Chapter 2
Technology Leaders and Adopters

Abstract This chapter gives an overview of the nature of technology and investigates many of the other technologies which are combined for photogrammetry to emerge in its current state. From general technology theory to a brief history of photogrammetry, it investigates some of the technologies which incorporate photogrammetry technologies and are also connected to the fields of design and entertainment: Microsoft Kinect, photosynth, Weta Digital: Photospace, Autodesk 123D Catch. This chapter concludes by investigating some of the current challenges and limitations.

Keywords Major technology · Convergence · Future studies · Technology cycles · Art and design · Photogrammetry history · Nature of technology · Photogrammetry · Microsoft Kinect · Photosynth · Kinect fusion · What a digital · Photos space · Autodesk 123D catch · Challenges · Limitations

2.1 The Nature of Technological Spread

Technology has evolved in alongside human societies for the last several thousand years. While multiple definitions exist, a combination of its qualities shows it to be a continuously evolving process of harnessing and amplifying sources of power which were originally part of the natural world in the form of tools or processes which serve to increase human abilities to fulfill our needs and desires [1]. Two components of the nature of technology are being addressed here: the nature of technology and accelerating change.

The nature of technology reflects similarities to the evolutionary nature of biological organisms. There are evolutionary cycles in technology similar to biological development; many new technologies are tested, and the most useful combinations move ahead. The combinations often start off somewhat weak (birth) but then (grow) strengthen and optimize (mature) over time. As the technologies reach maturity, there is often a need to combine with additional technologies in order to spawn a new cycle in order to avoid disuse (decline).

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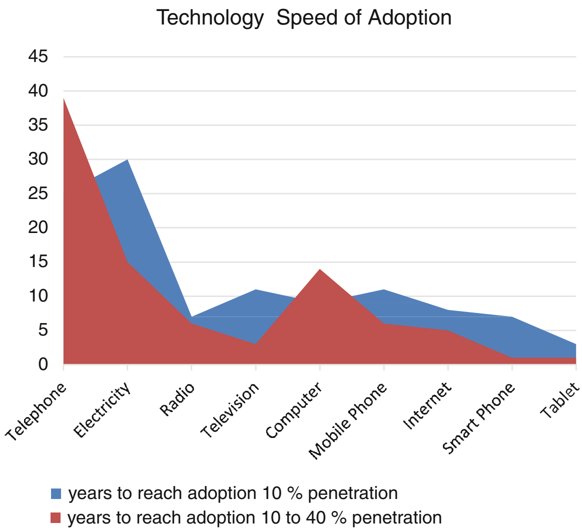

Fig. 2.1 Mass use of inventions [Technology Review, ITU, New York Times, WSJ, US Census Bureau]

The field of future studies has described accelerating change as the perception of increased numbers of technological changes over the last 2,000 years of history. There has been a growing amount of statistical research showing a logarithmic trend of major technological change, combined with a reduction in the time a society takes to adopt the technology. Figure 2.1 presents several recent technologies and their speed of adoption [2]. A simple but controversial view connects Moore's Law, which describes the logarithmic growth of transistors in microprocessors, to accelerating technological progress [3]. While there is some controversy as to exact formula, others work to present more accurate ones [4]. Some of the factors linked for new technology adoption appear to be costly and technically difficult to use.

The result of the accelerating change has been perceived as "disruptions" to many fields, which had been stable. The disruptive technologies have at times completely destroyed (or radically changed) whole industries.

Over the last 20 years, 3D computer graphics has been a rapidly moving, growing, and evolving field. Many of the technical challenges within the field have been solved. The creation of 3D objects has been in high demand for use in multiple fields, from visual effects, animated films, architecture, video games, etc. Creating those objects has been done by the briefly described process of 3D modeling. Over time, those tools have improved and an industry has developed around building necessary 3D objects. While there have been incremental improvements in the tools and processes used for creating 3D objects, the field of 3D modeling had a similarity to skilled craftsmen's guild, due to the mix of high technical skill mixed with artistic knowledge. Given the pace of technology, it seemed inevitable for this field to have a disruptive change. This change is in the

Technology	Approximate Dates
Photography & plane tables	1850-1900
Stereoplotters & Airplanes	1901-1950
Computers & Mathematical Models	1951-1971
Digital & Computer Vision	1972-Present

Fig. 2.2 Stages of photogrammetry development

integration of photogrammetry (using real images and video technology) and procedural object creation (objects made by the use of pre-programmed algorithms). In this book, we will be focusing on the emerging workflow that involves photogrammetry and retopologization.

