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1. DIFFERENCE BETWEEN DIGITAL AND TRADITIONAL PHOTOGRAPHY

Photographers worldwide have differing opinions on whether a digital or film camera is better. As technology evolves, photographers are continually upgrading their cameras. On the other hand, many still rely on traditional film cameras.

The major difference between traditional film cameras and digital cameras is you need to purchase film and to develop it to see the images. Most people scan their negatives but traditionally photographers created prints in the darkroom. Digital cameras use digital storage to save images and generally need a digital device to edit the images.

Digital Cameras	Traditional Film Cameras
Easier access to editing: just need a computer, tablet, or smartphone	Generally higher-resolution photos with better color rendition
Some digital cameras show in real-time what the camera sees (smartphones and mirrorless cameras)	Prints last longer much longer but require a darkroom to print yourself
High initial cost	Costs add up over time (buy film, need to develop film, & scans)
images are ready to share immediately	Need to develop negatives to see the images
All digital cameras require batteries and needs to be recharged	Many film cameras only need batteries for the light meter and still work fine without them

The most significant similarity between a digital and a film camera is their ability to take photos but they differ on how and what you do after you take the image. Whether you're capturing a moment you want to remember forever, taking portraits, landscapes, or street photography both types of cameras will do an excellent job. Both cameras can produce high-quality images.

Most digital and film cameras come equipped with a lens, flash, and a viewfinder. Aperture, shutter, and ISO settings are essential pieces of photography to control the light entering the camera so both camera types have these tools.

Both Analog and Digital cameras have a lens, flash, and viewfinder, and both take photos. Nevertheless, there are many differences, advantages, and disadvantages to using each.

Digital photos can be easily manipulated. Photos taken on a film camera cannot be manipulated until the negatives are scanned or used to make a print in the darkroom. However, digital cameras are constantly evolving with new technology so much so that your new digital camera may be obsolete in a few years like many from the 1990s. Film cameras never go out of style or lose their advantages and many cameras made as early as the 1920s (or before) still work just fine.

Cost of Film and Digital Photography

The cost can be an essential factor in determining if you want to use a digital or ordinary camera. Regardless of which type of photography or camera you choose, it's an investment well worth it. Digital photography may be cheaper in the long run, mostly because you can immediately fix photo issues by taking a new one. In contrast, the film would require extra hours and lost film.

Film cameras are time and money investment. The cost of film, developing, and scanning adds up over time. The best way to save some money with film photography is to develop the film yourself – after investing in the right chemicals and equipment. On the other hand, digital photography has an expensive up-front investment, but there's not much more money involved after that. After the initial investment of buying the camera and desired add-ons, there isn't much more you need to buy.

Comparing Image Quality

Digital cameras have controls that automatically adjusts exposure and focuses the image for you. To get the best quality photos on a DSLR, it's best to stay in program or manual mode. This makes it easier to be as precise as possible when taking digital images. Severe under or overexposure can be difficult to fix in editing.

Film cameras have a higher resolution (depending on the scan) and more latitude, so photographers don't need to be too precise with the exposure. A good photo taken with an analog camera is typically higher in quality. Film photography also has a higher dynamic range, better color transitions, and controls the highlights better. On the other hand, digital camera handle shadows much better.

When thinking of convenience and time spent on analog vs. digital photography, it's essential to consider how much time you want to spend on it. For quick and efficient photos, digital is the way to go. From taking a shot to editing and sharing, the process can take as little as 10 minutes if you're using a smartphone or tablet.

If you have the time to invest in analog photography, the photo quality could be well worth it. The same shooting process, processing, scanning, and editing can take up to two or more days. If you send your film to a company to develop the negatives for you, it could take much longer.

Shelf Life and Storage of Photos

Memory card storage and permanent storage for files from a digital camera are much cheaper than storing film photos. They don't take up a lot of space and are relatively inexpensive. Film cameras require film canisters and film storage books, which can take up a lot of space, and need to be properly stored away from sunlight, humidity, and heat. However, memory cards are easily lost, can be corrupted (lose your date), and aren't waterproof.

