GUIDELINES FOR RECORDING MONUMENTS AT BAGAN

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Contents

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Finally, the authors wish to thank all those individuals and institutions that in one way or another helped with the completion of these guidelines.

References for material contained within this document are provided at the end.

Introduction

Good practices in heritage conservation are based on timely, relevant and accurate information about the conditions, materials and transformation of built heritage. Therefore, documentation, recording and analysis of heritage sites are an essential part for their management and conservation.

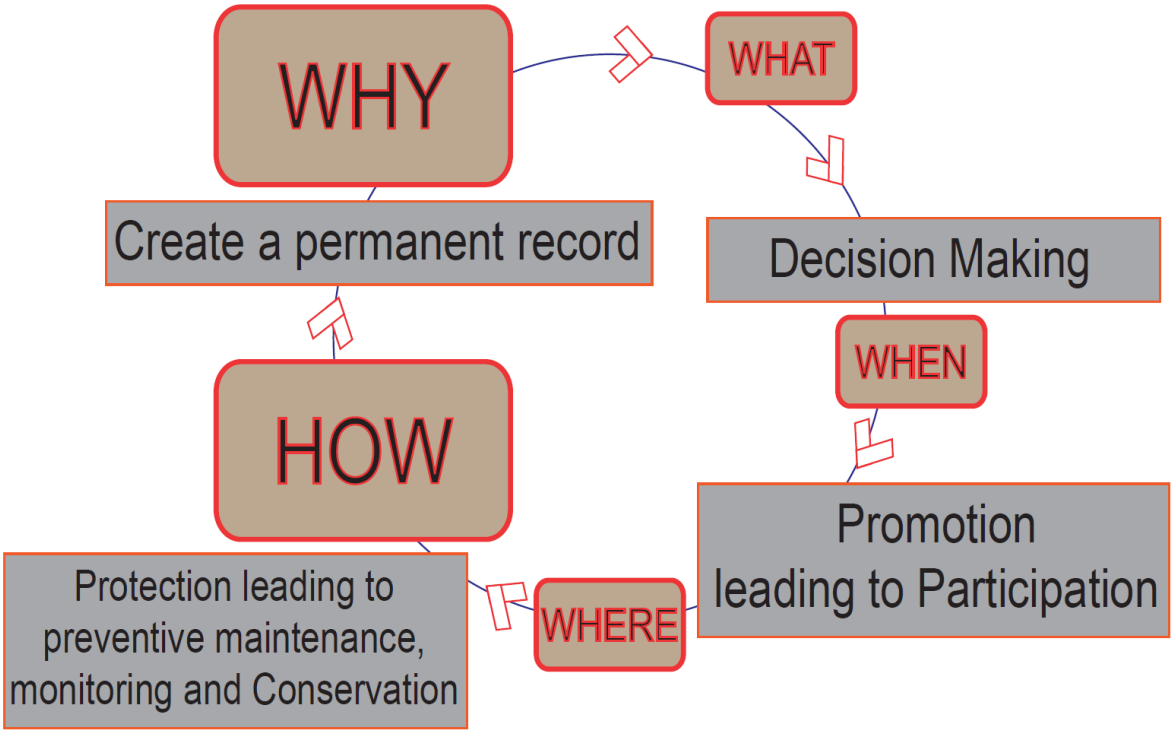

Figure 1 Diagram depicting why and how recording heritage places.

Why are these guidelines useful?

The document aims at providing step by step specification on the most efficient recording strategies for the particular architectural features of Bagan built heritage. The Guidelines aim at providing a methodology and empirical specification to update the Bagan inventories for the maintenance, conservation and eventual nomination of this heritage site. Bagan built heritage is characterised by irregular shapes (also due to the high level of damage such as cracks, pathologies, structural problems, etc., affecting these fabrics) and buildings complexity (fabric's structural behaviour, architectural details, decorative elements, etc.). Considering the complexity of these historic structures and the limited number of DoA staff, recording techniques have been selected according to four criteria.

These criteria include:

- *Accuracy*: capability to capture the complexity of monuments in detail (according to the scale of the architectural drawings to be elaborated, such as scale 1:100 or 1:200).
- *Time*: developing data capturing phase (field survey) in a relatively short amount of time (from 4/6 days up to14 days for each monument depending on its size).
- *Cost:* employing affordable techniques and tools for the data capturing phase, such as photogrammetry, where only a DSLR camera (already owned by the DoA staff), and a software for the data processing phase are needed. Whenever possible open source software for the data processing phase have been selected.
- *User friendly*: employing user friendly techniques and software (if possible) providing at the same time a step by step guide (in the protocols) on how to use and manage tools and software.

Therefore, these guidelines are useful for the DoA staff (and anyone involved in the conservation of Bagan structures), to record built heritage according to a time and cost efficient methodology, employing advanced tools and techniques to gain an high level of accuracy and detail of the recorded buildings.

Hence, this document explains how to:

What is this document explaining?

- Understand the role of visual information gathering in historic conservation, according to national and international standards.
- Identify strengths and limitations of relevant recording techniques.
- Measure & Analyze sites using different IT- supported techniques.
- Understand the relationship between recording and good conservation decision-making.
- Learn how to integrate information gathered through these techniques for two dimensional drawings elaboration.

Additionally to these issues the document describes a surveying strategy replicable to all Bagan monuments in vision to the World Heritage nomination.

The challenge to combine technical innovation with local resources for documenting Bagan heritage is also addressed.

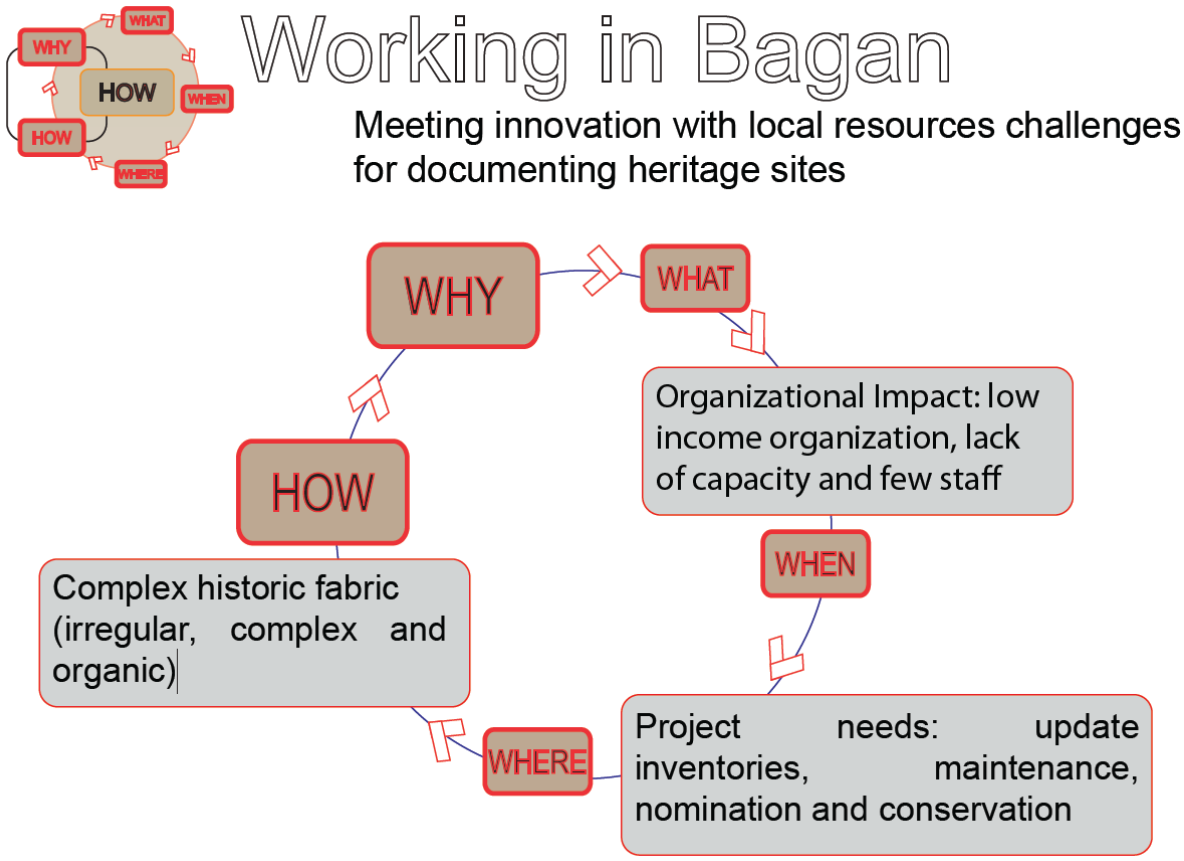

Figure 2 Diagram depicting challenges and needs in documenting Bagan built heritage.

The document illustrates how to document the Bagan built heritage employing four different techniques. The Guidelines explain how to use these techniques to generate a series of architectural drawings to map the conditions of Bagan monuments as well as their architectural significance (character defining elements).

The techniques described are:

- Hand survey drawings;
- Reflectorless Eletronic Distance Measurement (REDM) measurements (using a Total Station TheoLt);
- Photogrammetric Survey;
- Record Photography[1] .

Guidelines structure

The Guidelines are articulated into two sections: the field survey and the data processing phase. In the first section tools, techniques and the different steps to be followed in the field survey are presented.

[1] Due to the high cost of a laser scanner (about $40.000) and of the licence for the related software for data processing, the laser scanner technique has not been considered in this document.

The second section presents how to process the data acquired in the field survey. This part presents how to use different software and applications to elaborate line drawings.