2.2 A Further Introduction and History of Photogrammetry

Photogrammetry relies on gathering data from images that can be analyzed to extract and yield further information. It has an extensive history, with origins connected to mathematics, optics, and geometry, which can be traced as far back as 1492, with DiVinci describing the principles of optical perspectivity [5]. Over time, its first broad application was to aid in the creation of highly detailed cartography. As the technology progressed, the data that photogrammetry and remote sensing equipment are capable of acquiring have expanded to physical, temporal, and semantic types of information ([8], p. 4). The field, however, still has strong connection to its origins. Photogrammetry falls under the field of “remote sensing.” This is because while it is doing advanced calculations and analytic measurement of objects, there is no physical contact during analysis.

In the scientific fields, there are sometimes additional categorizations which place the remote sensing aspect of photogrammetry as information only from imagery which is received from satellites (images from above the earth). For the sake of this book, we will mostly discuss photogrammetry as it is being applied to the creation of 3D objects and will not be addressing the scientific and mathematical components of remote sensing.

The history of photogrammetry can be separated into four close differing stages based on improvements in technology. The stages, titles, and dates vary slightly by different scholars ([6, 7], p. 282) and ([8], p. 7); however, the general stages of development can be separated into the following approximated time periods (Fig. 2.2).

Fig. 2.3 Perspective can be generated using Euclidean geometry

2.2.1 Photography and Plane Tables

The current state of photogrammetry required many technological advancements over the last several hundred years. Mathematics and optics were critical initial components, since photogrammetry relies on the scientific analysis of photographs. As previously mentioned, the history of photogrammetry in the West can be traced back to as far as the fifteenth century [10] (Italian Renaissance). Rules of linear perspective can be derived from the basic Euclidean geometry. To this day, artists use underlying principles of Euclidean geometry within their drawings to create realistic 3D representations of the world. The translation from real-world 3D image, can be done “by eye” seen from real life, or using more exact processes such as camera obscura images projected onto a grid, or more recently images taken with a digital camera which can then be traced. The goal of photogrammetry is to do the opposite: to use mathematics to extract information from images.

Photography and plane table analysis was performed on images taken from high rooftops, from hills, or from balloons or even using kites and pigeons. Once these images were taken, linear perspective combined with simple math was able to manually compare the known heights in order to derive additional highs of objects within the image (Fig. 2.3).

2.2.2 Stereoplotters and Airplanes

Stereoplotters are stereoscopic images combined with technologies for automating the measurements of objects from two overlapping and optically corrected images. There were multiple inventions (floating mark, stereocomparator, stereoautographs, serial-photo aerial camera, etc.), which began to automate height analysis of images in the early twentieth century. By the 1930s, advances and refinements of these technologies as well as improvements in aviation resulted in the use of aerial stereophotography becoming the main method of map making.

2.2.3 Computers and Mathematical Models

The further refinement of analog devices for stereoplotting and photography was combined with the rapid calculations which are able to be performed by computers allowed for even greater accuracy. Specifically, some of the more complex "algorithms for orientation and triangulation…" were developed, dramatically accelerating results and accuracy.

2.2.4 Digital and Computer Vision

The first readable images of Earth sent from orbit were from Landsat in 1972. The transition from partial to near-complete automation has taken another 40 years. Digital photography, further improvements in algorithms, as well as the ability to record in multiple formats allow for greater interpretations. "Pan-chromic imagery, near-infrared, and color" could all be taken simultaneously using digital, removing the need for chemical development of images and scanning. Also, many of the physical plotting devices such as the stereoplotters have been replaced by lIght and range detecting (LIDAR) remote sensing technology that uses lasers instead of analglyphic stereoimagery to map depth and distance information.

2.2.5 Looking Ahead

When it started, the field was used for extremely large mapping applications, but in the near future, a microscopy technique using stereophotogrammetry is being planned for the analysis and creation of ultrasmall components [9]. The technology is also being used to look and map areas farther away. Currently LIDAR, a remote sensing technology, which combines laser and radar technology, is mapping the moon. Many of the photogrammetry techniques are beginning to move into other research fields as well as become accessible to mainstream population for use in creative, educational, or hobbyist application.

2.2.6 The Cycle Between Art and Science

A current list [6] of applications of photogrammetry is

- Mapping and acquisition of geoinformation
- Documentation
- Monument preservation and architecture
- Aerial, terrestrial, and underwater archaeology
- Monitoring earth surface and building deformations
- Civil engineering studies
- Automobile, aeronautical, and nautical industries
- Dental, orthopedic medicine and biomechanics
- Forensic applications.