Also, generally, the image quality of a digital photo doesn't worsen over time, whereas analog photos tend to disintegrate over time – like slide film – even if properly stored.

Digital photography is becoming more popular with the age of smartphones. It's quicker, more comfortable, and convenient than traditional film or DSLR photography. Electronic photodetectors capture an image either manually or automatically focused by the camera's lens. Digital photography allows users to take images without the need for developing with chemicals, the use of negative film, and allows for them to be edit electronically.

Digital cameras produce images of the modern world. They provide instant gratification, making it easy to quickly share your image with friends and family. The pros and cons below describe what's great (and not so great) about digital photography:

Pros of Digital Photography	Cons of Digital Photography
Instant photo review	Equipement is expensive and can easily break
You can correct problems with photos by quickly taking another	Picture quality isn't always perfect
Memory cards provide semi-permanent storage	Exposure problems are hard to fix

Traditional film photography has been around since about the 1900s. The process used to create images using a film camera won't be changing anytime soon. This form of photography uses photographic negative film to capture images. The film is usually plastic, transparent, and coated with microscopic light-sensitive crystals on one side. You need to develop the images in darkness before you can see the images.

After capturing the photo, the photographer uses a combination of a light-tight room or bag and developing tank with a series of specialized chemicals to treat the film to create a negative. Then the photographer uses an enlarger in a darkroom, usually lit by a red light, to project light through the film negative onto light-sensitive photography paper to create a visible image.

The darkroom with a red light is necessary because darkroom paper is exceptionally light-sensitive until adequately treated, except for specific colors like red.

Traditional photography is an age-old tradition. There's nothing like the anticipation while waiting for a beautiful photo to come to life in the darkroom. The following pros and cons outline the best – and worst – aspects of traditional photography:

Pros of Traditional Photography	Cons of Traditional Photography
Don't need to know how to use a computer to print and produce photos	There's a delay between capturing an image and seeing the results
Cameras are inexpensive and don't require large batteries	Developing the negative film and/or paper is a time-consuming activity; it's often hard to get the exact image you wanted
Photo details are arguably better than digital	Pictures can't be easily edited or manipulated as digital images

Adapted from: https://hellofuture.orange.com/en/interactive/new-technologies-pushing-the-boundaries-of-art/#artist-algorithms-are-shaking-up-our-conception-of-creativity

New technologies: *PUSHING THE BOUNDARIES OF ART*

The ongoing digitalization of our societies is creating a new playground for art, through virtual worlds and new methods of trading. It is also changing the rules of the game, shaking up the very notion of an artist in the age of networks.

The rise of the internet and web technologies has had a deep impact on artistic creation, which includes much more collaboration, appropriation, and participation. In the 1990s, the development of the internet gave rise to Net art, a term referring to works conceived "by, for, and with the Internet". Net artists use the "network of networks" as a delivery media, as an artistic production tool, and as a living space for works, all at once. They take inspiration from its distinctive characteristics to invent original works of art, but also to experiment with new creative processes.

Free-culture and Artistic Collaboration

The history of the internet is closely linked to the free software culture, based on the opening up and sharing of software source-code and the voluntary contribution of researchers and programmers from a variety of backgrounds. Most of the internet building blocks are based on **free or open-source software** (the two terms may differ but they both refer to the notion of an open code): everybody can access the source code, use it, copy it, modify it, and redistribute it.
For example, in 1993, the World Wide Web software, which had just been invented by Tim Berners-Lee and Robert Cailliau, was put in the public domain, then under free license, which facilitated its rapid and massive distribution.

Artists who work with open-source software make up a community of users who help each other to solve technical and artistic problems. Some of them also contribute actively to the improvement of creative commons tools, of which *Processing* and *openFrameworks* are noteworthy, these are two **development environments** developed for visual arts by coder-artists.

Consequently, the works produced, the fruit of multiple contributions, are the result of a collective effort. Some of them come under a free license (such as *Creative Commons* or *Free Art License*). For example, the 2D animated movie "ZeMarmot", produced entirely with free software (GIMP, Blender, Ardour, etc.) is to be distributed under Free License. Its scriptwriter, Jehan, has been one of the main contributors to graphics software GIMP since 2012.