The manual aims at providing an approach for the effective use of recording systems in the conservation of built heritage. The information here presented provides a step-by-step approach for the use of the Reflectorless Electronic Distance Measurement Total Station (REDM) equipment, hand survey drawings, record photography and photogrammetric practices. These recording systems - combining image-based survey methods such as Photogrammetry and architectural survey such as Total Station - are employed to develop CAD (Computer Aided Design) drawings (floor plans, cross sections and elevations).

The methods and procedures used for producing architectural drawings - which include approaches for capturing the building fabric and geometry, as well as shape - are presented.

Furthermore, the detailed procedures for processing and integrating heritage information captured with different sensors are presented in the protocols. The types of tools (e.g., total station, drone, 3D scanner, DSLR camera) and software to be employed are also described.

The protocols that are referenced in the Guidelines are included in the Annex of this document.

The ultimate objective of this document consists in designing a documentation strategy for the DoA to determine a methodology and specific actions for interventions (long and immediate term) for the site of Bagan. In addition, the goals include also the production of reliable 2D and 3D records of the heritage structures for conservation purposes.

1. FIELD SURVEY PHASE

1.1 Principles for recording of monuments, groups of building and sites

During the recording phase it is recommended to keep in mind the ICOMOS *Principles for the recording of monuments, groups of buildings and sites (1996)* on "Contents of records". The principles are articulated into 5 main points here reported.

1) Any record should be identified by:

a) name of the building, group of buildings or site;

b) unique reference number;

c) date of compilation of the record;

d) name of the recording organization;

e) cross-references to related building records and reports, photographic, graphic, textual or biblio-graphic documentation, archaeological and environmental records.

2) The location and extent of the monument, group of buildings or site must be given accurately; this may be achieved by description, maps, plans or aerial photographs. In rural areas a map reference or triangulation to known points may be the only methods available. In urban areas an address or street reference may be sufficient.

3) New records should note the sources of all information not obtained directly from the monument, group of buildings or site itself.

4) Records should include some or all of the following information:

a) the type, form and dimensions of the building, monument or site;

b) the interior and exterior characteristics, as appropriate, of the monument, group of buildings or site;

c) the nature, quality, cultural, artistic and scientific significance of the heritage and its components and the cultural, artistic and scientific significance of:

i. the materials, constituent parts and construction, decoration, ornament or inscriptions,

ii. services, fittings and machinery,

iii. ancillary structures, the gardens, landscape and the cultural, topographical and natural features of the site;

d) the traditional and modern technology and skills used in construction and maintenance;

e) evidence to establish the date of origin, authorship, ownership, the original design, extent, use and decoration;

f) evidence to establish the subsequent history of its uses, associated events, structural or decorative alterations, and the impact of human or natural external forces;

g) the history of management, maintenance and repairs;

h) representative elements or samples of construction or site materials;

i) an assessment of the current condition of the heritage;

j) an assessment of the visual and functional relationship between the heritage and its setting;

k) an assessment of the conflicts and risks from human or natural causes, and from environmental pollution or adjacent land uses.

5) Considering the different reasons for recording different levels of detail will be required. All the above information, even if briefly stated, provides important data for local planning and building control and management. Information in greater detail is generally required for the site or building owner's, manager's or user's purposes for conservation, maintenance and use[2].

1.2 Survey toolbox

The toolbox consists of dimensional and visual tools for capturing the shape, scale, geometry and orientation of the building elements. It includes:

- Notes, pens, pencils, metal tape measure, plastic tape measure, profile gauge (possibly) and level (possibly).
- Laser Distance measuring (DISTO).
- Reflectorless Electronic Distance Measurement (REDM), measurements (Using a Total Station, TheoLt).
- GPS device.

[2] Source: http://www.icomos.org/charters/archives-e.pdf (last accessed 15/05/2015)

- DSLR camera equipped with a fisheye lens with a tripod.

The field measurements collected by the REDMs will have to be translated into Computer Aided Drafting (CAD) software. Due to the specificity of Bagan site, Distance measuring (DISTO) can be used to compute distance between straight surfaces. Photogrammetric techniques and rectified photography should instead be employed for elements that are difficult to survey by Total Station, such as stupas, stucco works, wall paintings, brickworks, mouldings and windows.

In the following paragraphs the different techniques associated with these tools are presented.

1.3 Field notes

In every method of heritage documentation (both traditional and digital recording) field notes are essential. The notes should include: the name of the recorder, date, site location, and any special circumstances of the environment. It is essential that all measured targets are clearly identified. Sketches are used primarily during the first phase of the survey to produce reference key plans for the location and point ID of the EDM targets and Total Station.

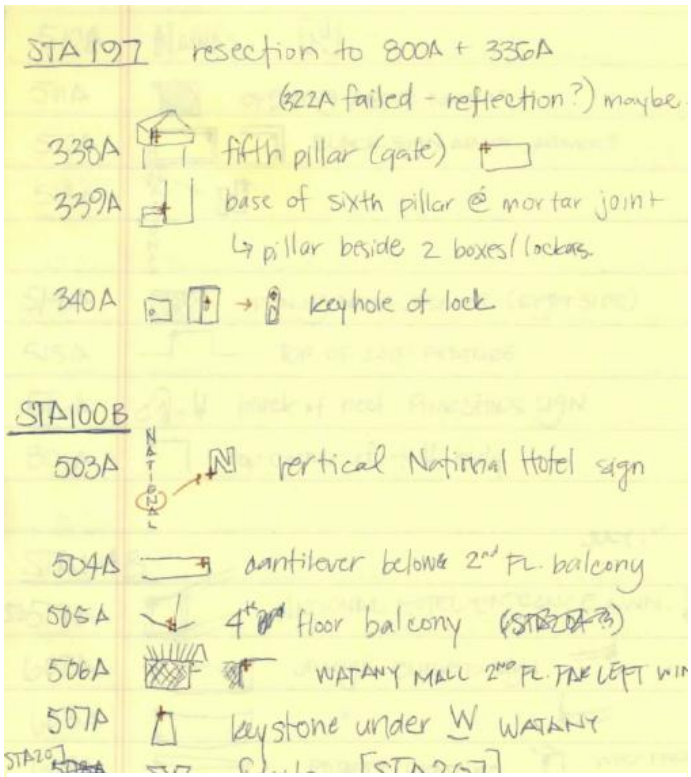

Figure 3 Example of field note with point ID and location of the targets.

Hand drawings should be used along all the field work process to report the information of the building details coming from hand measurements.

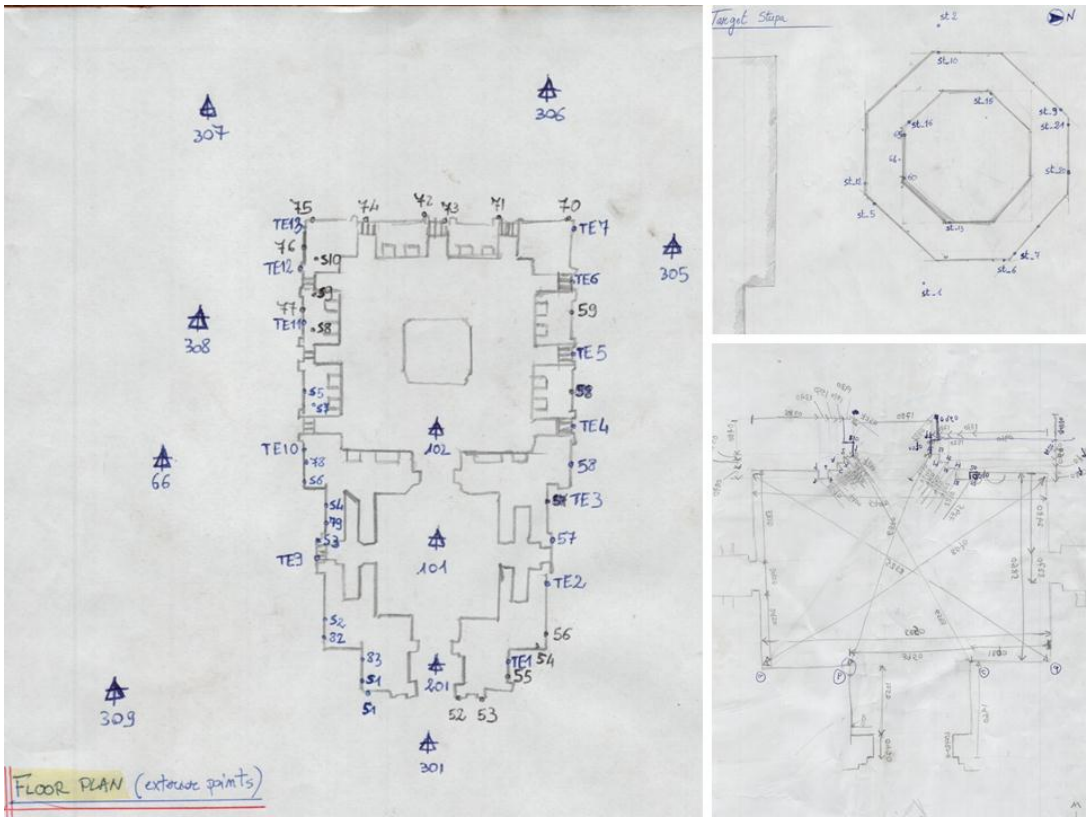

Figure 4 Sketches of the reference key plans for the location and point ID of the targets measured with the Total Station.

1.4 Total Station Survey

Metric survey answers the question "*How can heritage sites be documented?*" A Total Station survey is considered a very accurate and indirect technique to document historic sites. It provides data in the form of vector records. A Total Station is an electronic/optical instrument used in modern surveying. It is an electronic theodolite (transit) integrated with an electronic distance meter (EDM) to read distances from the instrument to a particular point.

