VIBE PROJECT

Virtual Biomedical and STEM/STEAM Education

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VIBE PROJECT

3D VISUALISATION & PRINTING

3D SCANNING

REVERSE ENGINEERING

3D scanning

3D scanning is a **process of analyzing** a **real object** or environment that collects data from its shape and possibly appearance (such as color). The collected data can then be used to **create digital 3D models**.

A 3D scanner can be based on a variety of technologies, each of them has its own **limitations, advantages and costs**. For example, with industrial computer tomographic scanning and structured light 3D scanners, can be used to make non-destructive surveys in order to generate digital 3D models. We can encounter a number of difficulties when surveying objects, for example, **optical technology** struggles with many **difficulties** in relation to **bright**, reflective or **transparent** objects.

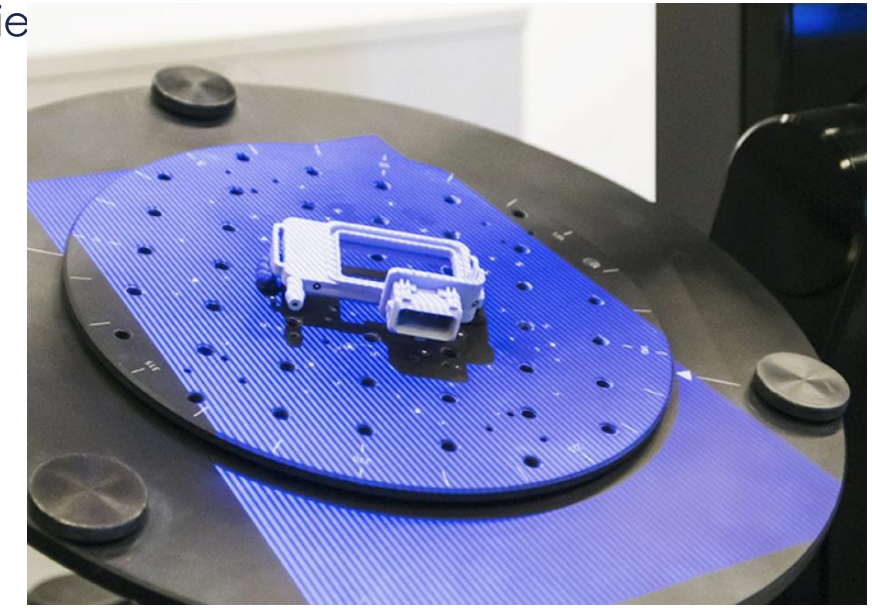
Collected 3D data **can be used in many ways**. These tools are widely used by the entertainment industry to develop films and video games, including virtual reality. Other general applications of this technology are the extended reality (XR), motion capture, gesture recognition, machine vision, industrial design, **orthotics and prosthetics**, **reverse engineering** and **prototyping**, quality control and cultural artwork digitization.

Reverse engineering

Reverse Engineering means **surveying existing components** or products to gain insight into their **design background and manufacture**. This usually includes **full disassembly** and documentation of all parts and assemblies, which is typically followed by **computerized digitization** to produce 3D models from the components. The most common applications include creating 3D files consisting of complex or **organic** surfaces, quality control of components and measurement of components that are no longer available for design documentation.

