3D-Scanner for Hochschule Esslingen

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Abstract

The work was done for Hochschule Esslingen and its main purpose was to provide the school with a comprehensive explanation of different 3-dimensional scanning systems and their functions. It was also deemed necessary for it to provide reviews of dimensional scanning equipment on the market with a detailed review of at least one system, as well as provide arguments to why the School should obtain the technology as a part of its process chain.

The research was done using the internet to search for different sources such as technology reviews, news articles and books sources as well as blogs and forums where enthusiasts talk about the subject matter. Finally, a free photogrammetry app was downloaded from the app store for practical review purposes.

The result of the research is a broad review of the current technology and what are considered the most eligible commercial scanners through different criteria's such as price, ease of use and accuracy, with some speculation of the future of the technology and its benefits.

Keywords/tags (subjects)
3d-scanning, photogrammetry, CMM

Miscellaneous

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1 Starter

The basis of this study is to research the currently available 3D-scanning technology and provide the Hochschule with:

- Comprehensive explanation of different systems
- Overview of existing scanners on the market

with lesser priorities being providing a detailed review of at least 1 scanner on the market and providing arguments for getting a 3D-scanner for the Hochschule. Predictions about the future of the technology was set as an optional goal.

Also, as this thesis is meant for mechanical engineering program and the purpose of it is to find a 3D-scanner for the Hochschule Esslingen, it will ignore expensive industrial scanners like Magnetic Resonance Imaging. The commercial scanners gone over are all commercial models in the price range of 0-3000€.

1.1 History of 3D-scanning

While the first impression about 3-dimensional scanning may give you the idea that it is a new practice, the truth is that the underlaying basic concept of gathering data from an object for later use is extremely old. There is evidence that as far back as the Ancient Egypt, people have been replicating existing objects through simple plaster casts. Of course, back then this was a long and arduous process, not to mention expensive as the materials were highly expensive and available on for the most important of personage such as Egyptian Pharaohs.

Nowadays copying the shape of a 3-dimensional object is far from pressing an object into a clay mold. The main force behind the change is the development of computer technology to store the data and recreate it. The earliest scanners in 1960’s were simple contact probes, though in 1980 lasers were brought in, leading to the development of optical scanners. These scanners were still fairly large and clumsy, with their industrial use limited to things like surface inspection, comparative measurement and deformation analysis. It wasn’t until the 90s that computer technology had become developed enough that it was feasible for 3D-scanners to start entering commercial markets. (1st Horizon 3D-scanner store, 2015)

The basic idea behind modern 3D-scanning is to use various ways to gather data points from an object into a 3-dimensional **Point Cloud**, which can then be deciphered into a 3-dimensional shape. In order to gather data to form the Cloud, scanners need at least one main component: the camera or sensor that gathers the data. Non-contact based scanning methods also need a source for radiation they use for scanning, be it laser, led-light or something else. Besides those two, there is of course also a need for a computer and a software to handle the data. (1st Horizon 3D-scanner store, 2015) (Laser design, 2017)

Photography too is considered a type of 3-dimensional scan, though its main use had been in cartography until the computers were developed to the point that allowed first **analytical photogrammetry** (see Figure 5), which was about calculating positions through pictures, in 1960 and then the more modern digital photogrammetry in 1980’s. (Politecnico Milano, 2017)

1.2 Future of 3D-scanning

The rampant increase in computing power and, most importantly, the data storage abilities 3D-scanning has become a rapidly growing branch of technology with numerous uses ranging from engineering to medical to artistic. Combined with the simultaneous growth in other technologies to utilize the data gained from 3D-scanning, this technology is becoming more and more widespread, with 9,61% growth in the global markets compound annual growth rate per year until 2022. With the market size already being at 5,41 Billion USD in 2015 the future of this technology seems promising. (MarketsandMarkets, 2016)

Thanks to the improved abilities of the scanners, their usability is growing and especially in manufacturing they cut the production costs by streamlining things like quality control. Another area where improving scanner tech is taking over is maintenance, for example checking pipe integrity through scanning is an important part of the current use of the technology. These are just few examples of the tech in use now and considering the evolution of the technology at the moment, no doubt new uses will be found and implemented in the future.

2 3D-Scanning methods

There are several ways to perform a 3-dimensional scan, usually divided into contact and non-contact methods depending on how the data is gathered. The contact methods involve, as the name says, direct contact between the scanner and the target while non-contact doesn't require it, though the scanning distance varies between methods. While there are naturally differences between the results of different methods, you can generally assume that a contact scanner is more precise than a non-contact one, but those are in return much faster and easier to use. It is also suggested that a contact scanner is more useful for geometric shapes and a non-contact for organic shapes.

2.1 Contact 3D-scanning

1. **Contact 3D-Scanning**
    - a. **Stitch Scanning**
    - b. **Analog Probe**
        - i. **Open Loop**
        - ii. **Closed Loop**
    - c. **Touch Trigger Probe**
    - d. **Optical Probes**

Figure 1 Contact 3D-scanning types

Contact scanning machines are usually referred to as Coordinate-measuring machines, CMM's for short. These machines operate by the way of a probe or a tactile sensor that trace the target object in order to gather highly accurate data. These probe types are analog probe and touch trigger probe. (Flick, 2014) Despite the CMM machines classification in this work as contact scanning devices, there are probe types that actually do not need contact, instead operating with either very short-range lasers or computer seeing methods very similar to photogrammetry. These probes are usually referred to as **optical probes**. (Genest, 1997)

The most prominent methods for contact scanning (see Figure 1) are as follows:

Stitch scanning is a method where the probe moves like a needle in a sewing machine, tapping the target's surface while moving forward. This method is not very good for complex objects and is very slow compared to other methods.