Mash-up: Artistic Appropriation in the Age of the Internet

Mash-up is a **composite art** that consists in reusing existing sounds, images, videos, or texts to obtain a new creation. Generally, the process adds very few original elements to the final work, just enough to combine the various components harmoniously. A well-known example of a mash-up is "The Grey Album" by musician Danger Mouse, which takes "a cappella" parts of "The Black

Album" by rapper Jay-Z and puts them onto samples (preexisting sound extracts) of the Beatles' "White Album". Whether they are aiming for parody, homage, or the repetition of a pattern, many "mash-uppers" manage to transcend the original material to give it new meaning and find their own creative expression.

Although mash-up originated well before the internet boom, in artistic appropriation and music sampling in particular, it truly developed as a form of artistic expression with the evolution of internet technologies. Digital file or peer-to-peer exchange hosting platforms provide internet users with a bounty of source material, and YouTube has become an inexhaustible source of extracts of music and films from all times and from any country. As for the distribution of new tools (production and mixing software), it facilitates working on this raw material.

Web 2.0 and Participatory Art

In 2013, contemporary artists Ai Weiwei and Olafur Eliasson launched their shared project **Moon**. Moon is a virtual collaborative space, presented as a moon divided into thousands of blank plots on which everyone was invited to leave their mark. This project, which brought together over 80,000 contributions between 2013 and 2017, and transcended borders and cultural differences, is a fine example of a participatory artistic experiment.

Interactive art, which is participatory by definition, already exploited new technologies to enable the public to explore and influence works. Sensors, interfaces, and algorithms play the role of intermediary between the public and the work, enabling the public to act and the work to react, all in real time.

Web 2.0 enables artists to go even further and develop higher degrees of interactivity with what French researcher Jean-Paul Fourmentraux calls "contribution devices". These devices enable internet users to take action on a virtual or physical installation by transforming it or by providing new data (in the case of Moon, these were drawings and text). They take part, sometimes according to predefined rules, sometimes not, in real time or non-real time, in the emergence of a collective piece of work of which they become co-authors.

Over the last decade or so, many artistic and cultural projects have seen the light of day thanks to this new means of funding. Although film and music were the first areas to benefit from this, all fields of creation are now concerned: from the visual arts to live entertainment, through literature.

Art Inspiring Technological Research

Cyberpunk and Virtual Reality Research

Many authors have investigated the links between science-fiction (sci-fi) and technology, and more specifically the influence of the former on the latter. English scientific author Jon Turney explains that technological research always implies **storytelling**. "Every technology begins in the imagination, and needs a description of what it will achieve […]. Every patent tells a story. Make this device, or follow this process, and certain things will be possible – things not seen before."

Anticipation can provide this storytelling, as was the case for example of the novel *The World Set Free*. Written by H.G. Wells in 1913, it was sent by physicist Leó Szilárd, conceptor of the nuclear chain reaction and contributor to the Manhattan Project, to potential investors to help them visualize his idea. As for Jeremy Bailenson, a psychology researcher at Stanford University, he

believes that many questions raised in **1980s cyberpunk literature** have become virtual reality research themes.

According to Bailenson, the world of virtual reality researchers has always been intimately interwoven with that of cyberpunk authors. There are two reasons for this: firstly, the two groups collaborate, as is shown by the relationship between Jaron Lanier, one of virtual reality's pioneers, and William Gibson, author of *Neuromancer*, iconic novel of the genre. Secondly, cyberpunk works shape the way in which virtual reality researchers approach certain concepts, such as the avatar, presence, or social interactions within virtual worlds.

This theory may not have full consensus, but it is obvious that the difference between **sci-fi and foresight** (the science aiming to predict the future evolution of societies) is sometimes tenuous. This is evident in the *Red Team* initiative, a team of sci-fi authors set up by the French Ministry of Armed Forces whose mission is to imagine the conflicts of tomorrow.

Science Fiction Predicting the Technology of Tomorrow

Science fiction literature and cinema has been the stuff of dreams for a long time now. The genre was pioneered by authors such as Jules Verne, who were already imagining tomorrow's technologies and uses, inspiring scientists to make the leap from fantasy to reality.