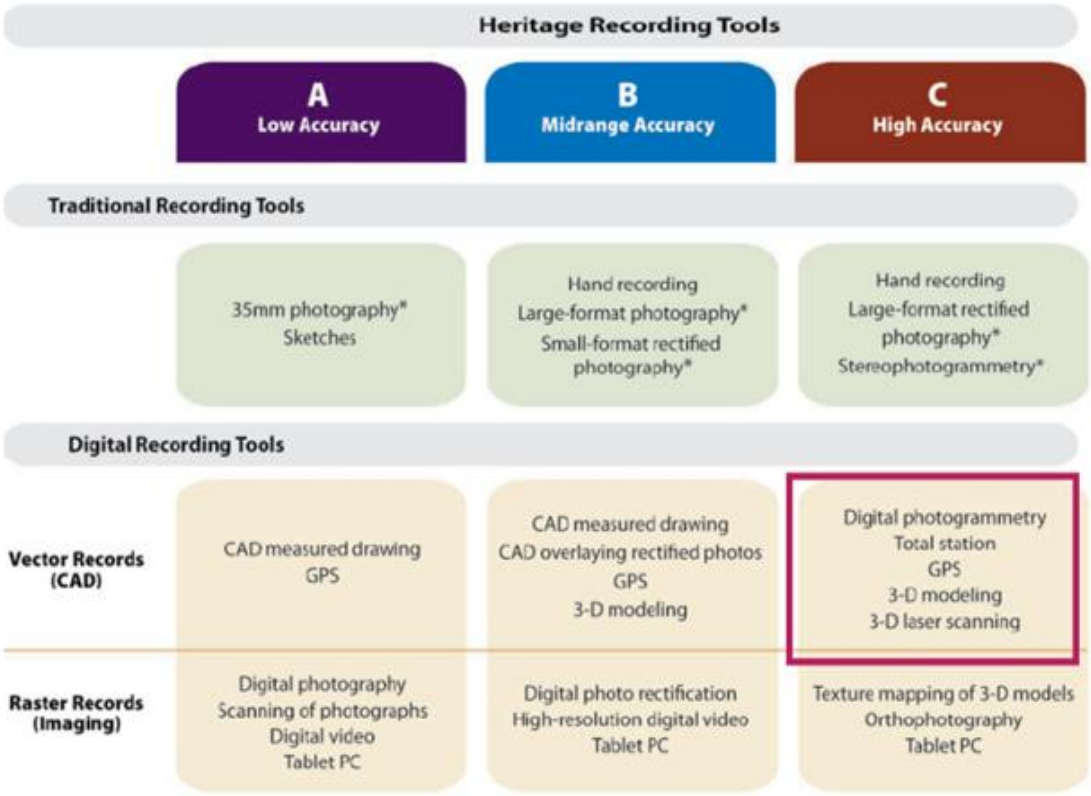

Figure 5 Diagram of the heritage recording tools indicating the Total Station as a high accuracy vector records. Source: Letellier, R. Schmid, W. LeBlanc, F. Guiding Principles Recording, Documentation, and Information Management for the Conservation of Heritage Places, Getty Conservation Institute, 2007 J. Paul Getty Trust, p.42.

The Total Station measures vertical and horizontal angles (with the built in theodolite), and distances (with the built in distance meter) at the same time, a three-dimensional coordinate point can be deducted. The Total Station transmits an infrared wavelength to a prism; target or object and is capable of calculating the distance as it measures the time that the light needs to bounce back. Currently, the Reflectorless EDM (REDM) Total Station can measure distances straight from a surface without a reflector and requires only one set-up or operator.

With both measurements, angles and distances, it is possible to calculate positions by using trigonometry.

The instrument is useful to record prominent features of the building such as edges or single points of interest. However, it cannot be used to easily acquire measurements of complex surfaces. Furthermore, the Total Station is also

used to establish a control network and to define building features at a 1:1 scale.

a. Equipment

The general equipment of a Total Station consist of:

- a Total Station;
- instrument height measuring meter;
- a mini prism with tip for mini prism pole;
- a mini prism rods (4x);
- batteries (2x);
- tripod;
- battery charger.

Figure 6 Photo presenting the equipment of a Total Station. Source: http://surveyequipment.com/media/catalog/product/cache/1/image/903be06a881aa18fc50d3dc96e8b9fba/l/e/leica-builder-200-300-total-station_2_1_1.jpg?1433293920. Accessed on August 14, 2015.

b. Set up

About how to set up and use a Total Station please check the 1_TS11_Protocol_CIMS Myanmar_2015.

Annex 1

1_TS11_Protocol_CIMSMyanmar_2015.pdf1_TS11_Protocol_CIMS Myanmar_2015.pdf

TECHNICAL ASSISTANCE FOR THE CONSERVATION OF BUILT HERITAGE AT BAGAN

Carleton University – Department of Archeology, National Museum and Library (DoA)

TS11_Protocol

CIMS

TS11_Protocol

Document Information

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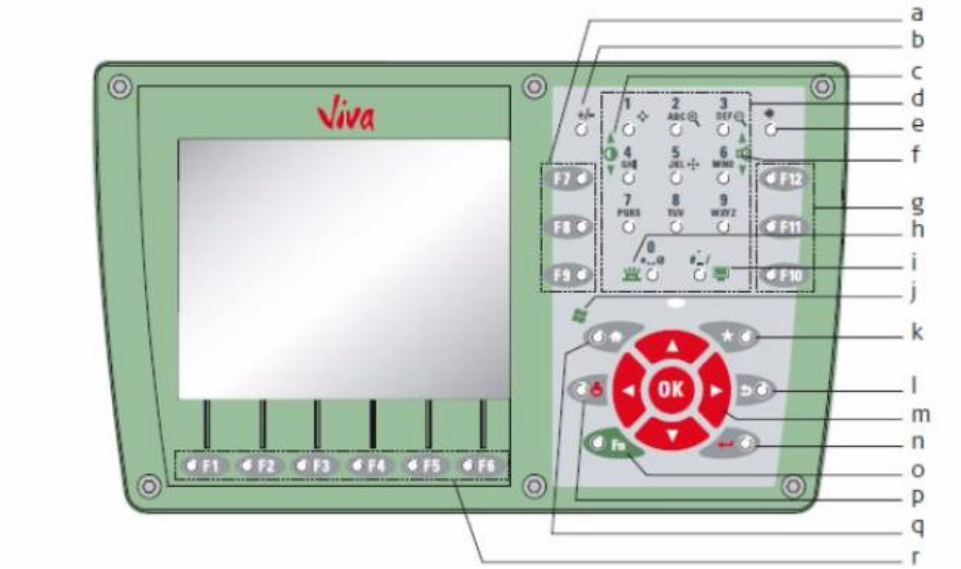
Date	Name	Changes

Background

The Total Station TS11 is used for measuring, calculating and capturing data. The user interface is operated either by the keyboard or by the touch screen with supplied stylus (the red stylus). The workflow is the same for the Keyboard and touch screen entry.



a) Function keys **F7** - **F9**
b) ± key
c) Brightness
d) Alphanumeric keys
e) Backspace
f) Volume
g) Function keys **F10** - **F12**
h) Keyboard illumination
i) Screenshot
j) Windows CE
k) Favourites
l) ESC
m) Arrow keys, **OK**
n) ENTER
o) **Fn**
p) ON/OFF
q) Home
r) Function keys **F1** - **F6**

c. Surveying network: Setting up a reliable coordinate system

The EDM Total Stations supports the photogrammetric, records and the survey of the individual spaces (plans, elevations and sections), by calculating a survey network of the interior and exterior perimeter of a building. The network have to be closed, verified and adjusted using traversing calculations.

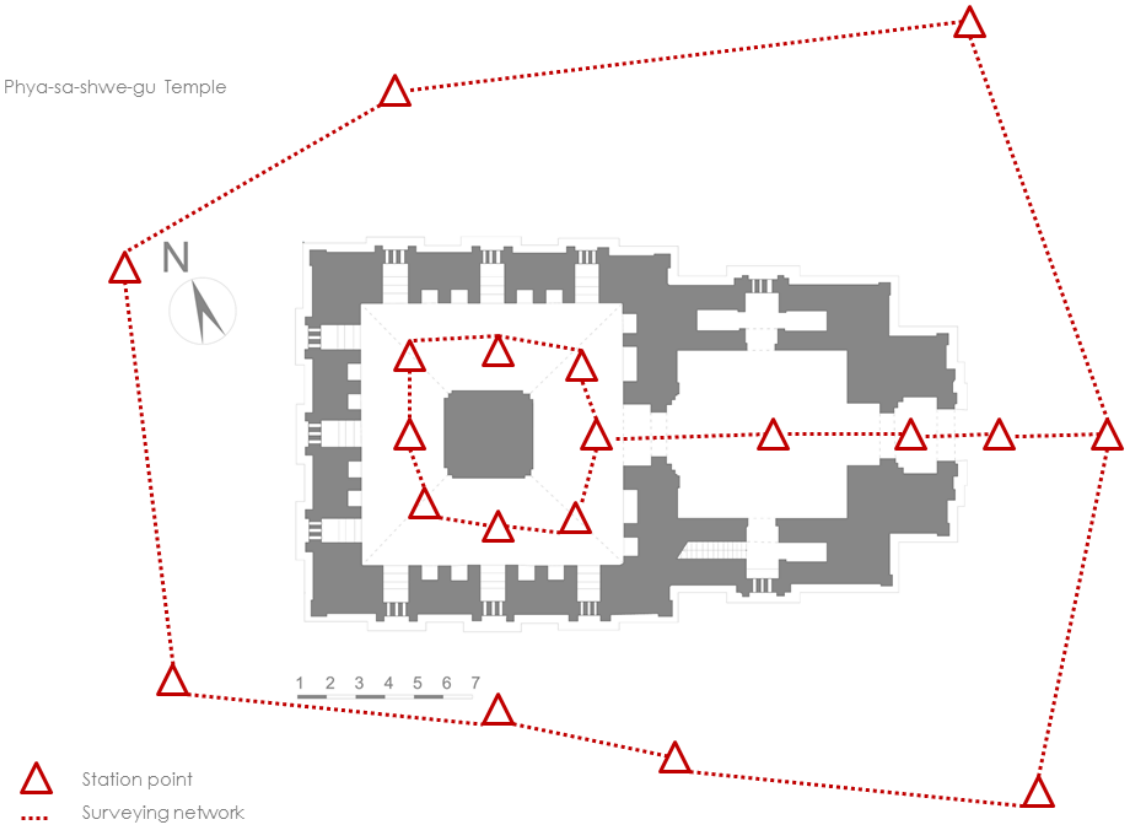


Figure 7 Example of survey network: the Phya-sa-shwe-gu temple in Bagan.