Analog probe is a sensor that keeps itself in contact with the target while moving, gathering a continuous stream of data and making the process much faster than stitch scanning. This method is further divided into two other methods, Open loop and Closed loop.

In **Open loop scanning**, also known as predefined scanning, the target object is of known and defined shape. The probe follows the basic shape programmed into the machine and records the deviations with extreme speed. Sometimes an Open loop scan is conducted after a Closed loop scan to improve the results. (Manganelli, 2000)

A **Closed loop scan** on the other hand, is meant to scan undefined, more complex objects. In this scan, the probe not only gathers accurate data from the objects surface, but actively detects the changes in order to keep the probe in contact with the object's exterior. (Manganelli, 2000)

A **Touch Trigger probe** is very similar to an analog probe, but keeping instead of keeping in contact like the analog version, it only taps the target object at certain points, gathering less data than an analog probe. An analog probe can also be used as a touch trigger probe with the right programming. (Wright, 2016)

2.2 Non-Contact 3D-scanning

2. Non-Contact 3D-Scanning
- **a. Short Range**
  - **i. Structured light**
  - **ii. Laser-Triangulation**
- **b. Long Range**
  - **i. Laser Pulse**
  - **ii. Phase Shift**

Figure 2 Non-Contact 3D-Scanning types

Non-contact 3D-scanning is a relatively new branch of the 3D-scanning technology and at the moment, the fastest developing. Especially the portability of the technology is being developed, with all the different methods (see Figure 2) already having some form of product that can be operated on the go, though for the best results a controlled environment is still the best.

2.2.1 Short Range

Many non-contact scanning methods are based on light, mostly on lasers but LED-lights have become more common, especially with Structured Light, also known as Blue- or White Light, scanners. These scanners project a series of lines, for example a grid, into the target.

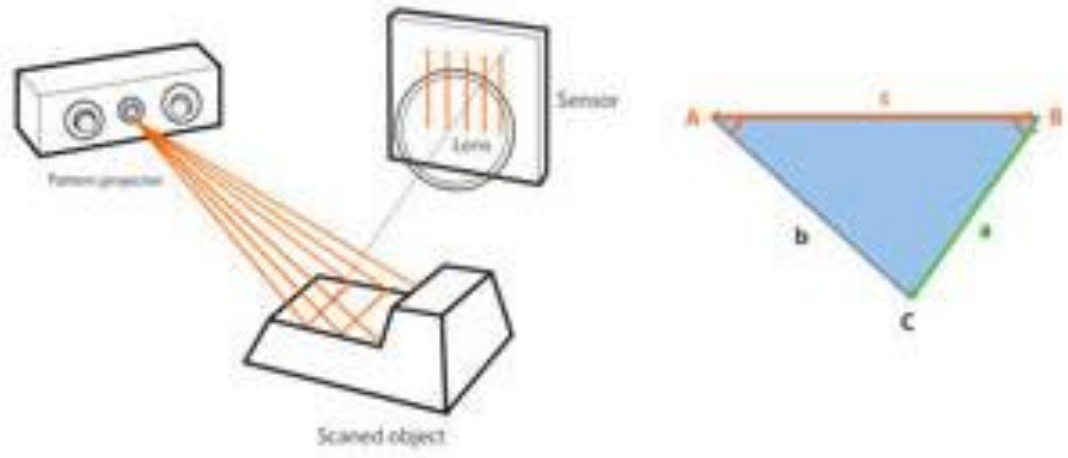

Figure 3 Structured Light Scanning (Source: Geomagic.com)

From there, the sensors detect edges of the pattern and uses them to calculate the shape of the object using the known starting point of the projection and the known position of the sensors to **triangulate** the shape of the object. In Figure 3 this would mean that if we assign the three objects as follows: Projector is A, Sensor is B and the target Object is C, with a being the unknown distance between B and C, while c is the known distance between A and B. The unknown distance between A and C is b. Lines a, b and c form the triangle. The angles at points A and B are known by the directions they send/receive the lines. From that point, calculating either of the unknown distances b and a is easy through the Law of sines. For example, distance a would be $a = SinA \times c$.

The results from this method are remarkably accurate and are of high resolution, but the equipment for this kind of scanning tend to be on the larger side, as well needing some preparations for the scan to succeed such as lighting and surface treatment for the object. (Geomagic, 2016)

Structured Light scanning is very similar to another scanning method called Laser Triangulation. In this method, a laser or a laser line is shot at the object as in Structured

Light method, but in this method the sensors detect the reflected laser for the triangulation calculation, see Figure 4.

