Photogrammetry Summary

Lab 58 Technology Research Brief

July 2020

Photogrammetry is "the science of making measurements from photographs". [1] Photogrammetric technology enables everyday photographs to be converted into many outputs, ranging from simple measurements, maps, and drawings to complex 3D models of real-world people, objects, or scenes.[1] The methodology behind this process can vary, but typically consists of either aerial or terrestrial methods. Within RTI, Lab 58 has been using the walk-around and turntable methods (terrestrial methodology) to generate complex 3D models, suited for many different use cases in the augmented and virtual reality markets especially. Scaled up application could include: mapping, civil and structural engineering, geology, archaeology, medicine, sports, real estate, film making and entertainment, forensics, and more.[2]

KEY TAKEAWAYS

Photogrammetry is "the science of making measurements from photographs".

Use cases for photogrammetry include mapping, civil and structural engineering, geology, archaeology, medicine, sports, real estate, film making and entertainment, forensics, and more.

There are 2 key methods used in photogrammetry: aerial and terrestrial. Lab 58 has significant experience using terrestrial photogrammetry, specifically the walk-around and turntable methods, to generate complex 3D models.

What is photogrammetry?

In its simplest form, photogrammetry is "the science of making measurements from photographs". [1] Photogrammetry is an essential tool for creating maps, 3D models, and the structural analysis of any site. It makes it easy, fast, and cheap to collect and analyze highly accurate data from imagery.

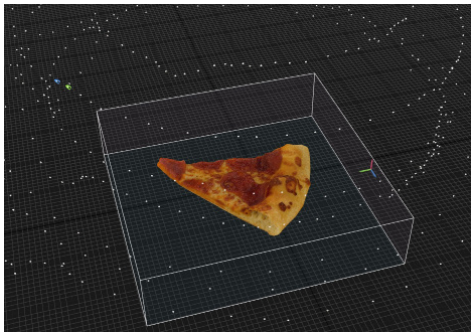


Figure 1: Above is a photogrammetric model of a slice of pizza that was generated by Lab 58.

Within RTI, Lab 58 focuses on generating 3D models using photogrammetric technology. This is done by first taking hundreds of overlapping photographs (the more, the better) of an object or space, either interior or exterior. The photographs are then imported into software, such as Reality Capture, for image alignment and creating a mesh. The mesh is then textured and finally exported as a 3D file. At this point, the mesh can be imported into another software tool for refinement, or it can be completed. Generally speaking, "the input to photogrammetry is photographs, and the output is typically a map, a drawing, a measurement, or a 3D model of some real-world object or scene." [1]

1. Photogrammetry. http://www.photogrammetry.com/
2. Planning Tank. https://planningtank.com/geographic-information-system/applications-advantages-disadvantages-of-photogrammetry

Workflow - Producing 3D Models

There are multiple steps in the workflow to produce 3D models using photogrammetry. The use of this technology requires some expertise, as well as access to various software tools. The workflow is described below

1. **Set up light sources**. Light sources must be even, and seemingly natural. Shadows cannot be included in the photos.
2. **Take photographs**. Photographs must be taken slowly and carefully, to ensure that they are clear, vivid, and each photo is overlapping the others. Producing a quality mesh is difficult with less than 100 photos, so the more images that can be captured, the better. Many 3D models use upwards of 500 photos.
3. **Upload the photos into software.** Put the photos into software, such as Reality Capture. There is a tool that aligns the images by finding all the overlapping connections. At this point, it is clear whether more images need to be taken to complete the mesh.
4. **Construct the mesh.** The mesh construction can take anywhere from 10 minutes to 1 hour, depending on the number of photos. The software will output a mesh.
5. **Edit the mesh.** The mesh can now be inspected and edited. It should be slick and smooth, made up of squares. Less squares are ideal for a clean mesh.
6. **Add texture.** At this point, texture can be added to the mesh. Some software platforms are better than others for this process.
7. **Export the 3D model file.** Export the file as a .obj or .fbx file, or any other compatible 3D file formats.
8. **Edit the final 3D model.** Import the file into a modelling software like Maya to be polished, or refine the textures in Substance Painter.

Common Photogrammetry Methods

The types of photogrammetry are distinguished by the camera technique that is used—flying cameras in drones or other aircraft is referred to as Aerial Photogrammetry, and closer-range approaches are referred to as Terrestrial Photogrammetry. [1]

Aerial Photogrammetry

In Aerial Photogrammetry, sometimes referred to as Drone Photogrammetry, the camera is mounted on an aircraft to take photographs of the land below. More recently, drones and UAVs have been used for their accuracy and steadiness in flight. The cameras take numerous overlapping photos throughout the flight and they utilize automated desktop systems to process this into relevant information.

