# Modelling Cultural Heritage with Photography: a New Approach for Image Acquisition using UAV

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# Motivation
## Digital Documentation

The current conditions of a construction, also called "as-is" building, must be correctly observed, obtained and analyzed in many applications [Remondino, 2011] such:

- Historic Documentation

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- Historic Documentation
- Restoration
- Conservation

# Motivation
## Digital Documentation

Laser sensors are commonly applied in building data acquisition, resulting in an extremely precise representation, although expensive and its high computational cost.

Figure: Field equipment necessary for acquisition. Source: [Oldow and Singleton, 2008]

# Motivation
## Digital Documentation

### Point Cloud

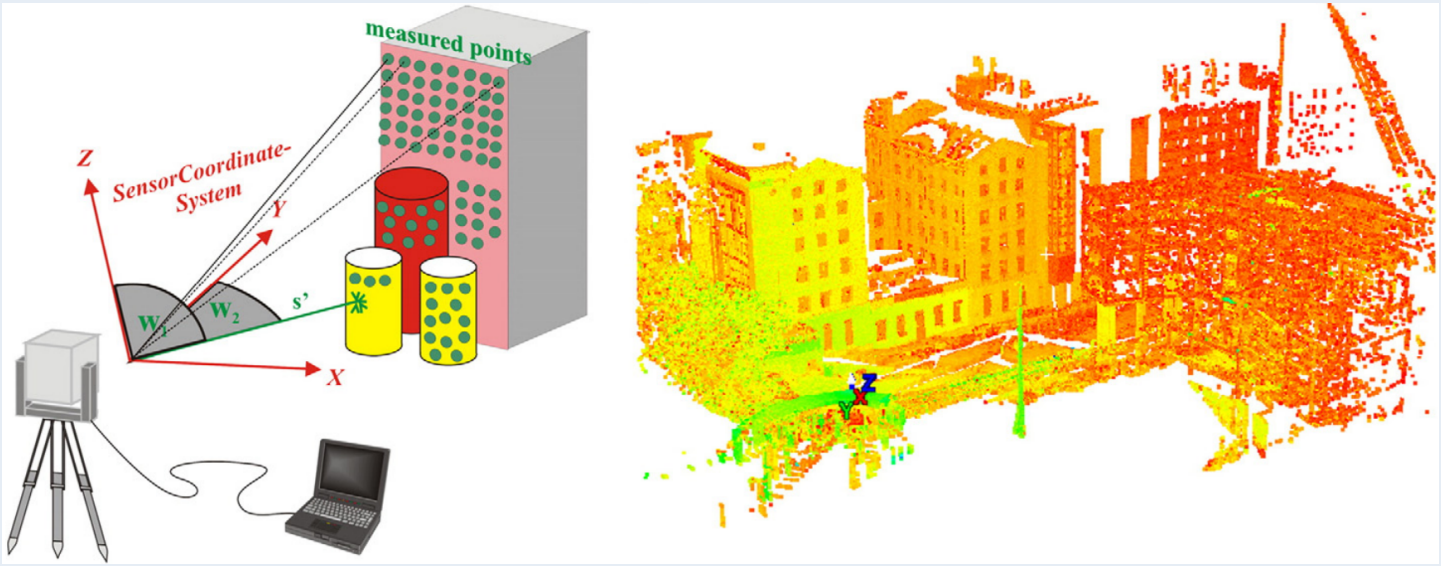


Figure: The laser scanning process for measuring 3D point. Source: [Tang et al., 2010]

# Motivation
## Digital Documentation

Combining a large set of pictures, toke from different angle, and applying a method called *Structure from Motion* a similar result can be achieved.

Figure: Point cloud generation with SfM. Source: Bundler Project.

# Motivation
## UAV acquisition difficulties

Unlike laser sensors, *Unmanned Aerial Veichels* (UAV) with digital cameras are now affordable and user-friendly.

Figure: Eight-rotor UAV platform (BNU-D8-1) fitted with Cannon 5DII. Source: [Xu et al., 2014].

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## UAV acquisition difficulties

Despite this, a universal data (image) acquisition protocol is not yet available, what make it an effective but still experimental process. Particularly in cultural heritage, is not a trivial task due:

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- Partial occlusion
- Element uniqueness
- Weather conditions

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- Element uniqueness
- Weather conditions
- etc...

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## UAV acquisition difficulties

### Question

What is required to develop a standard protocol applicable to image acquisition of heritage by adopting UAV systems?