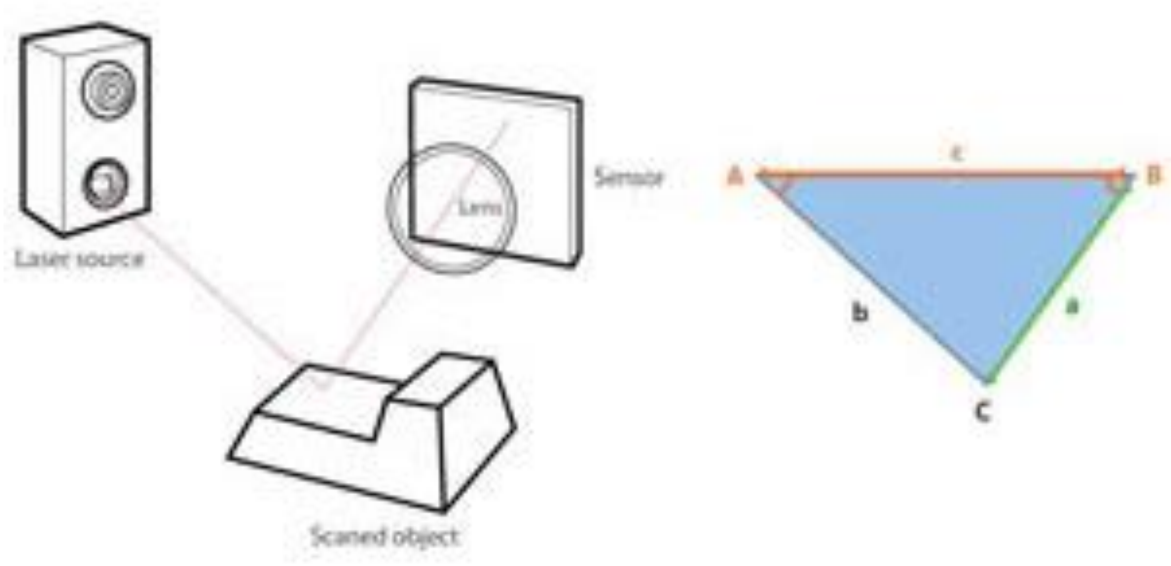

Figure 4 Laser Triangulation (Source: Geomagic.com)

The advantages of this method are that it is very portable and doesn't need advanced preparation to be done neither at the target object or the lighting of the area where it is used. The lack of prerequisites and small size of the technology also means that the Laser Triangulation method is easily used with different types of scanners. (Geomagic, 2016)

Both triangulation based scanning methods are usually referred to as short range scans, as their technology limits their scanning distance to somewhere around 1 meter, though their results are incredibly precise, down to tens of micrometers. (Geomagic, 2016)

2.2.2 Long Range

The third type of non-contact scanning is called **Laser Pulse** scanning, though it is also abbreviated as **LiDAR** (Light Detection And Ranging) and **Time of Flight** scan, based on its operating principle, which is to calculate the time it takes for laser beams to reach and reflect back from the target. Laser Pulse scanning's greatest advantage over the other methods is that it has a really variable range, going from as small as 2 meters to over 300 meters, though there is new technology on the markets that, while faster, has range of only 120 meters.

Laser Pulse scan also has a variation called **Phase Shift** scan, which works exactly like a Laser Pulse scan, except that instead of calculating shapes from the lasers flight time, it calculates them from the phase shift of the returning laser. A Phase shift scan is more accurate than a Laser Pulse scan, but in return it has less range than a Laser Pulse scan, topping out at 80 meters. (SurvTech Solutions, 2017)

2.2.3 Photogrammetry

3. **Photogrammetry**
    a. **Digital Photogrammetry**
    b. **Analytical Photogrammetry**

Figure 5 Photogrammetry types

Digital photogrammetry could also be counted as its own branch of 3-dimensional scanning, as it isn't actually about scanning the object itself but gathering the structural data about the subject through several overlapping photographs from known points through a mixture of computer seeing and computational geometry algorithms.

Notably, digital photogrammetry is almost completely software based and as such is a very economical option as there is no need to buy new equipment, though naturally higher quality equipment gives better results, with thing like camera lens affecting the scan distance and the computers calculating power affecting the time it takes to decipher the data. (Lanmar Services, 2014)

Digital photogrammetry is most known for its ability to capture realistic texture data.

3 Scanner Types

Just as there are many methods for conducting a 3D-scan, there are many types of scanners to go with them. With the advancement of the related technologies the needed components have become smaller and as such smaller and more mobile devices have started to appear on the market. Besides that, the as the improved camera technology has many other uses, some companies have started to plan ways of turning formerly unrelated devices into 3D-scanners.

3.1 Handheld

The most popular type of commercial 3d-scanner is the handheld type, though the exact scanning method varies, mainly between Laser Triangulation and Structured light scans. This popularity has only increased since with modern technology has improved the scan accuracy and removed the need for extra reference points formerly needed to accurately build a structure from a Point cloud. A modern handheld 3D-scanner is usually not much bigger than a hand and possibly cordless (see Image 1).

This type of scanners are very popular in industrial use as a part of quality control, designing and checking products that are being used for maintenance. The scanners are easy to use, with the handler having to only scan the object in question from different sides, a job which takes less and less time as the technology is perfected.

Image 1 Typical handheld scanner (Source: Creaform3d.com)

3.2 Measuring Arm

Thanks to the titular arm (see Image 2), Measuring Arm scanners are bulkier and have less freedom of movement than the Handheld Scanners, but as the Measuring Arms have positional sensors in the joints of the arms themselves, the data they gather is more accurate. The exact measuring method is variable, with support for both Contact and non-Contact methods available. In fact, with the right kind of sensor a Measuring Arm can provide just as good results as a CMM machine.

Measuring Arms see industrial use in quality control, inspection, on-machine verification, reverse engineering, virtual assembly and 3D modelling, with typical uses involving things like sheet metal parts and machined parts.

Image 2 Measuring Arm (Source: Cimtrix.com)

3.3 Tabletop

The third type of 3d-scanner is called the Tabletop scanner and they can come in one or two pieces depending on the model (see Image 3). The pieces themselves are the scanner itself and the turntable. The scanners usually favor the same short-range scanning methods as the handheld scanners, with the real difference coming from the turntable. The turntable is a round table, upon where the target object is placed and which is then allowed to spin in place for the duration of the scan, giving the scanner excellent pictures at all angles. The size of the table, however greatly limits the possible size of the target object.