Terrestrial Photogrammetry

In Terrestrial Photogrammetry, also known as Close-Range Photogrammetry or Image-Based Modeling, cameras are positioned on the ground to take photographs of the surroundings. Although this method does not typically produce topographical data for terrain models and topographical maps, it does produce drawings, 3D models, measurements, and point clouds. With this technology, "everyday cameras are used to model and measure buildings, engineering structures, forensic and accident scenes, mines, earth-works, stock-piles, archaeological artifacts, film sets, etc." Terrestrial photogrammetry can be broken up into two sub-categories, known as the walk-around method or the turntable method, which each have their own advantages and disadvantages.

The **walk-around method** is simple because it requires nothing more than a camera and good lighting, but it can be cumbersome to accurately take overlapping photos by hand. Whereas, the **turntable** method provides more consistency in the photos, and it is a quick method to capture smaller objects. Unfortunately, the turntable method limits the size of the object you capture, does not allow for interior/exterior spaces to be captured, and it requires more gear (turntable, tripod, lights, etc).

Figure 2: The turntable method, as shown on the left, provides more consistency in photos, and is a quick method to capture smaller objects.

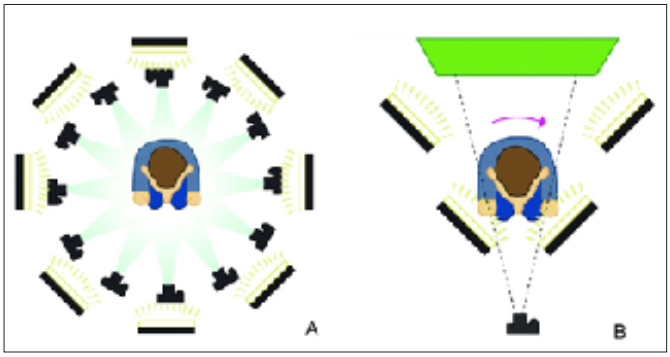


Figure 3: The walk-around method, pictured on the left, is requires nothing more than a camera and good lighting, but it can be cumbersome to accurately take overlapping photos by hand.

Considerations for Successful Photogrammetry Applications

Although photogrammetry is already being applied in various fields, especially in 3D modeling, there is still room for growth. Key considerations for the application of photogrammetric technology is outlined below:

Technical Feasibility

Photogrammetry continues to improve, and new computational methods continue to refine the speed and accuracy of this approach to gathering measurements and creating 3D models, however, researchers should apply the technology with the following technical considerations in mind:

- **Objects and spaces with transparent, shiny, or reflective objects are difficult to capture.** These properties often create holes in the meshes that are created in the model from photographs. Common technical approaches to solve this problem include spraying transparent objects with a substance that allows them to be rendered opaque or building those portions in the modeling software rather than using the photographs to generate them automatically.
- **Scene capture requires consistent lighting and object placement.** The technology is limited in its capabilities to survey without sufficient light, or when there is low visibility due to weather, obstructions in the view, etc. Also, shadows or under/over exposure can cause holes or deformations in the model. It is crucial that the light remains balanced and objects are kept still in each frame.
- **The images used must be clear and focused.** It is critical that the photographer takes their time when adjusting camera angles and taking photos. Any blurred images must be retaken due to the deformations that they can cause in the mesh.

Operational Limitations

When implementing photogrammetry in any use case, some technical requirements and recommendations will help achieve the greatest accuracy and success. Important operational limitations to consider are as follows:

- **Creating 3D models requires software access and significant computing power.** There are off-the-shelf tools that allow for easy access to photogrammetry technology. The use of the cloud versus computation on individual computers is currently an important distinction in the delivery of this technology. Reality Capture (RC) is often used within Lab 58, as it is the best software tool on the market for generating 3D models. RC costs $40/month, but is free on Stream. AutoCAD ReCap is a cloud-based tool that is used less frequently within the Lab because it renders and processes online so it requires waiting. There is also a limitation on the number of models that can be generated. The cost is dependent on the size of the model.
- **When using aerial methods, accuracy is dependent on altitude.** The accuracy of the collected measurements can significantly depend on the altitude of the flight that is surveying the land.
- **The technology is not yet working in real-time.** It requires processing time to generate measurements and 3D models.