d. Recording building's exterior and interior

Once set up the surveying network, it is possible to draw an outline of the walls and of the main elements of a building directly in AutoCAD from the Total Station. The lines in AutoCAD have to be divided into different layers, such as: windows, wall section, projected lines, etc. Features such as floor height elevations, changes in grade, finishes and openings can also be measured from the position of the Total Station. The same techniques can be used for recording the exterior and the interior part of a building.

Figure 8 Member of the Myanmar's Department of Archaeology and National Museum(DoA) drawing the outline of the external walls and of the main elements of the Phya-sa-shwe-gu temple directly in AutoCAD from the Total Station TS11.

1.5 Hand survey drawings

Hand survey drawings are used to verify and integrate the floor plans surveyed from the Total Station. In this phase the following steps have been followed:

- Generate sketches and hand survey by using Running Dimension and Triangulation.
- Use running dimension in order to get accurate dimensions[3].
- Employ Triangulation[4] to record the actual layout of the buildings.
- In all these steps the Distance measuring (DISTO) can be used.

[3] "Running dimensions" are used to measure an internal baseline selecting one of the walls of the space being surveyed.

[4] This technique measure horizontal distances using diagonals for triangulation.

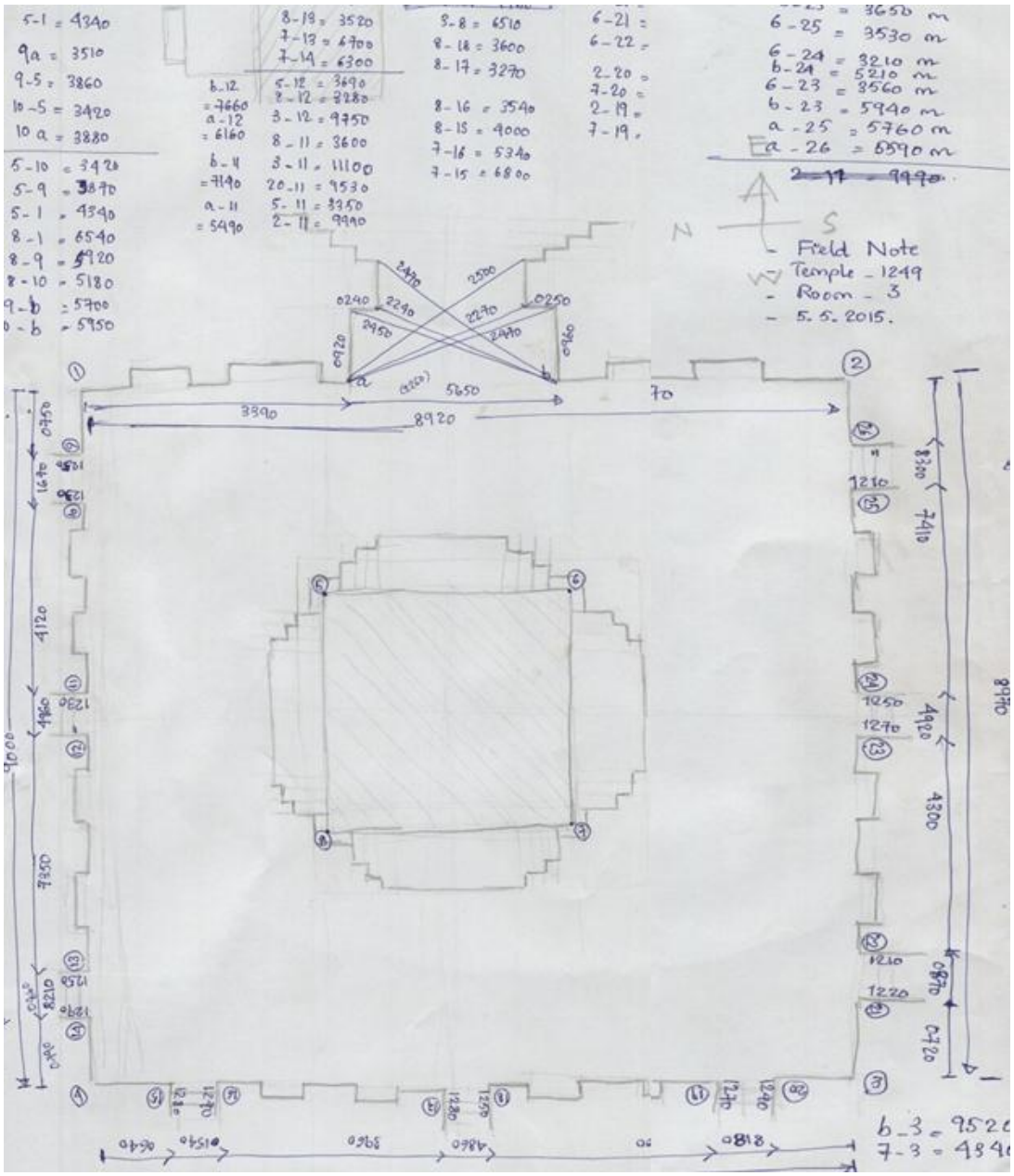


Figure 9 Example of hand survey drawing employing trilateration and using conventional hand survey techniques to draw a measured temple floor plan.

According to Leach[5], in the hand measurements the following steps have to be followed:

- *Running dimensions*: don't take a series of individual measurements. If one is wrong, then many of the others are displaced;

- *Measurement figures*: don't make a virtue of writing small! The figures must be eligible. Try to work from left to right and bottom to top of your survey

[5] Leach, P E. The Surveying of Archaeological Sites. Archetype Publications, 1994.

sheet; write your figures at right angles to your measuring line. So they are clearer.

- *Triangulation*: do have reasonable shaped triangles; not too acute or obtuse. Triangulate to the same points, NOT opposite corners of piers, etc.

- *Leaning walls*: these are always a problem as well as rounded corners. A good strategy consist in measuring from the bottom of the wall using a plumb-bob.

- *Level of plan*: a plan drawn at low level will show doorways, but not windows; higher up it will show windows, but no doors, The plan levels has therefore to be decided.

- *An internal baseline* with offsets or triangulation is more accurate than taking diagonals only.

- *Straight surfaces:* Distance measuring (DISTO) is a useful tool to compute distance between straight surfaces.

During the hand survey phase a profile gauge or contour gauge can also be employed. A contour gauge is a tool for recording the cross-sectional shape of a surface. Contour gauges consist of a set of steel or plastic pins that are set tightly against one another in a frame which keeps them in the same plane and parallel while allowing them to move independently, perpendicularly to the frame. When pressed against an object, the pins conform to the object. The gauge can then be used to draw the profile or to copy it on to another surface[6]. In the survey phase the steps to be followed are:

- Measure the profile;
- Check the profile;
- Draw the profile on a paper 1:1;
- Put dimensions on the profiles and indications.

[6] Source: http://en.wikipedia.org/wiki/Profile_gauge accessed 05/31/2015.

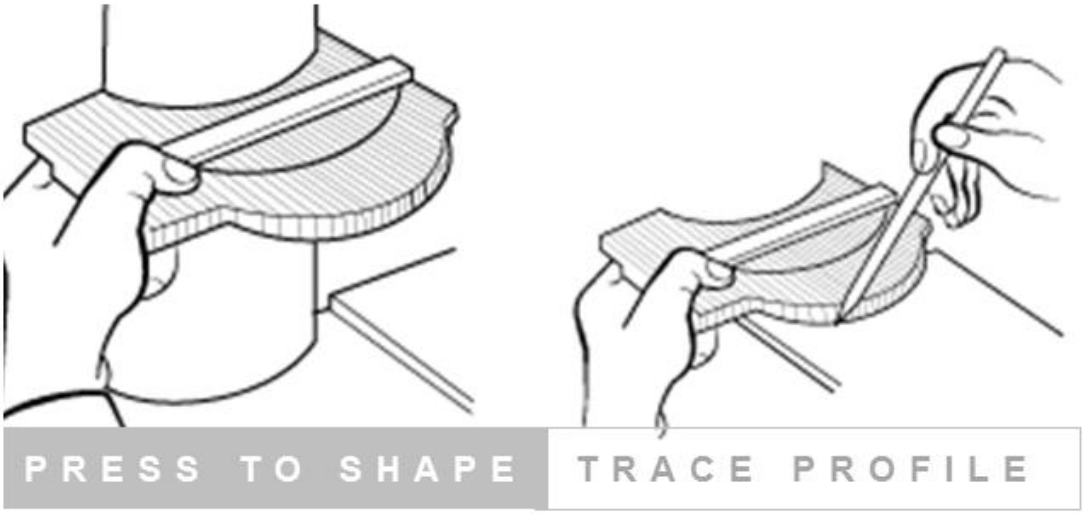


Figure 10 Image depicting a contour gauge recording the shape of a surface. Adapted from http://www.leevalley.com/US/images/item/woodworking/markmeasure/03n0101d1.gif

1.6 Global Positioning of local survey network

The Station points can be measured with the GPS Garmin owned by the DoA in order to locate the survey in a broader context. A number of points from the local network of fixpoints can be used to geo-reference the Total Station measurements with the photogrammetric model.