The Turntable by itself is a useful accessory for different kinds of scanners and as such some companies as well as amateur designers offer table designs that are compatible with not just purpose-built scanners, but also regular smartphones which can have 3D-scanning programs installed in them.

Image 3 Typical Tabletop scanner (Source: makepartsfast.com)

3.4 App

During the last decade cameras have become a staple to smartphones and tablets. With the advances to software, it is now possible to utilize photogrammetry programs on them too. These programs are of various qualities and have varying capabilities, but like with any software, they all are only as good as the hardware they are installed on, with more powerful machines being better.

For tablets, the companies have developed special sensors to be strapped on tablets (see Image 4) to improve their scanning ability. These add-ons greatly improve the quality of the scans, but the future of these add-ons looks uncertain as at the end of 2016 Wacom released a product called MobileStudio which incorporates the technology into the tablet, removing the need for strapping a bulky gadget to the tablet.

Image 4 Skaneckt model sensor attached to a tablet (Source: microfabricator.com)

4 Commercial 3D-Scanners

4.1 MFS1V1 (Matter and Form)

Image 5 Matter and Form MFS1V1 (Source: Amazon.com)

The MFS1V1 is a Tabletop scanner made by a company called Matter and Form Inc. that came to the markets in 2014 and has since become one of the best rated consumer 3D-scanners in the price class of under 3000$. What is even more impressive, is that even if the scanner was crowdfunded in 2013 and became commercial in

2014, it is still good enough scanner to have one of the top places on all review lists, no matter the judging criteria (see Appendice 1).

Type: Tabletop	
Scan Performance	
Maximum object size and weight	
Height	25 cm
Diameter	18 cm
Weight	3,0 kg
Scan Accuracy	
Smallest capture details	0,43 mm
Capture size	±0.25 mm
Scanner	
Optics	HD CMOS sensor 2 lasers
Connectivity	USB 2.0 high speed interface
Power input	110-240 V
Scanner size and weight	
Height	34,5 cm
Width	21 cm
Open length	34,5 cm
Closed length	8,5 cm
Weight	1,71 kg
Sold with	Matter and Form 3D Scanner USB B/power cable Calibration box User manual Product information booklet Matter and Form Scan software
Price	599,00 €

Table 1 Matter and Form MFS1V1 technical specs (source: Matterandform.net)

4.2 Cubify Sense (3D Systems)

Image 6 Cubify Sense (Source: Reichelt.de)

Cubify Sense, also known as 3D Systems 391230, is developed by company called 3D Systems. The company was co-founded 30 years ago by one of the inventors of modern 3D-printing, Chuck Hull, and as such has worked with just about all branches of 3D-printing from digitalization to manufacturing, from medical to industrial uses of the technology.

Type: Handheld	
Scan Performance	
Operating range	
Minimum distance	0,2 m
Maximum distance	1,6 m
Field of view	
Horizontal	45°
Vertical	57,5°
Diagonal	69°
Scan Accuracy	
Smallest capture details	0,43 mm
Capture size	±0.25 mm
Scan volume	
Min	0.2m x 0.2m x 0.2m
Max	2m x 2m x 2m
Maximum image throughput	30 fps
Scanner	
Connectivity	USB 3.0
Power input	110-240 V
Scanner size and weight	
Height	17.8 cm
Width	12.9 cm
Depth	3.3 cm
Weight	-
Sold with	Cubify Sense 3D-scanner 1.82 m USB cable Quick start guide Software can be downloaded from company webpage
Price	349,00 €

Table 2 Cubify Sense technical Specs (Source: 3dsystems.com)

4.3 Structure Sense (Occipital Inc)

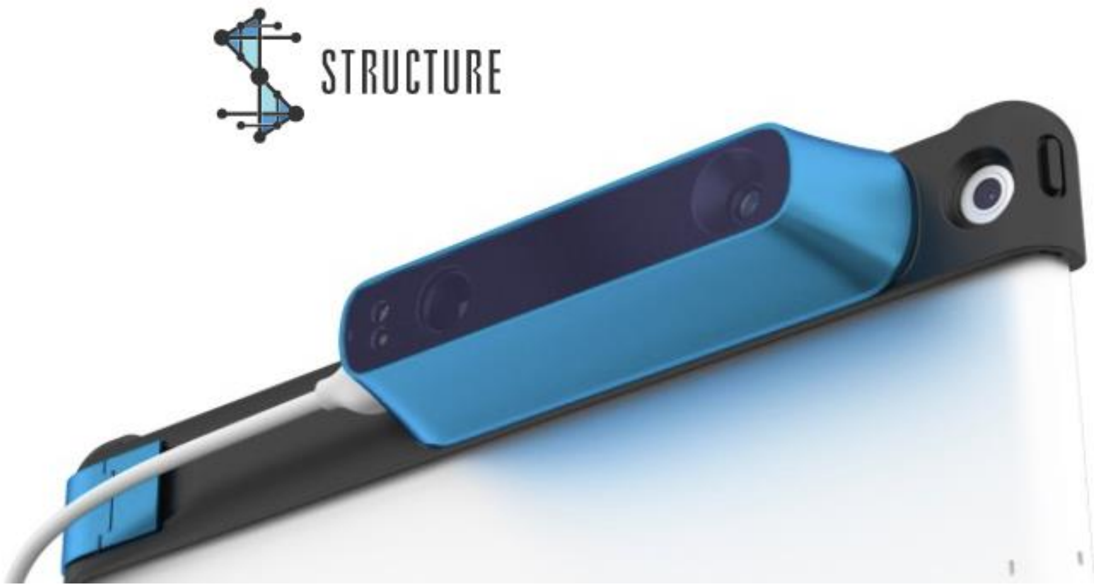

Image 7 Structure Sensor (source: 3printr.com)

Also known by the name Occipital Structure Sensor, the Structure Sense is developed by a private company called Occipital Inc. and it specializes in computer vision, with its origins rooting in barcode scanners in 2008. The Structure Sensor was the first 3D-scanner for mobile devices when it was released in 2013. Like the Matter and Form scanner, it too was crowdfunded. The design of the Structure Sensor was so good that the 3D Systems company made its own almost completely identical version of the product called iSense, but that was discontinued in 2016.