This can be divided into two main categorie

- 3D scanning
- Physical measurement

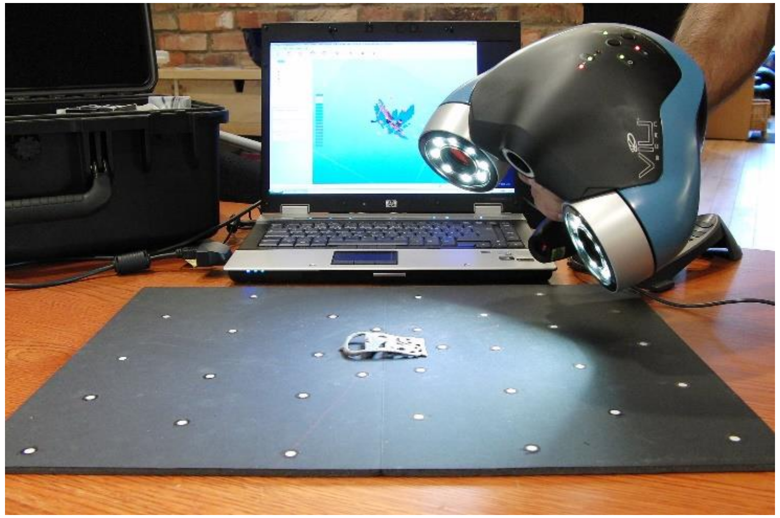


Principle of 3D scanning

The **goal** of 3D scanning is usually **creating a 3D model**. This model in the first round is the **point cloud** resulting from **geometric sampling** of the surface of the subject. These points are used to **reconstruct the shape** of the subject. If color information is collected at each point, the **colors** on the surface of the subject can also be **determined**.

3D scanners **resemble cameras** in many ways. They have a conical **field of view** and similarly to cameras they can only collect information about **visible surfaces**.

While the camera is collecting information about the color of the surfaces inside of it's field of view, the 3D scanner collects information about the **distance of the visible surfaces within it's range of view**. The "picture" made by the 3D scanner describes the distance of the surfaces of each point on the image. This allows the three-dimensional positioning of the picture's points.



Creating a 3D model from a Viking belt with handheld 3D laser scanner.

Technologies of 3D scanning

Basically, two types can be grouped: **touching** and **touch-free** surveys. Touch-free solutions can be classified into two main categories: **active** and **passive**.

3D scanning a whale skeleton

Touching 3D scanning

Touching

The subject is examined by **physical touch** while **lying** on a polished, precision, **flat surface plate**. If the object to be examined does not have a flat surface or can not be stable on a flat surface, it is supported by a **fastening element** and **keeps it in a rigid position**.

An example of the touching 3D scanners is the **coordinate-measuring machine**. It is mostly used in manufacturing and it can measure very accurately. However, the disadvantage is the object **has to be touched** during the survey. So you can modify or **damage** it. This factor is very important when digitalizing delicate, valuable and organic objects such as living tissues. Another disadvantage is that it is **relatively slow** compared to other scanning methods. The physical movement of the arm to which the probe is equipped, very slow, even the fastest machines can only measure with few **hundred hertz**. In contrast, a laser scanner can operate at 10-1000 kHz.

Touch-free-active survey

Touch-free-active

Active scanners **emit some radiation or light** and detect its reflection or radiation passing through the object. Possible types of emission: **light, ultrasound or x-ray**.

Time-of-flight (ToF)

The ToF scanners surveying the subjects by a **laser** and the basis of their operation is a ToF laser **distance meter**. This determines the distance of a surface by measuring the **time** of the **light pulse** back and forth. It emits a light pulse by means of a laser and then measures the time during which the reflected light **is detected**. The accuracy of laser scanner and time measurement is proportional to each other (under ~ 3.3 ps the light travels 1 millimeter in the air). The laser distance meter only detects the **distance of one point** in it’s visual direction. Thus, the scanner is surveying each point of it’s entire field of view **one by one** typically with the help of mirrors. The speed can be up to 1 million points / second.

Touch-free-active survey

Time-of-flight (ToF)