Here is an overview of the technologies imagined in the arts:

The Carpathian Castle — Jules Verne: Holograms

In his novel "The Carpathian Castle", published in 1892, Jules Verne writes about an opera singer who continues to perform after her death using a projection. Many years later, in 1948, a Hungarian engineer named Dennis Gabor actually invented the hologram.

Dick Tracy — Warren Beatty: Connected Watches

In his 1990 film, director Warren Beatty played Dick Tracy, the heroic policeman from a comic strip that has run since 1931 who wore a radio on his wrist that sent and received messages, that is a connected watch, that did actually reach the market only in the 1990s with the Seiko Receiver, the first watch that could receive messages like a pager.

2001: A Space Odyssey — Stanley Kubrick: Intelligent Voice Assistants

Stanley Kubrick's 1968 iconic science fiction film "2001: A Space Odyssey" was particularly visionary. In addition to the Discovery spacecraft having a smart onboard computer named HAL, which foreshadowed future smart assistants (such as Siri), the feature film also has video-calling scenes just like the video calls we now make using software such as Skype.

Star Trek — J.J. Abrams: Cell Phones

In the early 1970s, the Star Trek series inspired the genius creation of the cell phone. The sci-fi series sees Spock and Captain Kirk using a strange flip device — their pocket-sized communicator whose design is reminiscent of the first flip phones.

Back to the Future 2 — Robert Zemeckis: Augmented Reality

In Robert Zemeckis' 1989 film, a giant shark almost swallows Marty McFly at the beginning of the film. Not a real shark, but an augmented reality image superimposed at the movie theater entrance promoting the film *Jaws 19*.

Total Recall — Paul Verhoeven — Self-Driving Cars
Like in many science fiction films at the time, flying cars appear in Paul Verhoeven's 1990 film. However, *Total Recall* features another futuristic vehicle, the self-driving car, something that 5G has made possible today.

Minority Report — Steven Spielberg: Touch Screens
Adapted from a 1956 Philip K. Dick story, *Minority Report* is a Steven Spielberg film that was released in 2002. In this futuristic film, Tom Cruise uses gesture-controlled interfaces. By moving a finger or a hand, the screen stops, zooms in and so on, a little like the multi-touch screens offered on Apple iPhones in 2007.

Artist-Algorithms

Algorithms are now capable of creating original works of art by taking inspiration from thousands of images and inventing new artistic styles. One of the first examples of algorithmic art – art generated by algorithms – dates back to 1973, when English painter Harold Cohen wrote a computer program called **AARON** that could produce original drawings. American artist Jean-Pierre Hébert drew the outlines of this artistic movement twenty years later and invented the term "algorist". An artist is an algorist when they create a work of art from an algorithm that they have designed themselves. The act of creation is in the writing of the code, which becomes an integral part of the final work.

Advances made in artificial intelligence (AI) are questioning this definition and bringing about a new generation of models. Thanks to machine learning, algorithms no longer simply follow a set of pre-defined rules by the programmer-artist. Fed with a large amount of data, they assimilate the aesthetic characteristics of artistic corpora and become ever more autonomous in the production of content.

GANs
With the highly publicized auction of the *Portrait of Edmond de Belamy* at Christie's in 2018, generative models became the figurehead of algorithmic art. Indeed, this piece by arts-collective **Obvious** was generated by a Generative Adversarial Network (GAN).

Introduced by American researcher in machine learning Ian J. Goodfellow in 2014, GANs are a class of unsupervised machine learning algorithms where two artificial neural networks do battle: the *generator* and the *discriminator.* The system is fed with a database made up of works of art, for example thousands of images of early twentieth century cubist paintings. The generators must produce new paintings by imitating cubism. As for the discriminator, it must try to spot the difference between genuine works and those generated by its opponent. Depending on the result, the generator presents ever more convincing new images until the discriminator can no longer distinguish between genuine and fake.

The artist plays a more or less active role in this process. Failing actually building the generative algorithm, they select it, change it to obtain the desired result, and they run it. The artist gathers entry data (with the help of a *scraping* tool, a technique for automatically extracting data from websites), selects it (pre-curation), then sorts the content generated by the machine (post-curation). In *Fall of the House of Usher II* (2017), English artist Anna Ridler chose to create her own dataset by producing over 200 drawings.