Type: App (Tablet)	
Scan Performance	
Operating range	
Minimum distance	0,4 m
Maximum distance	3,5 m
Field of view	
Horizontal	58°
Vertical	45°
Diagonal	-
Scan Accuracy (Scales with distance)	
Smallest capture details	0,5 mm at 0,4m
Capture size	-
Scan volume	
Min	0.2m x 0.2m x 0.2m
Max	2m x 2m x 2m
Maximum image throughput	60 fps
Scanner	
Connectivity	-
Power input	-
Scanner size and weight	
Height	29 mm
Width	28 mm
Depth	119,2 mm
Sold with	iPad bracket CAD can be downloaded from company webpage
Price	360,74 €

Table 3 Structure Sense technical specs (source: structure.io/support)

4.4 Scanify (Fuel3D)

Image 8 Fuel3D Scanify (Source: Scanify.fuel-3d.com)

The Scanify is developed by the Fuel3D company, which has been operating since 2003. The company specializes in combining multiple image processing techniques and the Scanify is a good example of their work, combining technologies such as pre-calibrated stereo cameras with photometric imaging and optical localization to achieve impressive quality scans. The Scanify even won a CES Innovation award in 2015. The Scanify also has a built-in mount, so it can be set on a tripod.

However, Fuel3D has pulled the Scanify from European markets starting 11. of May 2017 in order to focus on the North American market.

Type: Handheld/Tabletop	
Scan Performance	
Operating range	
Minimum distance	350 mm
Maximum distance	450 mm
Field of view	
Information not provided	
Scan Accuracy	
Smallest capture details	0,35 mm
Scan volume	
Min	-
Max	0,21m x 0,3m (0,4m diagonal)
Maximum image throughput	-
Scanner	
Connectivity	Micro USB
Power input	AC power adapter (draws approx. 2A)
Scanner size and weight	
Height	24,5 cm
Width	25,5 cm
Depth	3.5 cm
Weight	0,51 kg
Sold with	Scanify handheld scanner three re-usable targets USB cable AC power cable Fuel3D Studio Professional editing software by download Quick start guide
Price	528,6€

Table 4 Scanify technical specs (source: scanify.fuel-3d.com)

4.5 NextEngine (NextEngine Inc)

Image 9 NextEngine (source: nextengine.com)

Developed by NextEngine Inc. the NextEngine scanner is a powerful tabletop scanner that boasts new technology and instead of needing the installation of its own software for accessing the data, its files are completely compatible with SolidWorks format. The company itself, founded in year 2000, is partner of such high-profile companies such as HP, Kodak and Seiko. The scanner boasts two scanning modes: macro and wide.

Type: Tabletop	
Scan Performance	
Maximum object size and weight	
Height	No preset limit, can assemble larger objects with supplied software
Diameter	
Weight	
Scan Accuracy	
Smallest capture details	0.127 mm (macro) 0.381 mm (wide)
Capture size	-
Scanner	
Optics	Twin 5.0 megapixel CMOS image sensors
Connectivity	USB 2.0 high speed interface
Power input	100-240 V
Scanner size and weight	
Height	27,7 cm
Width	22,35 cm
Depht	9,14 cm
Weight	3,2 kg
Sold with	Scanner, ScanStudio, AutoDrive, Part-Gripper, Powder Pen, PaintPens, 1 year support + hardware warranty
Price	2 631,56 €

Table 5 Nextengine technical specs (source: nextengine.com)

4.6 XYZprinting Handheld (XYZprinting Inc.)

Image 10 XYZprinting Handheld (source: eu.xyzprinting.com)

XYZprinting Inc. branched out of one of Taiwan's greatest electronics companies, called New Kinpo Group, in 2013 and has since made name for itself with reliable and comparatively fast machines, especially known for their Da Vinci brand of 3D-printers. Although new models of the flagship product have integrated 3D-scanning equipment, the best scanning equipment the company can offer is still the dedicated XYZprinting Handheld.

Type: Handheld	
Scan Performance	
Operating range	
Minimum distance	0,1 m
Maximum distance	0,7 m
Scan Accuracy	
Smallest capture details	1,5 mm
Capture size	-
Scan volume	
Min	5cm x 5cm x 5cm
Max	60cm x 60cm x 30cm (object mode) 40cm x 25cm x 40cm (head mode)
Maximum image throughput	30 fps
Scanner	
Connectivity	USB 3.0
Power input	-
Scanner size and weight	
Height	15,7 cm
Width	4.1 cm
Depth	6.1 cm
Weight	238g
Sold with	Scanner
Price	229€

Table 6 XYZprinting Handheld technical specs (source:shop.yoodoit.de)

5 Detailed review of Scann3d (SmartMobileVision)

Image 11 Scann3d is a photogrammetry app for smartphones (Source: Chip.de)

Scann3d is a free app that uses patent pending photogrammetry technology and certain open source softwares to create 3D models with smartphones and tablets. However, the app is still under testing, with possible bugs and improvements still ahead. Still, this review is done with a trial version of the final app and as such might not give a complete idea of the final products capabilities.