Leica P30

Trimble TX8

FARO Focus

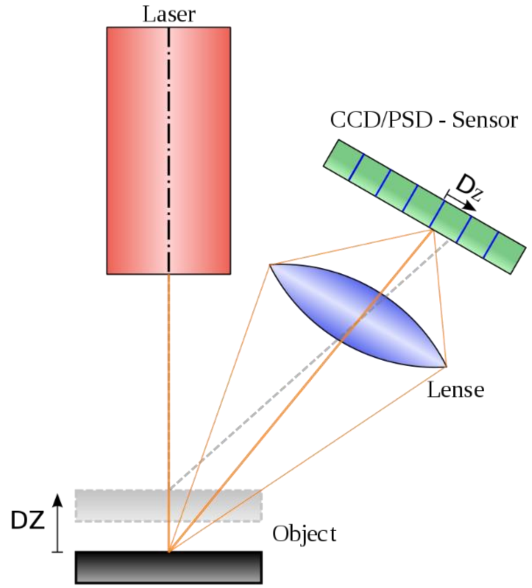
Riegl VZ-400i

Artec Ray

Leica BLK360

Touch-free-active survey

Triangulation
These are also active scanners that uses laser light to detect the environment. Compared to ToF laser scanners, the triangulation based scanner **projects a laser dot** to the object and **searches for it's location** using a **camera**. Depending on **how far the laser beam** reaches the surface, the laser spot appears in **different areas of the camera's field of view**. This technique is called a triangulation because the **laser spot**, the **camera** and the **laser emitting device form a triangle**. The length of one side of the triangle, i.e. the distance between the camera and the laser device and the angle at the laser device are known. The angle at the camera's point can be determined by finding the laser spot location in the camera's field of view. These three information fully **determines the size of the triangle** and specifies the exact location of the triangle laser spot.



Touch-free-active survey

Triangulation

Matter & Form v2 desktop laser scanner

Go!SCAN SPARK handheld laser scanner

Touch-free-active survey

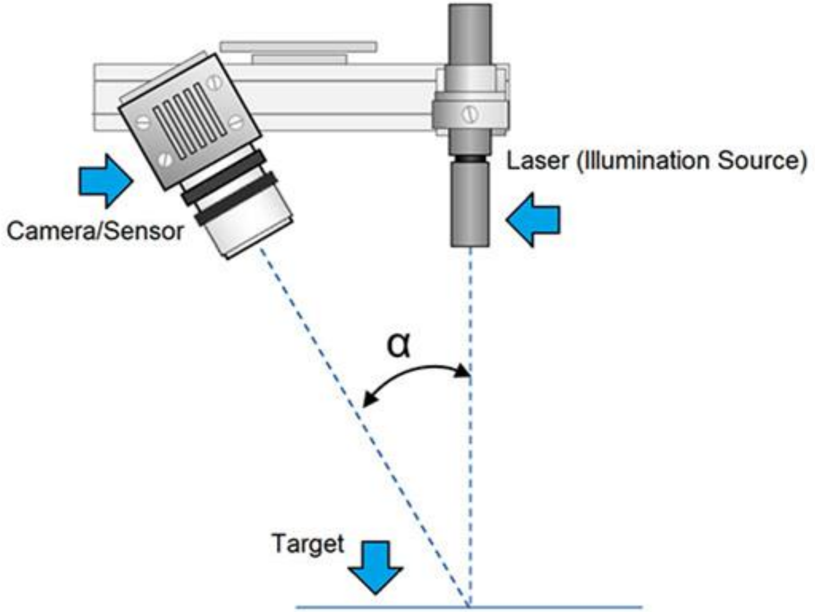
Triangulation

Video 1 Video 2

Touch-free-active survey

Triangulation

Advantages
The advantage of laser triangulation technology is the resolution and **accuracy**. The accuracy could be few ten micrometers of magnitude. It has a more favorable price and it's structure is relatively simple. **It is not affected by ambient light conditions.**



Disadvantage
The surface quality affects the scanning. Very **bright or transparent surfaces** can not be measured with it.

Touch-free-active survey

Structured light
The structured light-3D scanners **project a light pattern** to the subject and continuously **examine the deformation of this pattern**. It is projected to the surface using an LCD projector or other stable light source. A **camera** at a **known distance** from the light source records the change in the shape of the pattern and **calculates** the **distance of the points** in the field of view.