Nevertheless, the GPS measurements are not usable for geo-referencing all the measurements. Indeed, the GPS device indicates an average accuracy in the ranges of 3 meters.

1.7 Photogrammetry

Photogrammetry can be defined as “the art, science, and technology of obtaining reliable information about physical objects and the environment through the processes of recording, measuring, and interpreting photographic images.” (Wolf, Dewitt, & Wilkinson, 2014). This technique can obtain measurements of objects, buildings, sites or earth surfaces. When images are clear and captured at a high resolution it can be a very accurate technique based on the assumption that photographic images are in perspective as well as generated from a centrally projected system and, therefore, follows geometric and mathematical principles.

It is impossible to define the position in space of a certain point with only a single image, but using two perspectives or two photographs that are taken

from two different points allows for the calculation of spatial conditions from the images. With this scenario one should have enough information to assess the spatial position of every single point visible in both images. It will be enough to determine the intersection of the two projective bundles as we do when a certain measurement is taken with a total station from two different positions.

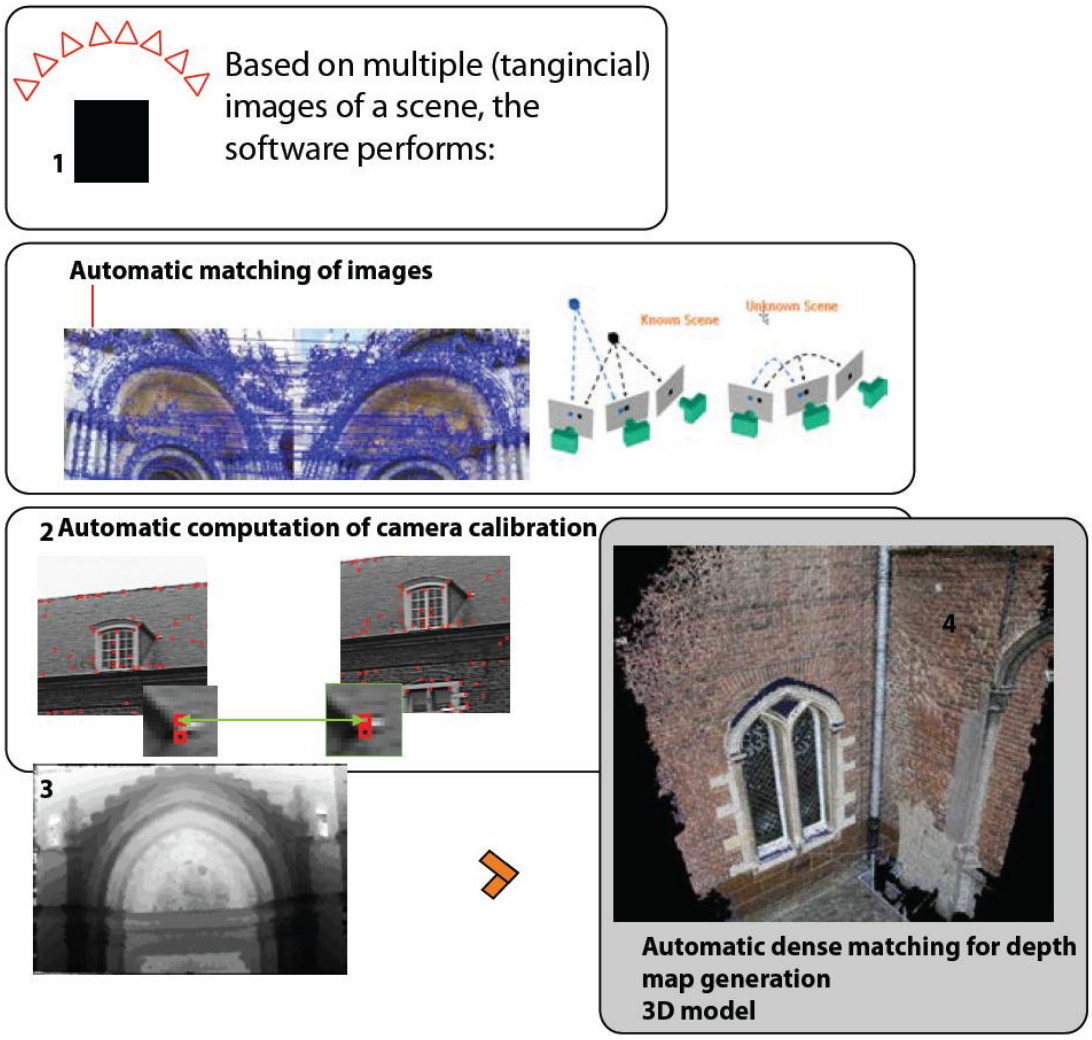


Figure 11 Images depicting the workflow of multi-image photogrammetry structure from motion.

In the case of Bagan, "multi-image photogrammetry or structure from motion"[7] can be used. This approach is strictly related to the recent developments in computer vision that allows us to obtain 3D scenes from 2D images using highly automated workflows.

[7] McCarthy, J. Multi-image photogrammetry as a practical tool for cultural heritage survey and community engagement, Journal of Archaeological Science, Vol 43, March 2014, Pp 175.

This can be carried out by capturing a sequence of overlapping and oblique images taken from a scene (or subject) at the same distance. Recent algorithms allow matching features between pairs of photographs in sequences, which along with the information contained in the images (adequate camera motion, overlap and structure scene) uses the camera parameters to calibrate the images. Subsequently, with this information a depth map is created with each pixel contained in the image producing a 3D dense point cloud and/or surface model. The results can be mesh models of important rooms and spaces. Photogrammetry is used to improve the efficiency and the accuracy of the outputs. Once completed a traverse network with Total Station, it is possible to use Photogrammetry to complement the survey. Photogrammetry is also useful in creating multiple drawing types, including orthographical photos for the drawings of building elevations. Photos of the elevations should be taken according to the photogrammetric rule (3x3), established by CIPA (ICOMOS CIPA, 2013), using photogrammetric strips with 60-80% of overlap. The photos have to be taken at an appropriate scale in order to capture the details of the structure[8]. The photos have to be referenced to the Total Station data and the project coordinate system, using the targets on the elevations captured in the same photos.

A low cost UAV drone device can also be employed to capture the roof of monuments and all that elements - such as stupas, roof moulding, etc. - that are difficult to be recorded from the ground level with a DSLR camera or with Total Station.

[8] Additional information are provided in the section “a. The photogrammetric rule (3x3)”, from page 21 to page 30.

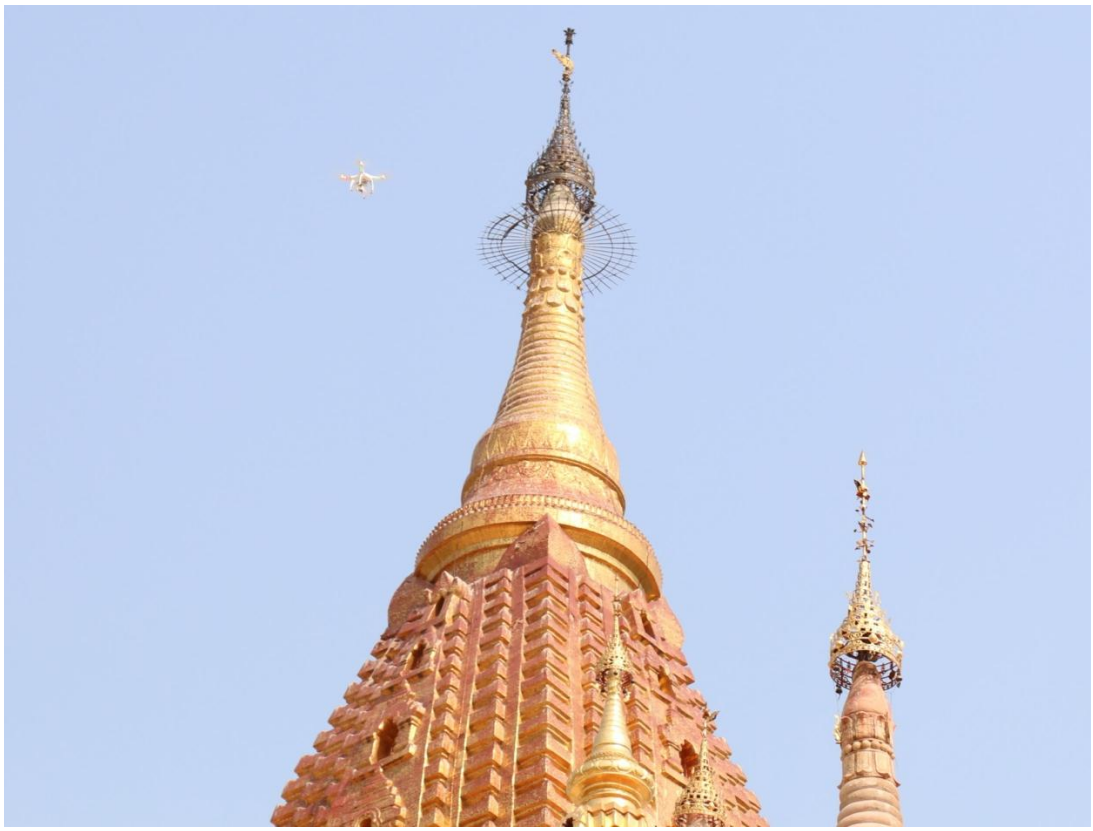


Figure 12 UAV drone (Drone Phantom 2 Vision +) flying around the Ananda temple, in Bagan, capturing the roof and stupa of the temple.

a. The photogrammetric rule (3x3)

Photos of the elevations have to be taken according to the photogrammetric rule (3x3), established by CIPA (ICOMOS CIPA, 2013).