Type: App (Smartphone)	
Scan Performance, Accuracy and Volume	
App automatically adjusts to match the camera of the device its installed on.	
Scanner size and weight	
Depends on the device.	
Price	Free

Table 7 Scann3d technical specs

5.1 Creators

Project Lead: Ferenc Bálazs

Team Lead: András Dudás

Core Logic Development: András Lehotay-Kéry

GUI Development: András Lehotay-Kéry, Milán Berecz

Development: András Lehotay-Kéry, András Dudás, Adrián Puszta, Béla Mihalik, János Kisházi

Research: Gergely Rosta

Testing & Quality Assurance: Szabina Szanyi

Graphics Design: Dávid Töltésy, Viola Varga

5.2 Open source software’s involved

1. Boost – C++ programming libraries for tasks like image processing and multithreading.
2. Ceres Solver – A C++ programming library for optimization-
3. Eigen – A C++ template library for linear algebra.
4. Flann – Library for performing fast approximate neighbor searches in high dimensional spaces.
5. jPCT – a 3D engine
6. OpenMVG – Computer vision library.
7. PCL – Image and Point Cloud processing
8. Poisson Surface Reconstructor Module – Surface reconstruction algorithm.

9. Stlplus – Collection of reusable C++ components for developers.
10. TAJTEEK – General purpose Java library and toolkit.
11. MVE – Image-based environment reconstruction software.
12. MVS-Texturing – Algorithm to texture 3D reconstruction from multi-view stereo images.
13. The Android Open Source Project – Open source software stack for ensuring compatibility for custom Android stacks.
14. TypefaceSpan – Changes typeface family
15. VTK OpenGL ES Rendering Toolkit – C++ rendering library for mobile devices.
16. XStream – Data storage
17. OrmLite – Object Relational Mapping
18. MultiUpCast – Allows code use for intersection types
19. Javassist – Java programming assistant
20. KAZE – Open cource code and Iguaxu dataset for image matching evaluation.
21. VLFeat – Open source library for computer vision algorithms.
22. ViewPagerIndicator – Paging indicator widget
23. SlidingTabBasics – Sliding tabs
24. Glide – Image loading and caching library
25. Glide-transformations – image transformations for Glide
26. Android-target-tooltip – Tooltip creator
27. ShowcaseView – In-app highlighting and showcasing
28. Icons8 icons – Free icons

5.3 The Company

The Scann3d app is created by the SmartMobileVision, abbreviated to SMV, a small Hungarian technology company formed in 2014 by alumni from prominent Hungarian universities. The company is still small, having only one other product to its name called Distance which is another smartphone app, but it uses machine vision to calculate distances from images.

Image 12 SmartMobileVision logo (Source: smartmobilevision.com)

5.4 Using Scann3d

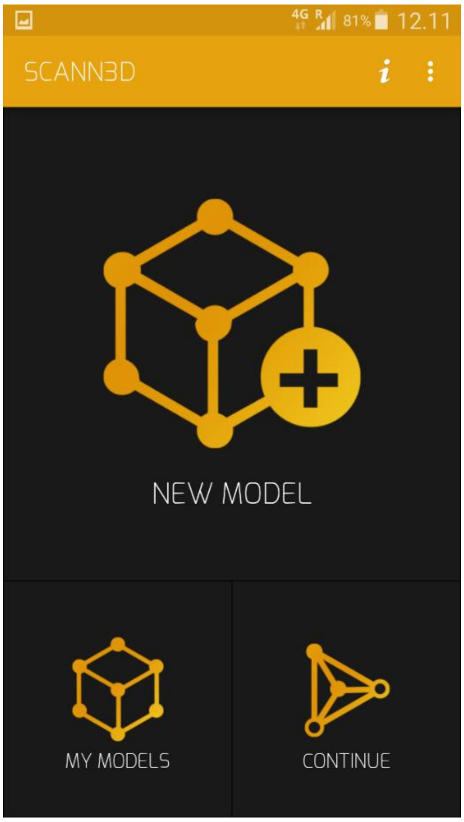

Image 14 Scann3d Main menu

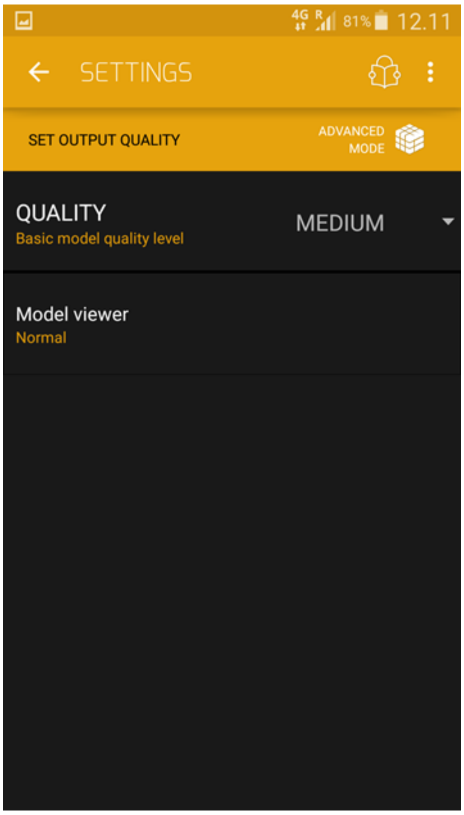

Image 13 Settings screen

The main menu of Scann3d is accessible after the, at the moment, non-functioning login screen. The menu is simple design, with five buttons. In the upper right corner is the three in a vertical line that an Android user recognizes as the settings button, with the **i** -button next to it standing for information. The information tab at the moment contains just background information about the app itself and the open source software's involved in its making.