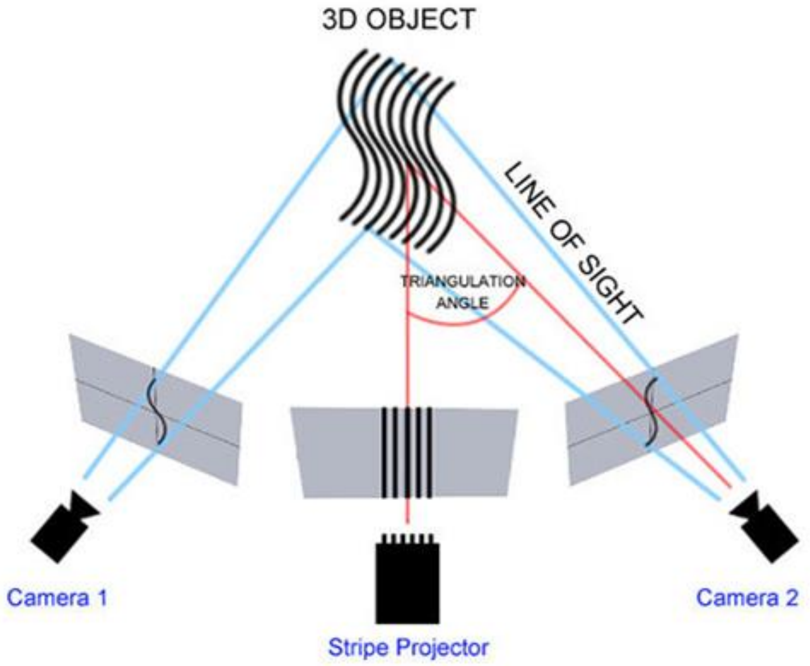
The advantages are of **speed and accuracy**. Instead of scanning a single point at a time, all the points of the **full field of view are scanned simultaneously**. Scanning of the full field of view under the fraction of a second **eliminates the distortions from movement**. Some systems are able to scan moving objects.

Touch-free-active survey

Structured light

Advantages
The scanning is fast and the **scanning area** is also larger. Like laser scanners, structured light scanners are extremely **accurate** and provides **high resolution**.

Disadvantages
One of the disadvantages of this type of scanners is that they may be **sensitive** to the **light conditions** of the given environment. This is less true for laser scanners. This may be an obstacle during the outside work.



Touch-free-active survey

TECHNICAL SPECIFICATIONS

3D point accuracy, *up to*	0.1 mm
3D resolution, *up to*	0.2 mm
3D accuracy over distance, *up to*	0.1 mm + 0.3 mm/m
HD Mode	Yes
Working distance	0.4 – 1 m
Linear field of view, *H×W @ closest range*	214 × 148 mm
Linear field of view, *H×W @ furthest range*	536 × 371 mm
Angular field of view, *H×W*	30 × 21°
Ability to capture texture	Yes
Texture resolution	1.3 mp
Colors	24 bpp
3D reconstruction rate, *up to*	16 fps
Data acquisition speed, *up to*	18 mln points/s
3D exposure time	0.0002 s
2D exposure time	0.00035 s
3D light source	Flash bulb
2D light source	White 12 LED array
Interface	1 × USB 2.0, USB 3.0 compatible
Calibration	No special equipment required

Computer requirements

Supported OS	Windows 7, 8 or 10 x64
Recommended computer requirements	Intel Core i7 or i9, 64+ GB RAM, NVIDIA GPU with CUDA 6.0+ and 8+ GB VRAM
Minimum computer requirements	**HD:** Intel Core i7 or i9, 32 GB RAM, NVIDIA GPU with CUDA 6.0+ and 2 GB VRAM

