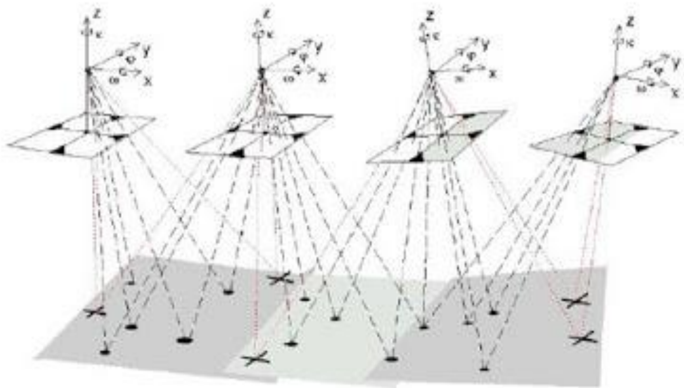
<u>Aerial triangulation</u>

In photogrammetry, aerial triangulation refers to techniques for determining and calculating 3-dimensional object coordinates using images taken from various angles and covering the same object.



We should be able to measure 3-dimensional coordinates for target elements on almost any object using aerial triangulation in aerial photogrammetry. We'll need at least a few known-position points visible in at least some of the images. The control points, which we refer to as ground control points or any control points, must be a part of the aerial triangulation.

Why we are using aerial triangulation?

Usually, it is more expensive to have people working out in the field, and it is also harder work than what it is to do the work is an office. Because of that different method has been developed to be able to reference a model with as few ground control points as possible. Still, we need at least five control points inside each aerial photogrammetry model to be able to do an absolute orientation of the model.

In aerial photogrammetry, to be able to get that many points a method named aerial triangulation is developed. This method is that we measure several unknown points clearly visible in the aerial triangulation in a stereo instrument. These new points together with the ground control points and the exposures positions for the camera are put together in a big computation. The result we get out of this is the coordinates in the reference system for all the new measured points.

What are the inputs for aerial triangulation?

1. Scanned Images
2. Camera Report
3. Ground Control Data/ Ground Control Point

<u>Bundle adjustment</u>

Given a set of images depicting a number of 3D points from different viewpoints, **bundle adjustment** can be defined as the problem of simultaneously refining the 3D coordinates describing the scene geometry, the parameters of the relative motion, and the optical characteristics of the camera(s) employed to acquire the images, according to an optimality criterion involving the corresponding image projections of all points.

In general, two approaches to perform bundle adjustment may be followed:

1. Free-network bundle adjustment: The free-network approach involves a calculation of the exterior parameters in an arbitrary coordinate system, followed by a 3D similarity transformation to align the network to the coordinate system of the control point (“the real-world system”). In classical aerial photogrammetry, this approach echoes the relative orientation (free network orientation) and the absolute orientation (similarity transformation) steps.

2. Block bundle adjustment: The block bundle approach involves a simultaneous least-squares estimation of the 3D point coordinates, the external camera parameters and, optionally, the internal camera parameters, in the coordinate system of the control points. This is done by introducing at least three control points and integrating them within the computation matrix. Appropriate weights can be applied to these observations.

Uses:
Bundle adjustment is almost always used as the last step of every feature-based 3D reconstruction algorithm. It amounts to an optimization problem on the 3D structure and viewing parameters (i.e., camera pose and possibly intrinsic calibration and radial distortion), to obtain a reconstruction which is optimal under certain assumptions regarding the noise pertaining to the observed image features: If the image error is zero-mean Gaussian, then bundle adjustment is the Maximum Likelihood Estimator.

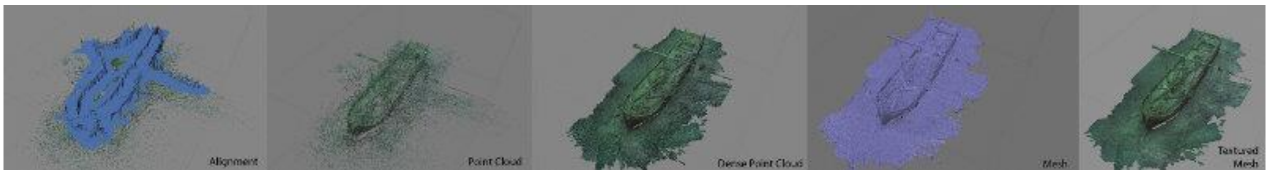
Its name refers to the bundles of light rays originating from each 3D feature and converging on each camera's optical center, which are adjusted optimally with respect to both the structure and viewing parameters (similarity in meaning to categorical bundle seems a pure coincidence).