Hence, artist and machine work together to cocreate a piece of art.

CANs Invent New Artistic Styles

In 2017, researchers from the Art and Artificial Intelligence laboratory of Rutgers University in the United States suggested a new method for generating original art, inventing creative GANs, Creative Adversarial Networks (CANs).

On the assumption that GANs are limited in their creativity due to the way in which they have been designed (their aim being to imitate existing works of art from a specific style as well as possible), they changed the process to make them capable of generating creative art by maximizing deviation of the system from established styles.

CANs pursue three goals. (1) They must generate works that are new but (2) without being too much so, and (3) the work generated must also increase stylistic ambiguity, meaning it is difficult to classify in a particular style.

Evolutionary Algorithms and Creative Thought

Less widely-publicized, **evolutionary algorithms** are also used to generate credible works of art. Inspired by Charles Darwin's theory of the evolution of species, they are based on the three fundamental principles of natural selection (variation, inheritance, and competition). The idea behind creative evolutionary algorithms is to reproduce the intellectual approach of the artist, who imagines, tests, and selects new ideas. This means modifying entry data randomly and in a variety of ways, selecting the best-adapted variant or variants, and repeating the process until a satisfactory idea emerges.

During this iterative process, the artist intervenes to choose the most aesthetic variations of a generation, but it is also possible to automate this step. The evolution of creative algorithms may have gone in the direction of increased autonomy in the production of works of art, but it is not clear whether this has made them more creative or they are destined to replace artists, or they will stay confined to the role of tools at the service of augmented creativity. These questions are the topics of debates. One thing is certain, the transmission of creativity, a notion intrinsically linked to human nature, to machines, is a huge challenge for machine learning.

Reinventing Cultural Mediation: Virtual Visits and Immersive Technologies

Original museum experiences thanks to immersive technologies, art popularization via social media, the emergence of new production modes with digital creation tools. New technologies are contributing to the distribution of art and culture to an ever-wider audience. In the early 2000s, digital arts made their way into museums, and cultural institutions started to explore the use of new technologies to rethink the showcasing of their collections. In parallel, the democratization of digital creation tools led to the emergence of new amateur practices and to new modes of artistic production, also helping to make art accessible to a wider audience.

Museums and exhibitions can now be explored remotely, from the comfort of the home. Launched in 2011, in partnership with seventeen cultural organizations, such as MoMA in New York or Tate Britain in London, Google Arts & Culture provides internet users with the possibility

of browsing different museum and world heritage sites, and of visualizing tens of thousands of works in high definition thanks to Street View technology.

The popularization of art must also include a reinvention of museography and the establishment of a link between visitors and works of art. To attract a wider, younger audience, several cultural institutions no longer hesitate to grasp technologies and experiment with new forms of mediation.

For example, in Paris, the *Grand Palais* offered to explore in AR and VR the Pompeii Garden House before the eruption of Mount Vesuvius and in the present day, thanks to 3D reconstitutions and very high-resolution photographs of the site. *Imperial War Museum* in London is scheduling a holographic exhibition that visitors will be able to discover from their home, without expensive technology, thanks to Desktop AR technology. Developed by startup Perception, this AR system turns an ordinary computer screen into a volumetric display, making 3D objects appear in front of the screen simply using a webcam and standard anaglyph glasses (using a different color filter for each eye).

MOOCs and Social Networks

Major efforts are also being made to spread knowledge of the arts. Digital is used as a medium for sharing artistic popularization content, making art accessible to all.

The Louvre, the Centre Pompidou, the Grand Palais, and several cultural and academic institutions throughout France and abroad, are producing more and more podcasts and MOOCs (Massive Online Open Courses). This is also the case of the Orange Foundation, which is offering cultural MOOCs linked with exhibitions taking place in France.