Touch-free-active survey

Touch-free-active survey

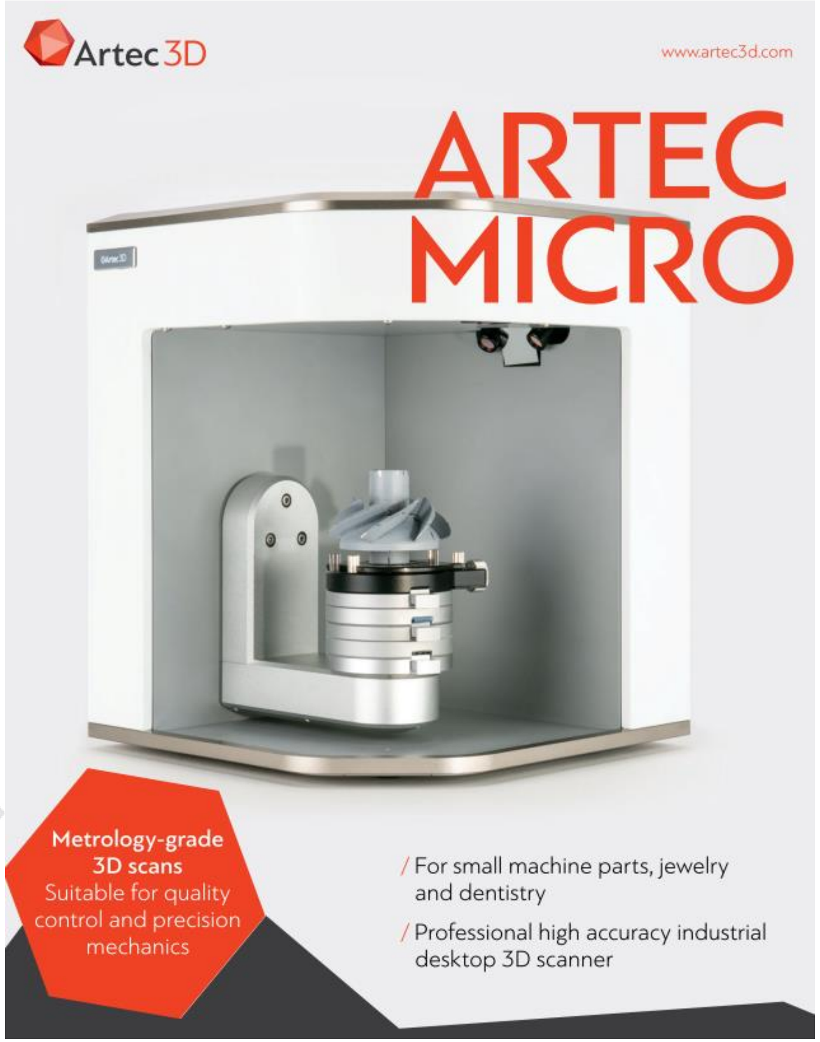
TECHNICAL SPECIFICATIONS

3D point accuracy, *up to*	0.05 mm
3D resolution, *up to*	0.1 mm
3D accuracy over distance, *up to*	0.05 mm + 0.3 mm/m
Working distance	0.2 – 0.3 m
Linear field of view, *H×W @ closest range*	90 × 70 mm
Linear field of view, *H×W @ furthest range*	180 × 140 mm
Angular field of view, *H×W*	30 × 21°
Ability to capture texture	Yes
Texture resolution	1.3 mp
Colors	24 bpp
3D reconstruction rate, *up to*	7.5 fps
Data acquisition speed, *up to*	1 mln points/s
3D exposure time	0.0002 s
2D exposure time	0.0002 s
3D light source	Blue LED
2D light source	White 6 LED array
Interface	1 × USB 2.0, USB 3.0 compatible

Computer requirements

Supported OS	Windows 7, 8 or 10 x64
Recommended computer requirements	Intel Core i7 or i9, 32 GB RAM, GPU with 2 GB VRAM
Minimum computer requirements	Intel Core i5, i7 or i9, 18 GB RAM, GPU with 2 GB VRAM

Touch-free-active survey



SPECIFICATIONS

	MICRO	SPACE SPIDER	EVA	LEO
3D point accuracy, *up to*	0.01 mm	0.05 mm	0.1 mm	0.1 mm
3D resolution, *up to*	0.029 mm	0.1 mm	0.2 mm	0.2 mm
Scanner type	Desktop	Handheld	Handheld	Handheld
Ability to capture texture	Yes	Yes	Yes	Yes
Texture resolution	6.4 mp	1.3 mp	1.3 mp	2.3 mp
Colors	24 bpp	24 bpp	24 bpp	24 bpp
Data acquisition speed, *up to*	1 mln points/s	1 mln points/s	18 mln points/s	35 mln points/s
3D exposure time	Customizable	0.0002 s	0.0002 s	0.0002 s
2D exposure time	Customizable	0.0002 s	0.00035 s	0.0002 s
3D light source	Blue LED	Blue LED	Flash bulb	VCSEL
Interface	USB 3.0	1 × USB 2.0, USB 3.0 compatible	1 × USB 2.0, USB 3.0 compatible	Wi-Fi, Ethernet, SD card
Supported OS	Windows 10 x64	Windows 7, 8 or 10 x64	Windows 7, 8 or 10 x64	**Scanning:** No computer required **Data processing:** Windows 7, 8, 10 x64
Recommended computer requirements *(Please refer to www.artec3d.com for detailed hardware requirements.)*	Intel Core i7 or i9, 64+ GB RAM, NVIDIA GPU with at least 3 GB VRAM, CUDA 3.5+	Intel Core i7 or i9, 32 GB RAM, GPU with 2 GB VRAM	Intel Core i7 or i9, 64+ GB RAM, NVIDIA GPU with 8+ GB VRAM, CUDA 6.0+	Intel Core i7 or i9, 64+ GB RAM, NVIDIA GPU with 8+ GB VRAM, CUDA 6.0+
Power source	AC power	AC power or external battery pack	AC power or external battery pack	Built-in exchangeable battery, optional AC power
Dimensions, *H × D × W*	290 × 290 × 340 mm	190 × 140 × 130 mm	262 × 158 × 63 mm	231 × 162 × 230 mm
Weight	12 kg / 26.7 lb	0.8 kg / 1.8 lb	0.9 kg / 2 lb	2.6 kg / 5.7 lb
3D mesh formats	OBJ, PLY, WRL, STL, AOP, ASC, Disney PTX (PTEX), E57, XYZRGB			
CAD formats	STEP, IGES, X_T			
Formats for measurements	CSV, DXF, XML			