This book specifically deals with some of the ways a new category is being added to this list:

The fields of art and entertainment, specifically how new technologies integrate into college 3D art and design education. Interestingly, in the past, artists adopted mathematics and linear perspective to derive 2D images that look 3D, and now, the current field of 3D computer graphics and digital design is once again connecting with the fields of science (photogrammetry) and full cycle, by adopting photogrammetry technology to derive 3D objects into artwork. The field of 3D computer graphics has begun using photogrammetry information to rapidly generate 3D models, in order to make visual images based on real life. While there have been various market leaders in industry who have sparsely applied these technologies, the factors of low cost and mass accessibility are laying the groundwork for broad adoption.

As the cycle continues of art, science, and technology, we will now introduce several of the applications created by the entertainment industry for use in research and application.

2.3 Photogrammetry Resources Connected to the Entertainment Industry

Photogrammetry for deriving 3D assets (and analysis) has existed in many forms and in various products within other fields. Within the design and technology fields, the technology has arrived relatively recently. In the next few sections, we will focus on a few technologies developed by Microsoft, Autodesk, and Weta Digital , due to their connections to the media and design fields. However, we have also compiled a list of additional photogrammetry resources in the appendix of this book.

2.4 Microsoft Kinect

Due to its industry-leading research laboratories in computer vision combined with its Xbox and Kinect video game platform, Microsoft has been a market leader with combining photogrammetry and computer vision technology. The Kinect, a breakthrough device, was launched as a peripheral to the Xbox 360 game system in November 2010. However, Microsoft (and others) launched additional software development kit (SDKs) which allowed the device to be used in ways beyond its intended use as a next-generation game controller.

The Kinect device combines a standard camera, infrared projector, and microphone. By analyzing visual information generated by the camera and depth information generated by the infrared sensor, it creates a large set of ways to interact with computers without a mouse or keyboard. Gesture-based interactive technology in the Kinect was acquired by Microsoft from a range camera developed by PrimeSense, an Israeli 3D sensing company. Beyond 3D sensing, the new 3D and gestural interface has had a large impact on the field of user interface design as well (Fig. 2.4).

In May 2013, **Xbox One** was announced by Microsoft, and the upgraded "Kinect One" sensor is due out with the release of the gaming system late 2013. With this product will come further improvements to the Kinect Fusion technology.

The Kinect One hardware will feature a big step forward in technology. It incorporates greater gesture recognition, up to six people tracking (via facial recognition) and a full HD 1080P resolution (as compared to the original sensor which offers only standard definition). It also promises to deliver a nearly latency-free workflow.

Probably, the most significant feature listed above in respect to this book is the nearly 4X increase in resolution and speed of capture. 3D computer models, which will be generated by the Kinect One, will have greater detail for more accuracy. This additional fidelity will make capturing 3D models much more accurate.

2.5 Microsoft (CV) Kinect Fusion

First presented at SIGGRAPH 2011, this technology is a series of software libraries that connect to the Kinect hardware. Kinect Fusion was developed at the Microsoft Computer Vision Laboratories. One component of the Kinect Fusion technology allows for high-quality, 3D renderings of environments and people in real time. Most current photogrammetry to 3D mesh workflows involves taking

Fig. 2.4 Microsoft Kinect sensor

multiple photographs and then having comparatively analyzed in order to extrapolate 3D point cloud volumes, from which 3D meshes are derived. Kinect Fusion develops 3D meshes in real time. We anticipate faster and more accurate detailed meshes that will rapidly emerge as the technology further evolves. Other products have also incorporated 3D the Kinect as a platform for scanning technologies (for example, http://reconstructme.net/).

In March 2013, Microsoft released a significant update to the Kinect SDK. This update **includes** the Kinect Fusion technology in the SDK feature set (Microsoft Kinect SDK) [11].

- Real-time, GPU-assisted 3D object and scene reconstruction by using the Kinect for Windows sensor
- Ability to infer relative sensor position and orientation from a 3D scene for augmented reality application
- Advanced algorithms that are powerful enough for large sensor movements and scene changes during scanning
- Direct X11 compatible graphics cards supported
- AMD Radeon 7950 and NVidia GTX560 have been validated to run at interactive rates
- Kinect Fusion Studio and samples demonstrate 3D scanning capabilities
- Non-real time CPU mode for non-interactive rate scenarios.