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# Theoretical Background

## Photogrammetry

Photogrammetry is the science of making measurements from photographs, based on camera calibration.

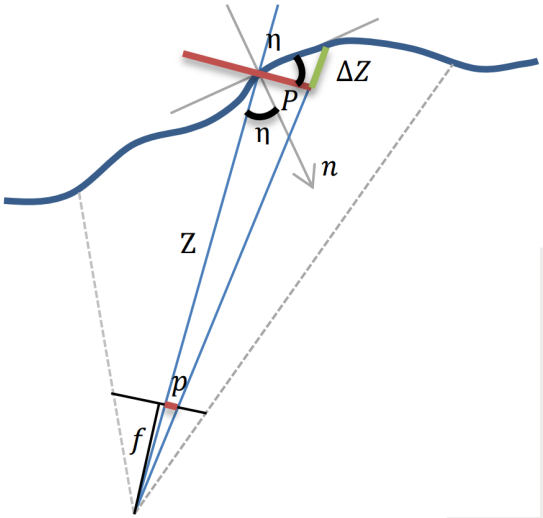


Figure: Camera parameters for distance estimation. Source: [Wenzel et al., 2013]

# Theoretical Background

## Photogrammetry

According to [Murtiyoso et al., 2016], there are different established and trustworthy image acquisition protocols. This methods share common characteristics, such as:

- Position and sensor calibration steps
- Angle convergence
- Image overlay

# Theoretical Background

## Structure from Motion

*Structure from Motion* (SfM) techniques uses overlapping pictures to extract object information by using camera internal parameters for orientation [Micheletti et al., 2015].

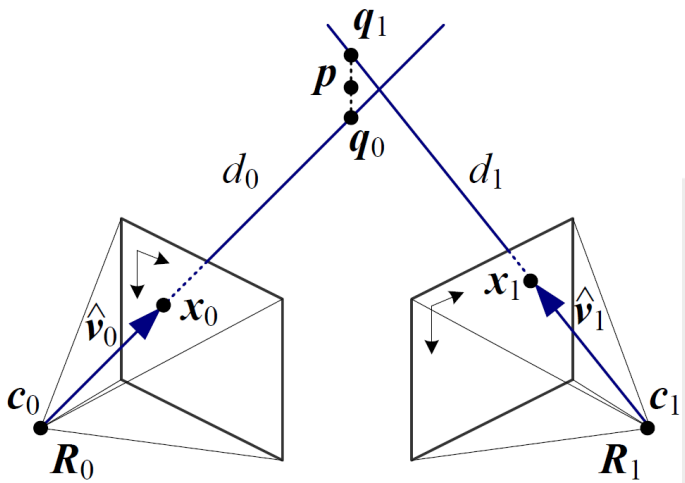


Figure: 3D point triangulation by finding the point $\mathbf{p}$ that lies nearest to all of the optical rays $\mathbf{c}_j + d_j\hat{\mathbf{v}}_j$. Source: [Szeliski, 2010]

# Theoretical Background

## Structure from Motion

For outstanding outcome, it is imperative:

- Generous collection of images
- Similar pictures took from rotated points of view (vertical and horizontal)
- Depth and range variable points of view