Touch-free-active survey

	LEO	EVA	SPACE SPIDER
Working distance	0.35 – 1.2 m	0.4 – 1 m	0.2 – 0.3 m
Volume capture zone	160,000 cm³	61,000 cm³	2,000 cm³
Linear field of view, *H × W @ closest range*	244 × 142 mm	214 × 148 mm	90 × 70 mm
Linear field of view, *H × W @ furthest range*	838 × 488 mm	536 × 371 mm	180 × 140 mm
Angular field of view, *H × W*	38.5 × 23°	30 × 21°	30 × 21°
3D resolution, *up to*	0.2 mm	0.2 mm	0.1 mm
3D point accuracy, *up to*	0.1 mm	0.1 mm	0.05 mm
3D accuracy over distance, *up to*	0.1 mm + 0.3 mm/m	0.1 mm + 0.3 mm/m	0.05 mm + 0.3 mm/m
Texture resolution	2.3 mp	1.3 mp	1.3 mp
HD Mode	Yes	Yes	N/A
Colors	24 bpp	24 bpp	24 bpp
3D reconstruction rate for real-time fusion, *up to*	22 fps	16 fps	7.5 fps
3D reconstruction rate for 3D video recording, *up to*	44 fps	16 fps	7.5 fps
3D reconstruction rate for 3D video streaming, *up to*	80 fps	–	–
Data acquisition speed, *up to*	35 mln points/s	18 mln points/s	1 mln points/s
3D exposure time	0.0002 s	0.0002 s	0.0002 s
2D exposure time	0.0002 s	0.00035 s	0.0002 s
3D light source	VCSEL	Flash bulb	Blue LED
2D light source	White 12 LED array	White 12 LED array	White 6 LED array
Position sensors	Built-in 9 DoF inertial system	–	–
Display / touchscreen	Integrated 5.5" half HD, CTP, optional Wi-Fi / Ethernet video streaming to external device	USB streaming through an external computer	USB streaming through an external computer
Multi core processing	Embedded processors: NVIDIA® Jetson™ TX1 Quad-core ARM® Cortex®-A57 MPCore Processor NVIDIA Maxwell™ 1 TFLOPS GPU with 256 NVIDIA® CUDA® Cores	On external computer	On external computer
Interface	Wi-Fi, Ethernet, SD card	1 × USB 2.0, USB 3.0 compatible	1 × USB 2.0, USB 3.0 compatible
Internal hard drive	256 GB SSD	–	–

Touch-free-active survey

Structured light

HP Structured Light Pro S3 scanner mounted on stand

Shining3D EinScan Pro 2X (up) XYZprinting Scanner 2.0 (down)