The rules include:

- 3 geometric rules;
- 3 camera rules;
- 3 procedural rules.

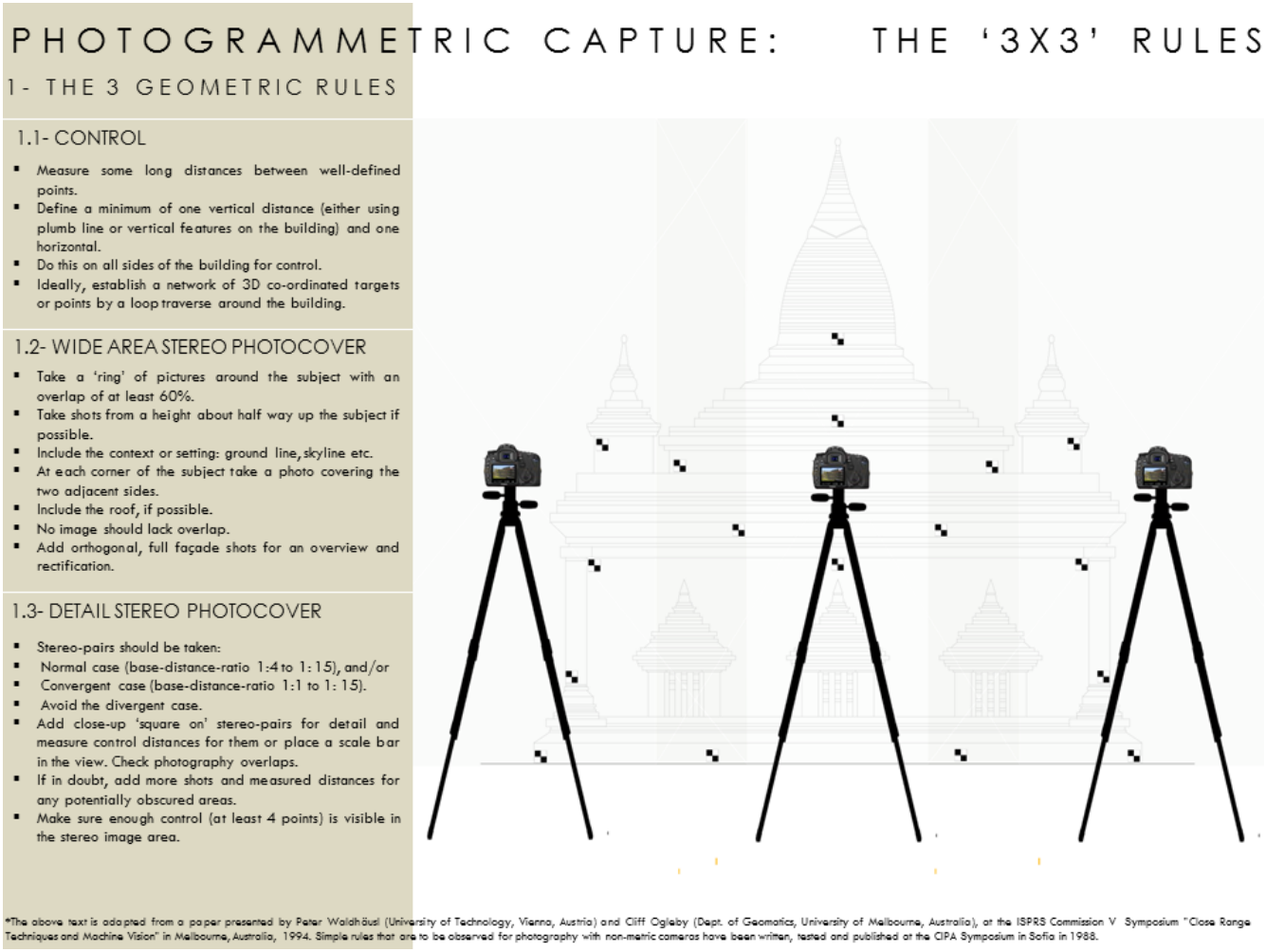


Figure 13 Image presenting the 3 geometric rules within the photogrammetric rule (3x3), established by CIPA (ICOMOS CIPA, 2013).

The 3 geometrical rules are articulated into:

1. Control;
    - Measure some long distances between well-defined points.
    - Define a minimum of one vertical distance (either using plumb line or vertical features on the building) and one horizontal.
    - Do this on all sides of the building for control.
    - Ideally, establish a network of 3D co-ordinated targets or points by a loop traverse around the monument.
2. Wide area stereo photocover;
    - Take a 'ring' of pictures around the subject with an overlap of at least 60%.
    - Take shots from a height about half way up the subject if possible.

- Include the context or setting: ground line, skyline etc.
  - At each corner of the monument take a photo covering the two adjacent sides.
- Include the roof, if possible.
- No image should lack overlap.
- Add orthogonal, full façade shots for an overview and rectification.

3. Detail stereo photocover.
   - Stereo-pairs should be taken:
   - Normal case (base-distance-ratio 1:4 to 1: 15), and/or convergent case (base-distance-ratio 1:1 to 1: 15).
   - Avoid the divergent case.
   - Add close-up ‘square on’ stereo-pairs for detail and measure control distances for them or place a scale bar in the view. Check photography overlaps.
   - If in doubt, add more shots and measured distances for any potentially obscured areas.
   - Make sure enough control (at least 4 points) is visible in the stereo image area.

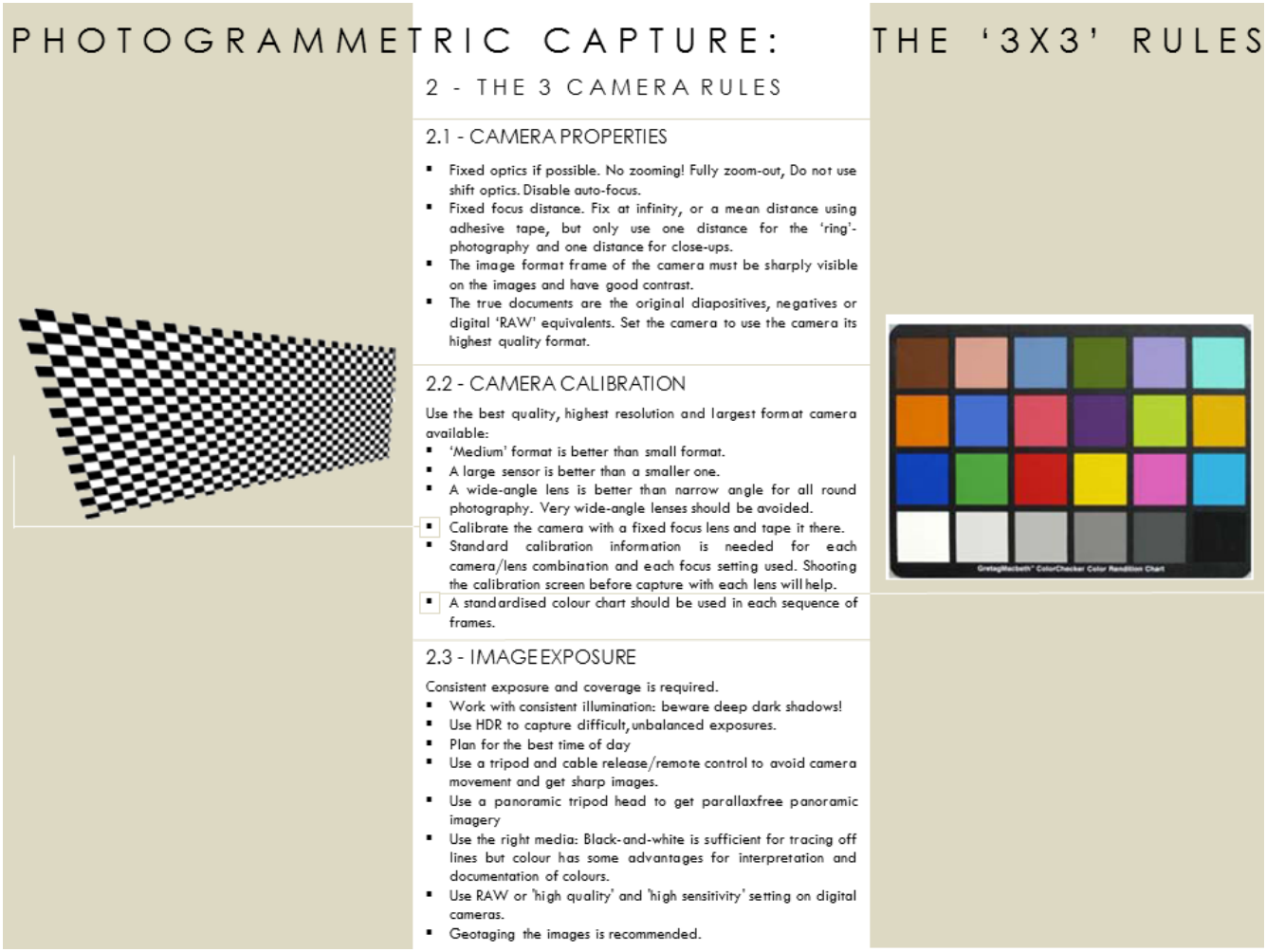


Figure 14 Image presenting the 3 camera rules within the photogrammetric rule (3x3), established by CIPA (ICOMOS CIPA, 2013).