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# Proposed Approach

## Pipeline

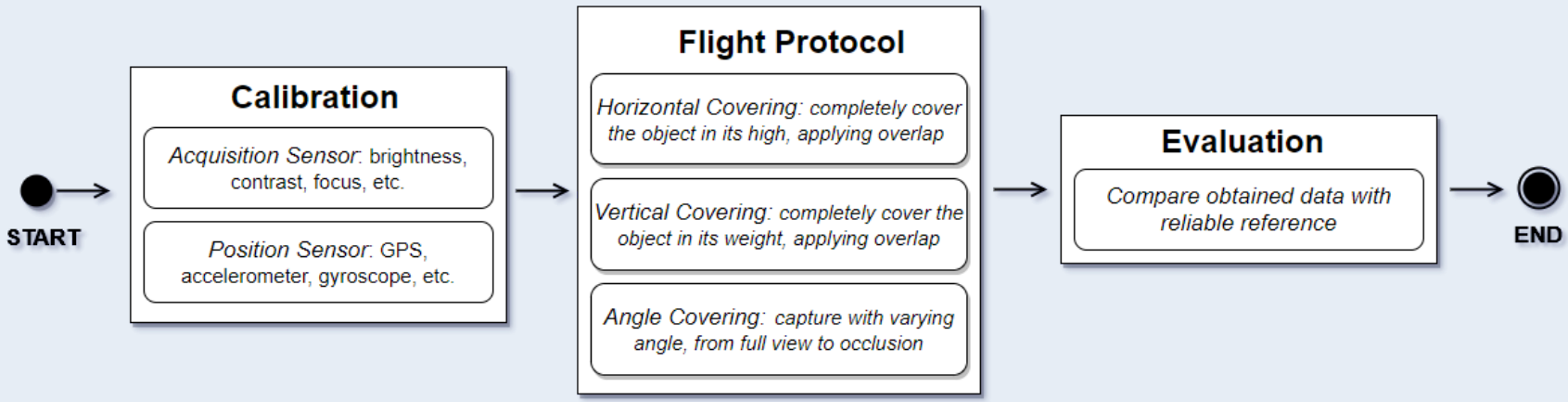


Figure: Activity diagram of an effective approach for acquisition systems to structure modeling using SfM techniques. Source: author.

# Proposed Approach
## Calibration

- 3D model construction requires precise sensor position estimation
  - Start from the highest point, allowing satellite synchronization (as much as possible).
- Regarding the camera
  - Brightness, focus, contrast and saturation are currently well adjustable in auto-mode

# Proposed Approach
## Flight Protocol

A path capable to cover full angle variation of the structure, parallel and perpendicular, is the hardest challenge in UAV flight planning.

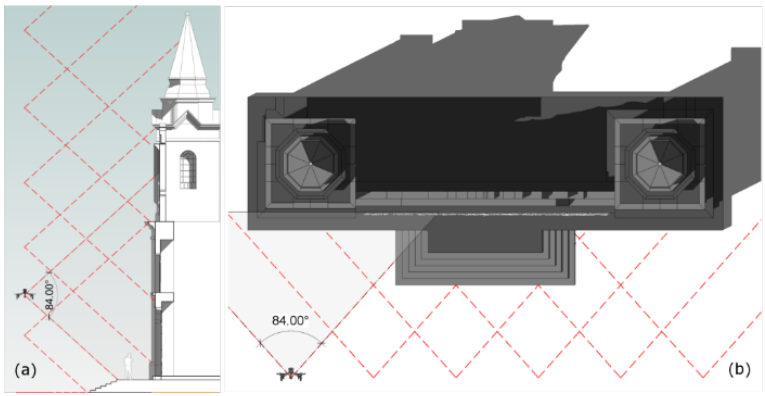


Figure: Height and weight portions fully covered.

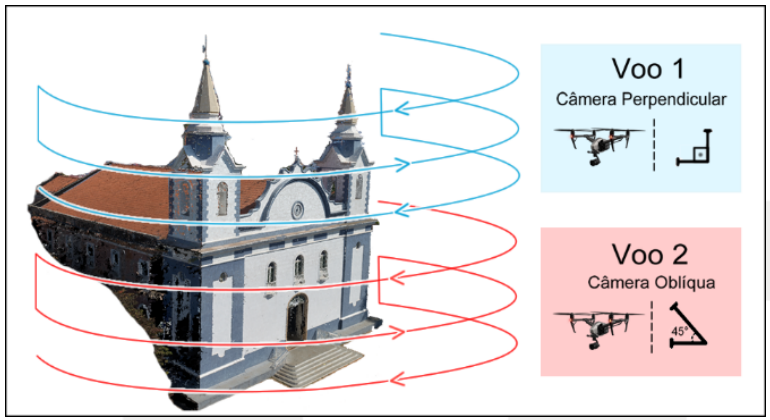


Figure: Flight plan with high angle variation.

(Source: author)

# Proposed Approach
## Evaluation

Once collected and processed, data could be evaluated comparing regional projection of point cloud to it equivalent "as-design".