The settings screen is simple and, for the most part, self-explanatory. The interesting part is the button labeled "advanced mode" on the upper right. Activating this mode brings out options to customize the mesh generation for model building.

The "My models" and "Continue" buttons back in the main menu are a bit confusing as they both lead to the "My works" page, just different tabs, with the former leading to finished models and the latter leading to the list of different imagesets to create models. There is also a smaller version of the main page's new model button with the same function, as well as the option to import files from somewhere else.

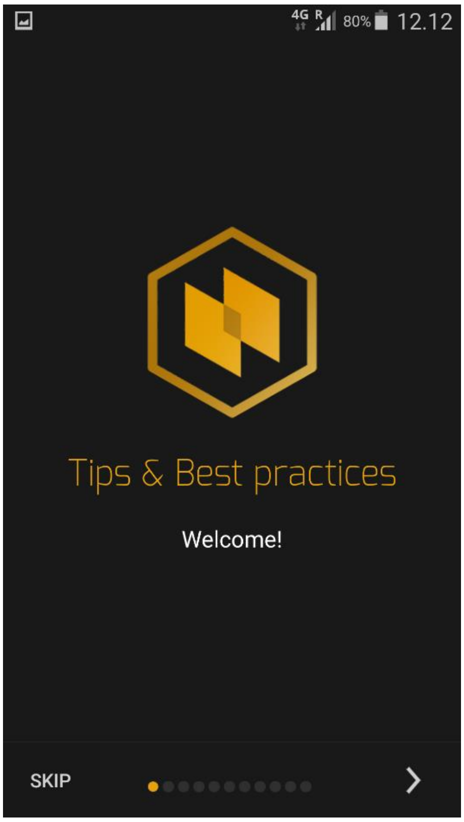

Image 16 Scann3d tutorial screen

In the Imageset tab, it is possible to look through and modify all saved imagesets, though the modifying is at the moment limited to just adding and removing pictures, as well as reordering and naming them. The Models tab is more barren, only providing the list of models for opening in the model viewer.

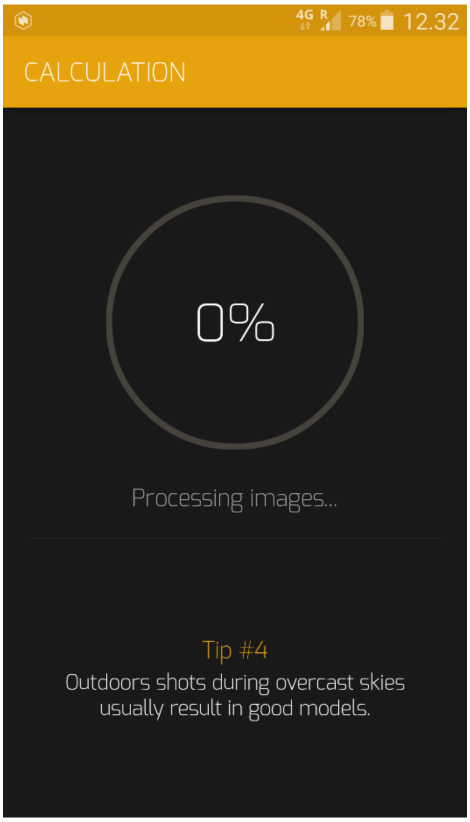

Image 15 Image processing screen

The "New Model" button on the main page is for starting a new project. The first time it is used, it leads into a quick tutorial for using the app. The tutorial can be skipped with a labeled button and at the last slide of the tutorial is an option to turn the tutorial off, with a note that the tutorial can be replayed through the settings page. The tutorial itself is comprehensive, covering things like what materials are easier to capture and what kind of lighting is best. The only hang up it has is that it doesn't specify the range of the scan beyond recommending fitting the object in 20 pictures.

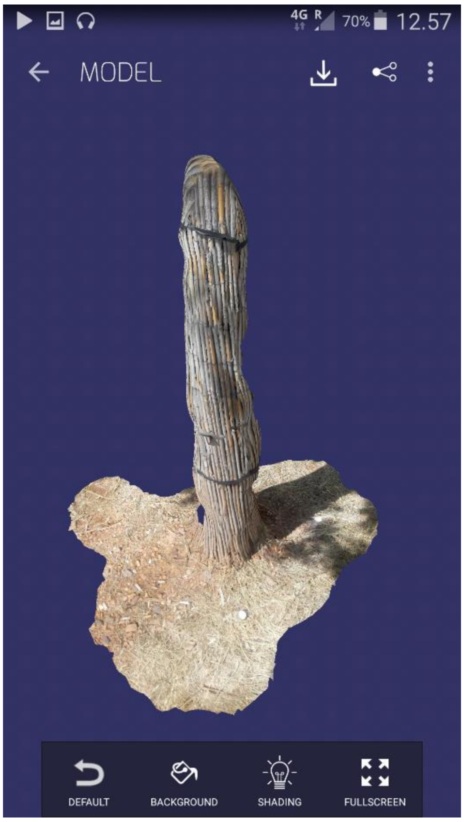

Image 17 A model of a tree in model viewer

After the tutorial, the app opens the camera. The camera works as normal, but there is a couple new buttons: one for altering the settings of the app and another for finishing the image set.

After an image set is finished, the app offers to automatically compile the images into a 3D-model. The user doesn't have to use all the pictures they have taken, they can also modify the imageset in the same manner it is done in "My works" page. The progress takes some time, but the device can be used as normal while this is going on. Of course, the process slows down the device considerably and drains batteries fast. The process may also fail, but the app gives no indication as to why so the user just has to start again from the beginning or hope the problem can be fixed by deleting pictures from the imageset.