Structure from Motion Photogrammetry
Structure from Motion (SfM) photogrammetry is a method of approximating a three-dimensional structure using two dimensional images. Photographs are stitched together using photogrammetry software to make the three-dimensional (3D) model and other products like photomosaic maps. It has become an efficient method for rapidly recording underwater archaeological sites, and can also be used to characterize seafloor features, such as coral reefs.

How does it work?
Photogrammetry consists of collecting images using either a remotely operated vehicle (ROV) or a team of divers. A camera moves over the site in a pre-planned route, taking hundreds or thousands of still shots from the top, sides, and inside of the structure. It is important for the photos to overlap so that every inch of the site is recorded at more than one distance and angle. Video footage can also be used for photogrammetry by creating still images through video capture.

What happens next?
Once the divers or ROV have finished collecting imagery, the photos are merged into one large file and corrected for color balance and exposure. Next, the images are processed through photogrammetry

software. The program uses an algorithm to create a photo mosaic, which retains the detail of each individual image, and then searches for common landmarks within the photos such as a ship hull fragment. Each landmark is oriented on the landscape using data about its size, surface area, and spatial position; all of this information creates what is called a data point cloud. This point cloud is used to map nodes or vertices onto a solid surface, resulting in a 3D model of the site. At this point, the model is completely colorless, so the software uses color data from the original images in order to “paint” in the pixel of every feature.



The steps of producing a basic photogrammetric model. From left to right is the initial alignment of images and point cloud generation. Next is the dense point cloud, followed by blank mesh interpolated from the dense points. The textured mesh uses the pixel values from the original images to assign color values across the surface of the solid mesh.

Multi view stereo reconstruction

Multi-View Stereo (MVS) as a low-cost technique for precise 3D reconstruction can be a rival for laser scanners if the scale of the model is resolved. A fusion of stereo imaging equipment with photogrammetric bundle adjustment and MVS methods, known as photogrammetric MVS, can generate correctly scaled 3D models without using any known object distances. Although a huge number of stereo images (e.g., 200 high resolution images from a small object) captured of the object contains redundant data that allows detailed and accurate 3D reconstruction, the capture and processing time is increased when a vast number of high-resolution images are employed.

Moreover, some parts of the object are often missing due to the lack of coverage of all areas. These problems demand a logical selection of the most suitable stereo camera views from the large image dataset. The approach focuses on the two key steps of image clustering and iterative image selection.

The method is developed within a software application called Imaging Network Designer (IND) and tested by the 3D recording of a gearbox and three metric reference objects. A comparison is made between IND and CMVS, which is a free package for selecting vantage images.

The final 3D models obtained from the IND and CMVS approaches are compared with datasets generated with an MMDx Nikon Laser scanner. Results demonstrate that IND can provide a better image selection for MVS than CMVS in terms of surface coordinate uncertainty and completeness.

Multiple view geometry

Multiple view geometry is the subject where relations between coordinates of feature points in different views are studied. It is an important tool for understanding the image formation process for several cameras and for designing reconstruction algorithms.

- Recover camera and geometry up to ambiguity: Use affine approximation (affine SFM), Algebraic methods, Factorization methods

❖ Metric upgrade to obtain solution up to scale (remove perspective or affine ambiguity)
❖ Bundle adjustment (optimize solution across all observations)

<u>What is PDAL</u>

PDAL is a set of C libraries and command-line applications designed to work with topology-free point data (i.e., not gridded)

Why use PDAL?

PDAL was designed to meet the needs of users working with airborne LiDAR datasets. It has since grown to accommodate a number of different styles of point cloud data, and ways to use them. It was an early adopter of the LAS 1.4 community standard, and offers the best open-source, interoperable point cloud data processing engine we have seen to date.

<u>GDAL</u>

GDAL stands for "Geospatial Data Abstraction Library"

GDAL works on both raster and vector data types, and is an incredible useful tool to be familiar with when working with geospatial data. While the GDAL library can be used programmatically, GDAL also includes a CLI (**C**ommand **L**ine **I**nterface).

Some common uses:

- Quickly getting basic information about a dataset
- Converting between geospatial file types
- Clipping one dataset against another, and more.

Commonly-used commands

- ogrinfo Get information about a vector dataset
- gdalinfo Get information about a raster dataset
- ogr2ogr Convert vector data between file formats
- gdal_translate Convert raster data between file formats

We can also use GDAL to convert raster data from one file format to another.

<u>References:</u>

- http://photogrammetrydevelopment.blogspot.com/2010/08/what-is-aerial-triangulation.html#:~:text=Aerial%20Triangulation%20in%20Photogrammetry%20is,positions%2C%20covering%20the%20same%20object.&text=We%20need%20at%20least%20some,least%20some%20of%20the%20photographs.
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