These **customizable courses**, which often offer various fun educational activities, are given online on specialized platforms such as *France université numérique* (France digital university) or *Coursera*. Well aware of this trend, cultural institutions are turning to social networks more and more, producing content specifically for these distribution channels and working together with influencers. For example, in December 2020, many of them accepted the invitation from TikTok, who were organizing a special operation in France to enable its (young) community to attend tours and shows live, and to go behind the scenes of prestigious French museums and theatres.

NFTs

Placed in the spotlight in 2021, NFTs (non-fungible tokens), have become highly popular with art dealers, collectors, and even museums. This blockchain-based technology is transforming the art market and opening up new perspectives for artists.

In March 2021, a collective named **Burnt Banksy** burnt an original Banksy print live on Twitter, then *reincarnated* it as a digital piece of work associated with a non-fungible token (NFT). A sacrilege for some, revolutionary for others, this action propelled the art world into a new universe, that of crypto art.

The term *crypto art* refers to works of art, most often digital, accompanied by NFTs, which can in fact be associated with any kind of digital object (*virtual trading cards, video game objects, music files*, etc.). An NFT is a type of unique cryptographic token, meaning it is not interchangeable (unlike a cryptocurrency), stored in a blockchain. It points to a digital file representing a work of art and containing a certain amount of information aimed at potential buyers: its title, its creation date, the author’s name, a description, or even its ownership history.

NFTs can be created – the word *minting* is used, a process consisting in converting a digital file into an NFT, i.e. a digital asset stored in the blockchain – and sold on specialized platforms such as OpenSea, Rarible, or SuperRare. The buyer acquires the property rights to the original work included in this NFT via a smart contract. The artist does however conserve their intellectual property and reproduction rights. They can also include a resale right in the contract, enabling them to receive a percentage of each resale of the NFT.

The Crypto Art Gold Rush

The first artistic NFT was created in 2014 by American digital artist Kevin McCoy. However, it wasn't until 2017 that the use of NFTs started to become popular, with the launch of CryptoPunks, a series of 10,000 unique characters generated by an algorithm. In March 2021, the sale, by Christie's auction house for 69.3 million dollars, of the virtual collage *Everydays: the First 5000 Days* by American artist Beeple, marked the beginning of the true crypto art gold rush into which many artists and collectors from a wide range of backgrounds have entered.

According to some researchers, crypto art is not a new form of art as NFTs are only a tool enabling the sale of digital works saved in the blockchain.

Thanks to the properties of blockchain, NFTs give uniqueness upon digital files which are, by definition, infinitely reproducible, they guarantee that buyers own both an authentic digital work and an original "print" – which was previously impossible. Consequently, many private art galleries and auction houses have started to include crypto art works in their catalogues.

Museums too are looking into NFTs, which could be a potential source of income for them. In late 2021, the British Museum in London, in a partnership with French startup LaCollection, put up for sale over 200 digital reproductions of emblematic prints by Japanese painter Hokusai during an exhibition dedicated to the artist.

A Chance for Artists?

A priori the arrival of NFTs onto the art market provides many advantages for artists. By enabling them to monetize their creations more easily, NFTs can provide them with the means to live better from their work.

In a world where art critics, curators, dealers, and collectors play an essential role in artistic recognition as well as in the evaluation of the aesthetic and market values of works, NFTs also appear as disruptive agents. They make it possible to bypass traditional circuits and give artists the possibility to be freed from intermediates so as to distribute their work to a wider audience.

De facto, crypto art platforms enable everyone to own virtual works of art. Up until now, they have mainly encouraged new buyers (tech and finance personalities, young celebrities, long-time holders of cryptocurrencies, etc.) to enter the world of art.

However, NFTs are the subject of harsh criticism, in particular from artists, many of whom refuse to use them because of their environmental footprint or due to their belief that NFTs contribute to the financialization of art. Some also believe that, far from protecting their creations, the crypto art market and the appetites it whets make them more vulnerable to theft and appropriation.

Finally, the creation and sale of NFTs being associated with numerous fees (*minting fees, listing fees, withdrawal fees, percentage of sale price requested by platforms*, etc.) can turn out to be disadvantageous for artists.

If NFTs are to become a long-term part of the artistic picture, the startups and platforms that are riding the crypto art wave will have to meet several challenges such as guarantee the durability of NFT works, improve their environmental footprint, fight against fakes, or imagine models that are truly profitable for artists.