2.6 Photosynth

This product allows for two different types of visualization based on photogrammetry technologies. It was developed in collaboration between University of Washington and Microsoft research laboratories. There are currently two functions within Photosynth, Synths, and panoramas. The "synth" uses multiple images that are analyzed in order to generate a three-dimensional image of the space. The second is a panorama which allows the user to take multiple pictures in a three-dimensional space. These pictures are then processed. The processing analyzes the images and combines them in a process called stitching. Figure 2.5 demonstrates

Fig. 2.5 Stitched image

the output of a stitched image, warped in a way so that it can be mapped to a spherical interactive QuickTime VR environment. This image was created using Photosynth, a product developed by Microsoft computer vision research laboratories.

There are a large number of Photosynth experiences is available on the Microsoft Web site: http://photosynth.net/explore.aspx. In addition to giving a description and showing the date created, many of them are geotagged (GPS info embedded in the metadata) for easy connection to map information.

2.7 Weta Digital: Photospace

In their presentation and published paper [12], they discuss the integration of a photogrammetry-based workflow for physical props for digitization and use in visual effects sequences. In their paper, they discuss previous workflows which use photographic reference, 3D modeling and 3D scanners. They describe the photogrammetry (vision-based) approach as combining the best features of multiple approaches. They described the workflow process as having three parts: (1) the capture session, (2) photogrammetry processing session, and (3) reference generation session. Images are captured, they are processed, and then, the three-dimensional models that are generated are handed to 3D artists for retopologizing or remodeling in order to make them efficient for use in the rendering pipeline. They also discussed many of the challenges and limitations connected to other photogrammetry-based workflows (see below).

2.8 Autodesk 123D Catch

123D Catch is a free photogrammetry software tool created by Autodesk Corporation. It has been produced for online use, in mobile device "app" form as well as standard desktop. The simplicity and quality of output generated by this software have made it very popular. Creating 3D meshes from photography is a simple process. The user takes 20–40 images of an object (with a maximum of 70) and feeds them to the program, which develops a 3D mesh from an analysis of the images. The software finds and matches common features in order to construct a 3D mesh from the identified feature sets.

2.9 Challenges and Current Limitations

While there have been many improvements in both speed and accuracy over the last 20 years, there are still hurdles to overcome. Many of the algorithms that are used for translating computer vision resources into 3D mesh objects can be easily broken, which generates a failed, problematic, or incomplete 3D mesh. These limitations listed below are fairly standard among the previously listed and most other current photogrammetry technologies. However, most softwares list these as heuristics to overcome many of the issues with current programs, because knowing the use guidelines can help overcome failed or problematic meshes.

2.9.1 Occlusions and Number of Photographs Necessary

Occlusions can cause problems. An occlusion is when and unwanted object comes between the camera and the target photogrammetry object. In small scenes, this can be things like imaging a human who wears glasses (also see below regarding transparent objects). An example of a similar problem for a large exterior scene would be a tree in front of a house. Most semicomplex objects have moderate self-occlusion, especially if they have multiple folding or complex parts. However, with enough images from the correct angle, many current photogrammetry algorithms are robust enough to solve for the objects. For heavy occlusion, images every 5–10°, overlapping as much as 50 %, might be necessary. For object with little or no occlusion, images ever 20° or more can be used for excellent results.

2.9.2 Photographs Need Features

The algorithm searches for parallax shifts between known features within multiple images. Taking images of blank walls or large empty/non-focused areas will cause the algorithm to fail. Patterns, strong lines, and differentiated features are what the algorithm looks for when tracking. Sometimes adding features with tape, stickers, or draped cloth can get better results. Similar to objects with no features (like the previously discussed blank wall), repetition of features can cause a similar confusion for the algorithm when trying to match feature sets.

2.9.3 No Transparent, Reflective, or Glossy Subjects

This creates certain difficulties for many objects. Even semitransparent objects can pose problems. When applicable, spray-painting them with matte finish can remove any transparent or shiny qualities. However, for large objects, for example buildings with reflective and semitransparent windows, they can pose difficulties.

2.9.4 Subjects Cannot Move During the Image Capture Process

In order for the algorithm to match the feature sets, object cannot significantly move.

2.9.5 Consistent Lighting

This not only means not changing light sources, but the algorithm works best **without** strong directional sources of light. Meaning outdoors, cloudy days (ambient light) would create the best lighting conditions. Indoors might require diffusers to create as ambient and consistent lighting conditions as possible. Additionally, the use of a flash will cause problems due to the fact it will create a unique (directional) lighting situation for each image.

For further reference listing the limitations of the 123D Catch, please follow this link to the following video: http://www.youtube.com/watch?v=7TfXXJxDsXw#at=64.

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