de/en/news/key-topics/digital-twin/>