After the model is created, the app opens the new model in its model viewer. The viewer is a simple tool that allows the observation of the model from any angle and distance, with limited options available to modify the shading of the object and to change the background color of the model. Besides those options, there are also buttons for sharing the object in Sketchfab (a 3D-content storage and sharing platform) and saving the object in formats such as *.obj, *.pcd, *.ply and *.stl for exporting.

The model itself is of middling quality. As shown in Image 13, from the default middling distance it looks passable, the textures and general shape are easily recognizable, but when zoomed in it becomes easier to see how it is made of parts. In the case of Image 13 the parts become especially visible through the directions of the thin branches that make up the surface, as their unnatural bending is easy to spot. There is also some spots where the surfacing has simply failed. One spot is visible in the picture: at the base of the trunk is surfaceless spot with background blue shining through. Another spot is on the backside of the picture, with most of the tree lacking surface. This is probably caused by the uneven lighting coming from the sun shining directly from behind the tree when pictures were taken.

Overall, the quality of the model is surprisingly high for something running completely on a smartphone's capabilities. Even the compiling of the 3D model took just around 10 minutes for an old Galaxy S4 to do.

6 Arguments for a 3D-scanner

All in all, the branch of technology that deals with 3D-modeling is growing. New innovations and with them, new uses are being made all the time. Already the use of scanners for numerous tasks from quality control to reverse engineering to streamlining automated processes is a sizable part of larger industry, but the lowering prices are also bringing the technology to the reach of smaller companies.

For the Hochschule, just about all the engineering programs could benefit from the addition of a 3D-scanner. Their convenience for measuring and quality control alone ensure that the student's would more likely than not run into some sort of scanning equipment in their future careers and adding just one opportunity for them to familiarize themselves with the technology during their studies could give them an edge for the future.

Besides manufacturing, fields like automotive engineering can also product from 3D-scanning. Besides the quality checking, the technology can also be used for prototyping and analyzing parts, or reconstructing broken parts for finding out how and why they broke.

Another greatly benefiting program would be automation. 3D-scanners convenience for detecting deviances from patterns, be they from wrong measurements or misalignment is great. Calibration systems for automated manufacturing lines are commonplace with bigger companies.

As such, 3D-scanning is a technology of future and it is imperative for it to be included in the process of formal learning.

7 References

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Appendices

Appendix 1. 3D-scanners as recommended by different reviewers on the internet.

A=	http://www.toptenreviews.com/computers/scanners/best-3d-scanners/
B=	https://all3dp.com/1/best-3d-scanner-diy-handheld-app-software/
C=	http://www.aniwaa.com/best-3d-scanner/
D=	https://3dprint.com/138629/2016-3d-scanner-buying-guide/
E=	https://www.sculpteo.com/blog/2016/08/10/top-10-best-3d-scanners-for-every-budget/
F=	https://nerdtechy.com/best-3d-scanners-reviews
G=	https://pinshape.com/blog/the-11-best-3d-scanners-on-the-market/
H=	https://www.top5reviewed.com/3d-scanners/
I=	https://3dprinterchat.com/2017/01/top-7-3d-scanners-on-a-low-budget/
J=	https://i.materialise.com/blog/most-popular-3d-scanners-and-3d-scanning-software/
K=	https://www.youtube.com/watch?v=ZN9LKIT95wM
L=	https://www.youtube.com/watch?v=LYfaRFfG4Ho

Top 8		Discontinued Models
Matter and Form MFS1V1	Tabletop	iSense
Cubify Sense	Handheld	Autodesk 123D Catch
iSense	Tablet	
Structure Sense	Tablet	
NextEngine	Tabletop	
XYZprinting Handheld	Handheld	

	A	B	C	D	E	F	G	H	I	J	K	L	
Cubify Sense/3D Systems 391230	1	1		1	1		1	1	1	1		1	9
Da Vinci	1												1
DAVID SLS-2	1	1	1				1				1		5
Fuel3D Scanify	1	1		1	1		1			1			6
IIIDScan PrimeSense	1	1					1					1	4
iSense	1	1		1			1	1	1	1		1	8
Makerbot Digitizer	1	1		1						1		1	5
Matter and Form MFS1V1	1	1	1	1	1	1	1	1	1	1	1	1	12
NextEngine	1	1	1	1			1			1			6
Structure Sense/Occipital Structure Sensor	1	1	1	1	1		1		1		1	1	9
Einscan SE/SP		1	1	1									3
Einscan Pro		1	1										2
Microsoft Kinect		1			1		1		1	1			5
Fabscan Pi		1											1
XYZprinting Handheld		1	1	1			1	1		1		1	7
Murobo Atlas		1											1
BQ Ciclop		1	1	1			1		1	1		1	7
XYZprinting Da vinci 1.0 All in one		1						1		1		1	4
XYZprinting Da vinci 1.0 Pro 3-in-1		1			1		1						3
AIO Robotics Zeus		1											1
Artec Eva		1											1
Zeiss T-scan CS		1											1
Hexagon Global Evo		1											1
Autodesk 123D Catch		1		1	1					1			4
Trnio		1											1
Autodesk ReMake		1											1
Agisoft Photoscan		1											1
Einscan Pro+			1										1
Rangevision smart			1	1						1			3
Agisoft PhotoScan				1									1
David SLS-3				1	1	1			1		1		5
Solutionix Rexcan 4					1								1
MetraSCAN 750					1								1
Einscan-S						1	1		1		1	1	5
EORA 3D Scanner									1	1			2
Agisoft										1			1
Zmorph 3D Scanner										1			1
Rubicon 3d-Scanner													0