Technology To Protect Masterpieces

Digital technologies such as 3D laser scanners, AI, Big Data, robotics, 3D printing, etc. are increasing the means available to professionals involved in the preservation of cultural heritage. Digitization, artificial intelligence, 3D-modelling, and robotics are helping to conserve and restore key works of art over time, to reveal their secrets, and to add value to heritage.

3D-Digitization of Art

The digitization of original works of art makes it possible to limit their handling and to archive them, thus guaranteeing their long-term availability. Based on ever more sophisticated techniques, this has become common practice for museums and libraries, many of which partner with specialist companies to conserve their masterpieces in digital format.

In 2018, **Tate Modern** in London and **Arius Technology** signed a partnership to digitize and reproduce around ten master paintings. The Canadian company works with the museum's curators and historians to capture 3D scans thanks to proprietary ultra-high-resolution art capture technology, which records the color and geometry of paintings with an extremely fine level of detail without touching the surface of the painting.

Ten years earlier, the **European Commission (EC)** had launched a project aiming to give access to the digital objects and collections of Member States. Today, the European platform brings together over 50 million digital documents (*books, audiovisual material, photographs, archive documents*, etc.) provided by over 3,000 cultural institutions across Europe.

Travelling Back in Time thanks to AI and Big Data

Time Machine is another project supported by the EC. Its aim is to create a huge distributed information system, fed by the digitization of the collections of European museums and libraries, which exploits new technologies to explore the history and vast cultural heritage of our continent.

Time Machine provides for the building of a *4D engine*, enabling **spatiotemporal simulations** thanks to the *megadata* of the past. This technology will be used as a basis for developing l*ocal time machines*, to travel to different sites at different times (such as the lost ports of Belgian city Bruges). It will also be used to create *mirror worlds*, true digital twins of our cities.

Larger than Life Facsimiles

Digitization constitutes the first step in the making of facsimiles. Established in 2001, **Factum Arte** is known for its particularly realistic replicas of Egyptian tombs or of famous paintings. The studio mixes traditional craftsmanship with homemade cutting-edge technologies, such as the **Lucida 3D scanner** that they developed for the digitization of paintings and bas-reliefs.

This close-range non-contact system captures high-resolution data of the surface and texture of works of art – without color – by projecting a moving red line onto the surface. The distortions of light due to the relief are captured by two video cameras, saved as a black and white video, and

processed by software integrated into the scanner so as to produce a 3D model and a digital image of the data. Color data that is retrieved thanks to a photographic process is than added.

Once it has been digitized, the work of art can be reproduced with the help of several techniques, particularly 3D printing.

Imaging and AI for Revealing the Secrets of Canvases

Imaging techniques (*X-ray, infrared, spectral scanning*, etc.) combined with AI make it possible to analyze works in depth and to reveal elements that are undetectable to the naked eye. Indeed, many painters change the effect of their original composition by adding or removing elements (*pentimento*), or even cover up their painting completely. Also sometimes, all or part of a canvas is reworked by another painter (*repainting*).

The study of these transformations enables experts and art historians to identify the materials and techniques used by the artist, to improve attributions, or even to discover new masterpieces. This was the case with *The Lonesome Crouching Nude* by Picasso, hidden under another of the artist's paintings. Revealed by X-rays, it was recreated in 2021 by researchers at University College London thanks to AI and 3D printing. A **deep learning algorithm** was trained with Picasso paintings from his blue period so that it could learn his style and reproduce it. Once it had been recreated, the painting was printed onto canvas.

A Robot for Assembling Archeological Artefacts

Robotics is also involved. The European **RePaIR** (Reconstructing the Past: Artificial Intelligence and Robotics) project aims to develop a robotics system boosted by AI that is capable of recreating shattered artefacts, such as amphora or frescos. The idea is to build a robot equipped with mechanical arms, which scans fragments, recognizes them, and assembles them, handling them with care thanks to advanced sensors.

The first to benefit from this new method is none other than the archeological site of Pompeii in the south of Italy. Two world-renowned frescos, thousands of pieces of which are currently in storage, are soon to be restored.