The 3 camera rules, instead, are articulated into:

1. Camera properties;
    - Fixed optics if possible. No zooming. Fully zoom-out, Do not use shift optics. Disable auto-focus.
    - Fixed focus distance. Fix at infinity, or a mean distance using adhesive tape, but only use one distance for the 'ring'-photography and one distance for close-ups.
    - The image format frame of the camera must be sharply visible on the images and have good contrast.
    - The true documents are the original dispositives, negatives or digital 'RAW' equivalents. Set up the camera, employing its highest quality format.

- Make witnessing diagrams of:
  - The ground plan with the direction of north indicated.
  - The elevations of each façade (at an appropriate scale 1:50, 1:100 - 1: 500).
  - Photo locations and directions (with frame numbers).
  - Single photo coverage and stereo coverage.
  - Control point locations, distances and plumb-lines.
  - If using 'natural' points a clear diagram showing each point is required.

2. Camera calibration;
   - Use the best quality, highest resolution and largest format camera available:
     - 'Medium' format is better than small format. A large sensor is better than a smaller one.
     - A wide-angle lens is better than narrow angle for all round photography. Very wide-angle lenses should be avoided.
     - Calibrate the camera with a fixed focus lens and tape it there.
     - Standard calibration information is needed for each camera/lens combination and each focus setting used. Shooting the calibration screen before capture with each lens will help.
     - A standardised colour chart should be used in each sequence of frames.

3. Image exposure.
   - Consistent exposure and coverage is required.
   - Work with consistent illumination: beware deep dark shadows (particularly in the monuments interior).
   - Use HDR to capture difficult, unbalanced exposures.
   - Plan for the best time of day (i.e. not during sunset or sunrise when the light change quickly).

- Use a tripod and cable release/remote control to avoid camera movement and get sharp images.
- Use a panoramic tripod head to get parallaxfree panoramic imagery
- Use the right media: Black-and-white is sufficient for tracing off lines but colour has some advantages for interpretation and documentation of colors.
- Use RAW or 'high quality' and 'high sensitivity' setting on digital cameras.
- Geotagging images is recommended.

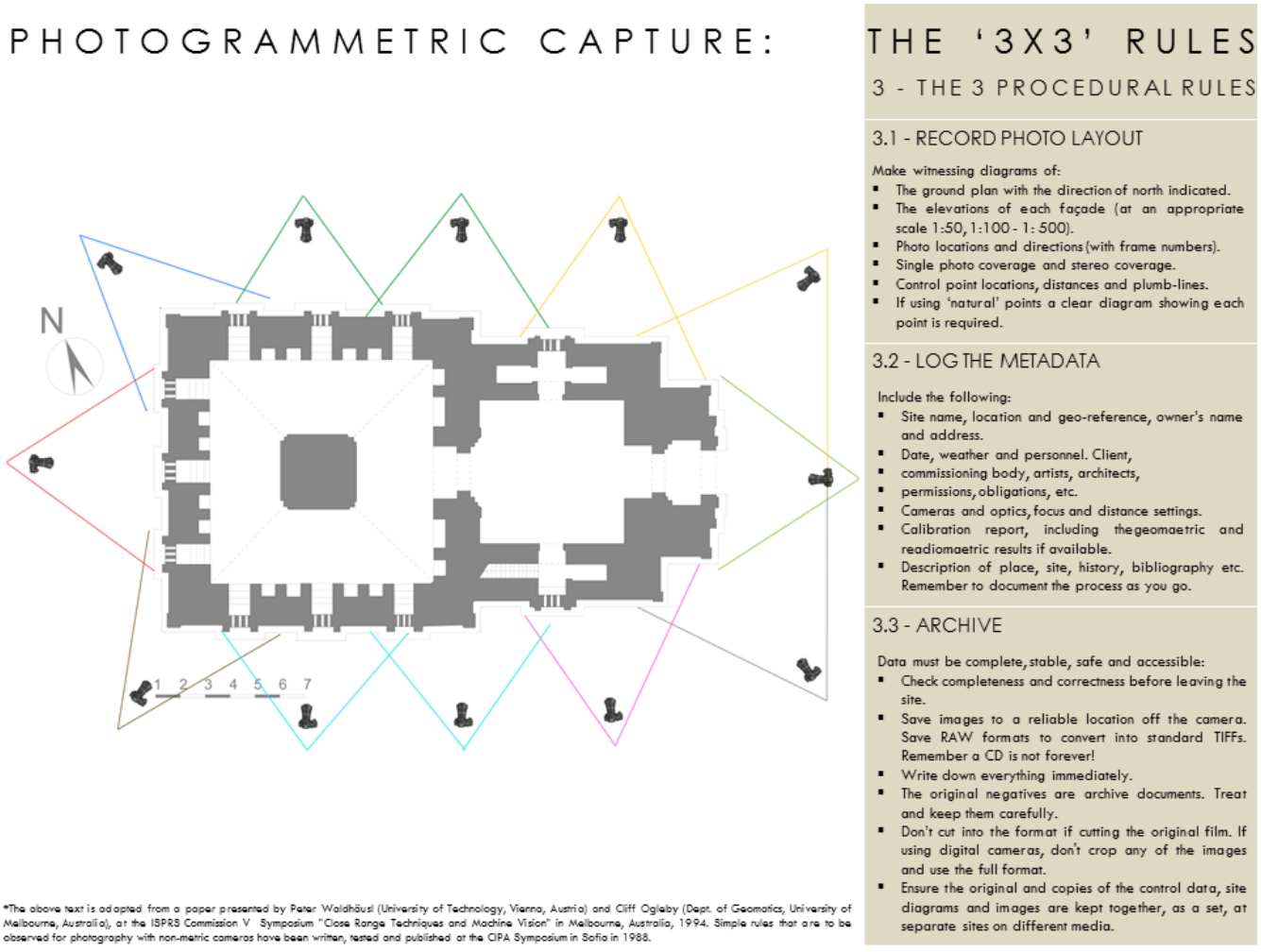


Figure 15 Image presenting the 3 procedural rules within the photogrammetric rule (3x3), established by CIPA (ICOMOS CIPA, 2013).

Finally the 3 procedural rules are articulated into:

1. Record photo layout;

- Make witnessing diagrams of:
  - The ground plan with the direction of north indicated.
  - The elevations of each façade (at an appropriate scale 1:50, 1:100 - 1: 500).
  - Photo locations and directions (with frame numbers).
  - Single photo coverage and stereo coverage.
  - Control point locations, distances and plumb-lines.
  - If using 'natural' points a clear diagram showing each point is required.

2. Log the metadata;

- Include the following:
  - Site name, monument number (according to Pierre Pichard inventory) location and geo-reference,
  - Date, weather and personnel such as archeologists, architects, (i.e. DoA staff and or AMA consultant, Yangon Technological University experts, etc.),
  - client, commissioning body,
  - permissions, obligations, etc.
  - Cameras and optics focus and distance settings.
  - Calibration report, including the geometric and radiometric results if available.
  - Description of place, site, history, bibliography, etc. Remember to document the process as you go.

3. Archive.

- Data must be complete, stable, safe and accessible:
- Check completeness and correctness before leaving the site.
- Save images to a reliable location off the camera. Save RAW formats to convert into standard TIFFs. Remember a CD is not forever!
- Write down everything immediately.

- The original negatives are archive documents. Treat and keep them carefully.
- Don't cut into the format if cutting the original film. If using digital cameras, don't crop any of the images and use the full format.
- Ensure the original and copies of the control data, site diagrams and images are kept together, as a set, at separate sites on different media.[9]

Another important aspect to be taken into account, during the data acquisition phase in photogrammetry, is the number of pixels. The smallest feature that can be measured in a photograph is a pixel. So, in order to tell something about the quality of the final image, it is necessary to know with which distance a pixel corresponds in reality. In photogrammetry this is called the Ground Sampling Distance (GSD).

GSD (mm) = D (mm). $CCD{\downarrow}width$ (mm)/ $N{\downarrow}w$. f (mm)

- D the distance to the object (in mm)
- f the camera focal length (in mm)
- Nw the number of pixels in the width direction of the taken photograph.

Example

- Canon Eos 400d (sensor size of 22,2 x 14,8 mm)
- image from a distance of 10 meter
- Using the full 10 MP
- focal length of 28mm

GSD (mm) = 10000 (mm). 22.2 (mm)/3888 . 28 (mm)

GSD (mm) =2.04 mm

RESULT : 1 pixel = 2.04 mm in reality

[9] The above text is adapted from a paper presented by Peter Waldhäusl (University of Technology, Vienna, Austria) and Cliff Ogleby (Dept. of Geomatics, University of Melbourne, Australia), at the ISPRS Commission V Symposium "Close Range Techniques and Machine Vision" in Melbourne, Australia, 1994. Simple rules that are to be observed for photography with non-metric cameras have been written, tested and published at the CIPA Symposium in Sofia in 1988.