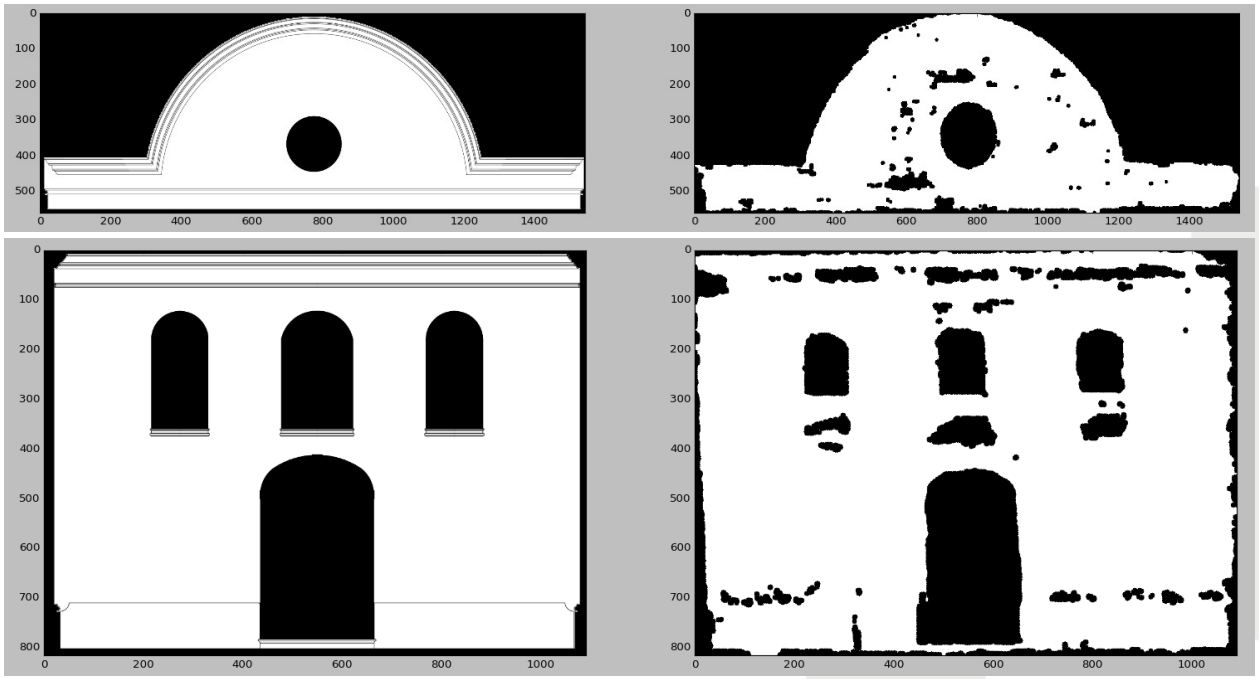

Figure: Comparative among projections and project views. Source: author

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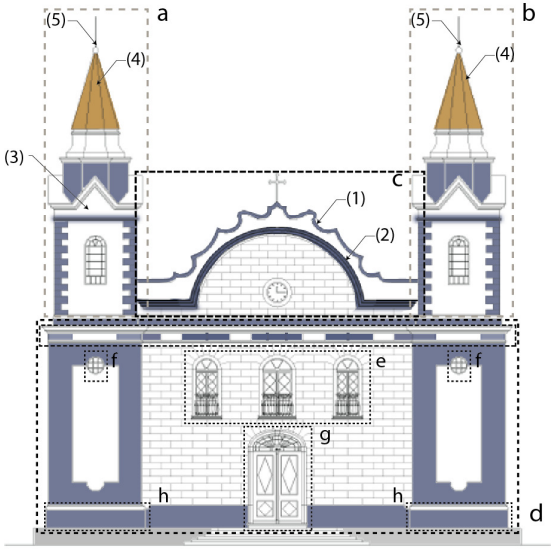
# Conclusion
## Partial Results




a. Right Bell Tower;

b. Left Bell Tower;

c. Double pediment with a clock on the tympanum. Straight cymatium (2) and scrolled pediment (1);

d. Frontispiece, with spare bell towers base (cornice highlighted in the figure made up of cymatium and friezes).

g. Main door with lintel in segmental arch and door frame both in carved stone.

h. Bell towers base;

Table: Analysis of segmented regions compared to the as-designed model.

| COMPONENTS | PRECISION | RECALL | ACCURACY |
|---|---|---|---|
| Frontispiece with voids of windows and doorways | 87,73 | 93,37 | 85,76 |
| Tower base (right) | 94,63 | 86,56 | 84,79 |
| Tower base (left) | 94,34 | 94,68 | 90,89 |
| Right Bell Tower | 85,30 | 89,45 | 83,44 |
| Left Bell Tower | 84,41 | 63,92 | 69,45 |
| Double pediment (tympanum and cymatium) | 55,68 | 39,29 | 82,32 |
| Scrolled pediment | 96,02 | 87,18 3 | 91,18 |

# Conclusion
## UAV and SfM popularization

- UAV popularization and SfM algorithms allow cultural heritage documenting and modelling
  - User-friendly

- This work introduced a UAV image acquisition protocol able to produce strong representation for cultural heritage applications

- Future analysis in method and application are necessary, especially with different heritage objects and SfM implementations.

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Thank you!