Touch-free-active scanning case studies

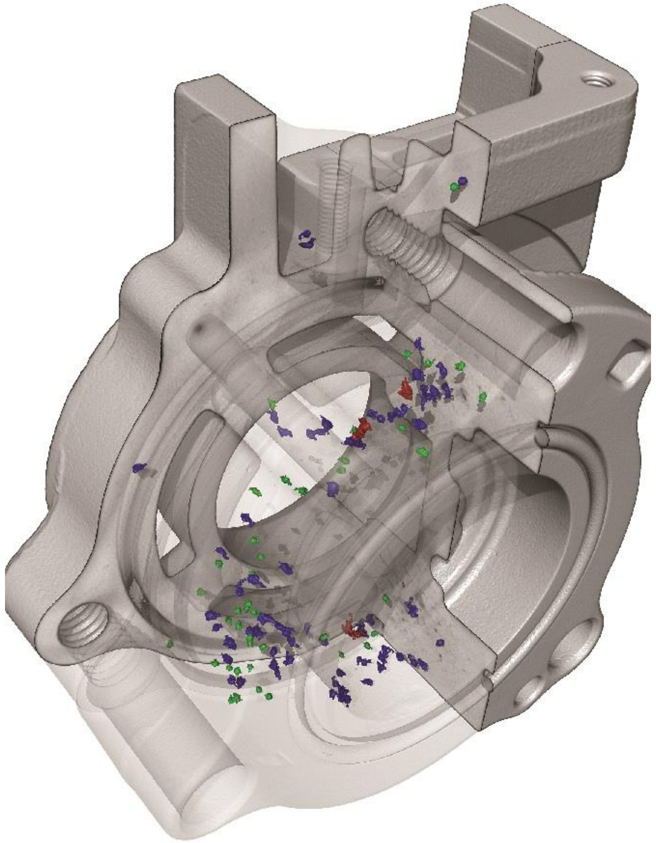
Artec scanner case studies
Artec scanned models collection

Shining 3D case studies

Touch-free-active survey

Modulated light
Modulated light 3D scanners projects a **sinusoidal amplitude light** to the subject. The **camera** detects the reflected light and determines the distance of the light from the **displacement of the pattern**. The modulated light allows the scanner to **ignore** the **light from a source other than the laser**, so there is no interference.

Volumetric Techniques
Computer Tomography (**CT**) is a medical imaging method that creates a three-dimensional image from a **series of two-dimensional X-rays** from the inside of the object similarly to the magnetic resonance imaging (**MRI**) that works with **strong magnetic fields**. With these techniques, you can also create 3D spatial models.



Aluminum casting CT testing for internal errors and cavities.

Touch-free-passive scanning

Passive 3D imaging solutions do **not radiate** any radiation, instead they rely on detection of **reflected environmental radiation**. Most of these types of solutions detect **visible light**. Different radiation, such as **infrared**, can also be used. Passive methods can be **considerably cheaper** because in most cases, there is **no special hardware** outside of simple digital **cameras**.

- **Stereoscopic** systems generally use **two camcorders** at **adjacent** position. By **analyzing the small differences** between the images of each camera, the **distance between the points** of the images can be determined. This method is based on the principle of human stereoscopic vision.
- **Photometric** systems generally use a **single camera**, but they also make **multiple images** with **variable light conditions**. With this technique, it determines the **orientation of the surface** of each pixel.
- **Silhouette** techniques **use outlines** created from a photo series around a three-dimensional object in front of a contrasting background. These **silhouettes are extruded** and **intersect** with each other to form the visual outer structure of the object. The **concave characteristics** of the object (such as the interior of a bowl) **can not be detected.**

Touch-free-passive scanning

Photogrammetry
The 3D shape of physical objects is analyzed **by photographs**. The result of the 3D data is typically displayed as a **3D point clouds or mesh**. Modern photogrammetric software automatically analyzes a **large amount of digital image** during 3D reconstruction, but manual preparation and intervention may also be needed.

- For **nearby photogrammetry**, you usually use a manual DSLR camera with a **fixed focal length lens** to capture the objects images. The objects may be smaller objects such as facade of the building, vehicles, **sculptures**, rocks and shoes.

Touch-free-passive scanning

- With **array cameras**, 3D point cloud can be made of **people or animals** by synchronizing multiple cameras.

Sources

- 3D scanning – Wikipedia
- Additional scans – 3D natives
- Pictures, case studies – Artec3D
- The 3D Printing Handbook – Ben Redwood, Filemon Schöffer, Brian Garret