Ethical Appropriateness

When considering various photogrammetric applications' ethical appropriateness, there are a few key ideas to keep in mind. The following are important considerations for appropriate use:

- **Aerial photogrammetry poses privacy concerns.** In big-picture drone footage, there are ethical concerns around capturing people's homes and other private property without gathering prior consent.
- **There is no policy in place to determine who and what can be 3D modeled.** The ability to recreate 3D model of humans raises questions around if everything should be modeled, or where the appropriate line should be drawn. Do 3D models of people have the same protections as pictures and videos would?

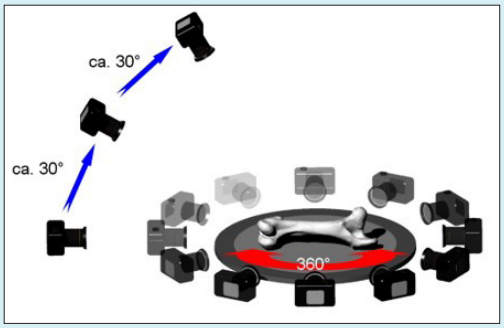
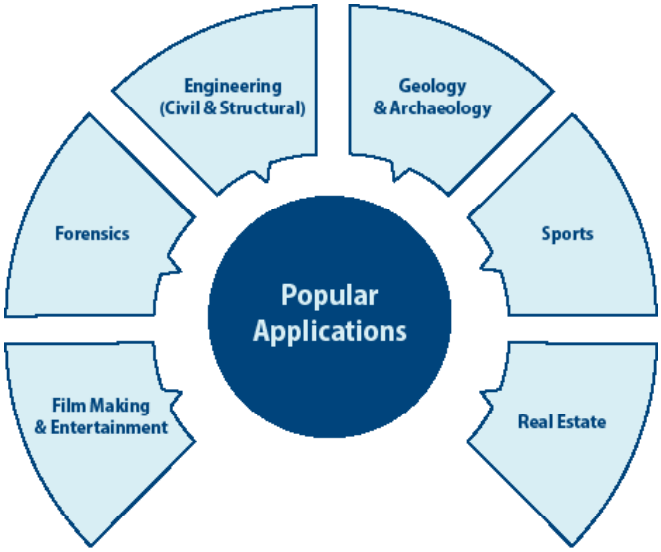


Figure 4: When photographing an object, the basic steps to follow are: move the camera angle, take a photo, rotate and take photos roughly every 10 degrees, repeat.

How can photogrammetry be used in business today?

Photogrammetry is currently used in a wide variety of use cases. Within Lab 58, we find that 3D modeling is a photogrammetric output that is incredibly useful, especially in the growing augmented and virtual reality markets. The 3D model outputs that we generate can add realistic qualities to video games and movies. For example, in Electronic Art's *Star Wars Battle Front* and *Black Panther*, photogrammetric outputs are seen where environment scenes and clothing were generated using 3D modeling. Generally, researchers and companies could find value from using this technology in the use cases below.



Photogrammetry is used in mapping, civil and structural engineering, geology, archaeology, medicine, sports, real estate, film making and entertainment, forensics, and more. [2]

Future Direction

The future is bright for applied photogrammetry. It can be used in a wide variety of important use cases, as seen above, and sparks the interest of many industry leaders and innovators. As the technology progresses, the labor of editing 3D models will be automated and the processing will be done quicker and quicker until models are able to be made in real time. As this becomes a reality, photogrammetric technology will simultaneously become more automated, more affordable, and easier to use. In the more distant future, photogrammetry will be a polished tool that can be used by any smartphone user to generate their own 3D models, almost instantaneously.

Overview of Photogrammetry Technology

Figure 5: Photogrammetric model of a bluebird shown from different angles.

Working with Lab 58—Just Three Easy Steps!

Thanks for your interest in our work! We invite you to reach out to us for a helping hand as you explore opportunities to work with photogrammetry. These three quick steps will get you started:

1. Email us at Lab58@rti.org.
2. We will set up a 30-minute, one-on-one chat to discuss opportunities and answer any questions. We are interested in finding a solution for you that meets client needs. We often present technologies to your clients or conduct brainstorming sessions with them.
3. The Lab 58 team is here to help you and your clients. Please reach out, we are happy to hear from you!

More Information

Lab58@rti.org

LAB 58