Additional best practices that can be followed are:

- Move between the photos, do not pan.
- Take many photos, the angle should be less than 10 degrees between the shots. A good practice is to take 3 photographs for each plane.
- Ensure large overlap between images. Ideally 60% - 90%
- Avoid blurry images due to motion blur or out-of-focus. Set the exposure and focus such that all parts of the object stays sharp and use a tripod if the lighting is dim.
- Avoid noisy images by reducing the ISO setting of your camera. Use a tripod if necessary.
- For best result, use the same camera settings: the same focal length (zoom) and the same resolution throughout the image sequence.
- Do not process your images. Do not change the Exif information.
- Surfaces have to be textured and non-reflective.
- Make sure there is homogenous illumination,
- Select the most stable and largest format available in the camera.
- The optimal position is pointing the camera lens parallel to the facade of the building (Figure 16).

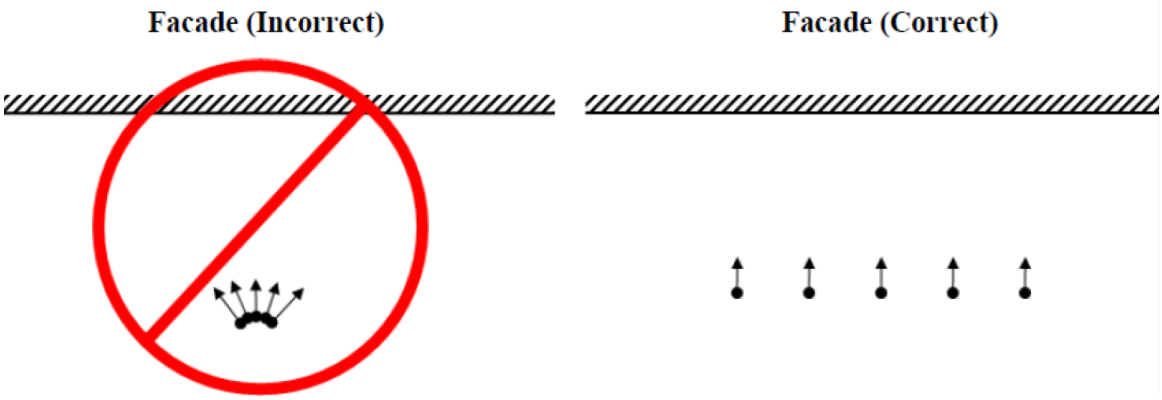


Figure 16 Optimal position pointing the camera lens parallel to the facade of the building to be recorded.

Photogrammetric techniques should be employed for elements that are difficult to survey by Total Station, such as stupas, stucco works, wall paintings, brickworks, mouldings and windows.

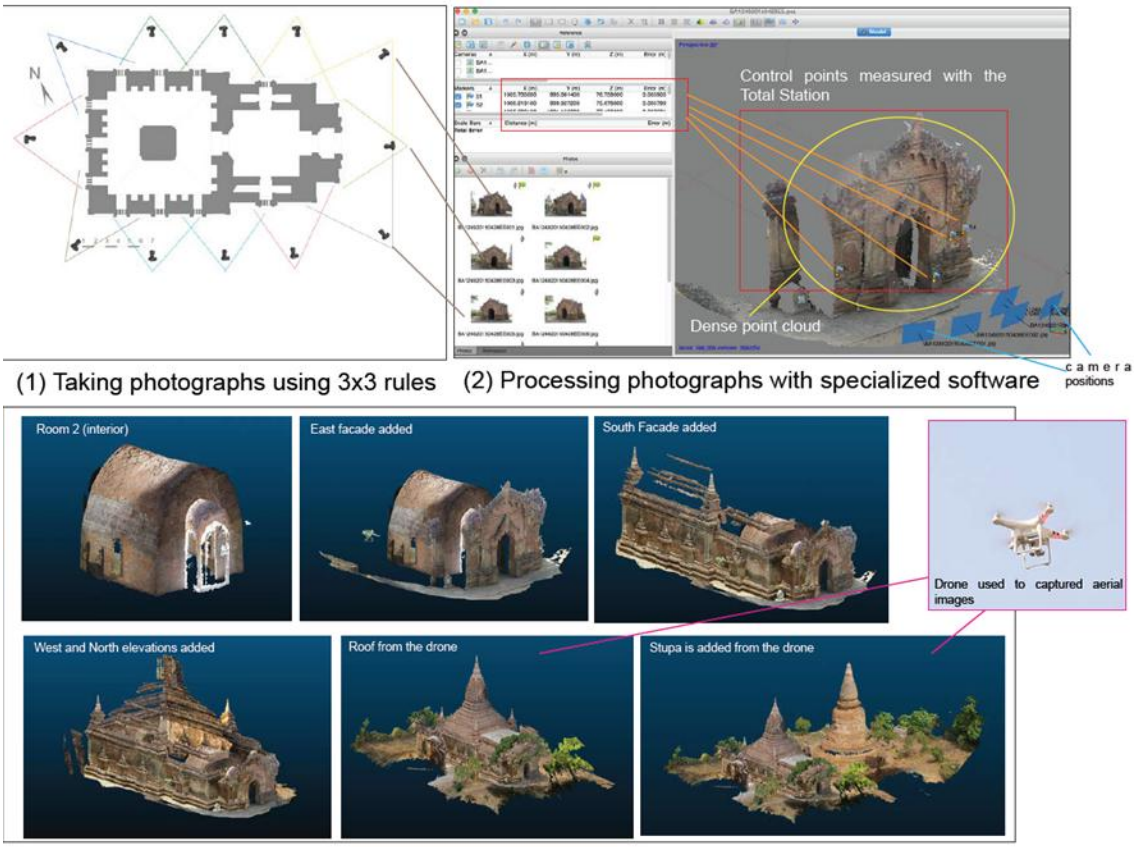


Figure 17 Image depicting the photogrammetric process.

1.8 Record Photography

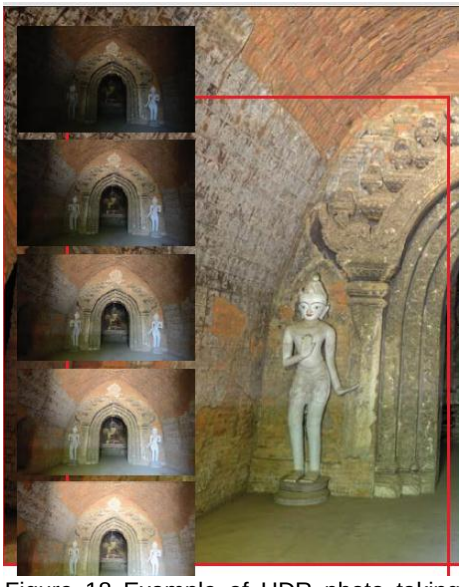


Figure 18 Example of HDR photo taking several shots of the same subject using different camera settings.

During the field work, record photographs can be taken. These photographs support the preparation of the two-dimensional drawings, showing additional details of rooms (such as: central shrine, vestibule, passages) to be surveyed. A photo key plan indicates the exact location and the orientation of the photographs. The photograph site portfolio includes character defining elements of both interior and exterior areas, as well as a condition assessment of the building. Some selected portions of interior spaces with decorated surfaces can be photographed

using High dynamic range photography with a high-resolution reflex camera.

This technique can provide quick and reliable "as built" condition of any property by capturing the geometry, texture, shape, and colours. For High Dynamic Range (HDR) photograph the following rules should be followed:

- Mount the camera on the tripod and place it according to the desired view;
- Shoot in "Auto-bracketing[10] mode" or "Auto-exposure mode" or, shoot in RAW (you can also create an HDR image out of a single RAW photo).[11]

Although there are many types of photography, architectural photographs for condition and character defining elements are the most relevant. These photographs can cover different scopes of recording, such as capturing details, external context views, internal spaces, perspective views and/or elevation.

The goals of this technique consist in recording features of the building relevant to understanding its condition, values and other issues related to the conservation of Bagan built heritage.

1.9 Panoramic Photography

Figure 19 Photos acquisition to generate panoramic photos using a Nikon D800 DSLR camera equipped with a fisheye Nikkor 10.5mm lens with a tripod.

A set of full spherical panoramic photographs of some selected interior and exterior locations can be provided. Selected panoramic photographs can be made taking overlapping photographs to generate a 360 degrees view. To generate a panoramic photograph the following steps should be followed:

- Mount the camera on a tripod with the panorama adapter;
- Shoot the sequence of overlapping images according to your Field of View (FOV).

[10] Bracketing is a technique of taking several shots of the same subject using different camera settings, for example shutter speed (exposure).

[11] If your camera does not have bracketing, use a tripod, place your camera, and take 3,5, to more shots of the same frame using different shutter speeds: 1/1000 s, 1/500 s, 1/250 s, 1/125 s, 1/60 s, 1/30 s, 1/15 s, 1/8 s, 1/4 s,1/2 s.

2. DATA PROCESSING PHASE

2.1 Field notes

The field measurements are useful along all the data processing phase to report the information recorded in the field such as target position, target ID, etc.

2.2 Total Station Surveying

The field measurements collected by the EDMs need to be translated into Computer Aided Drafting (CAD) software. Please check the 'Data Downloading' (pp. 23-28) and 'Import Data to AutoCAD' (pp. 29-32) sections in the protocol: 1_TS11_Protocol_CIMS Myanmar_2015.

Annex 1

1_TS11_Protocol_CIMSMyanmar_2015.pdf1_TS11_Protocol_CIMS Myanmar_2015.pdf

TECHNICAL ASSISTANCE FOR THE CONSERVATION OF BUILT HERITAGE AT BAGAN

Carleton University – Department of Archeology, National Museum and Library (DoA)

TS11_Protocol

CIMS

TS11_Protocol

Document Information

Document type: Protocol
Workgroup: Mario Santana Quintero, Davide Mezzino

Author: Davide Mezzino
Creation date: 02 May 2015

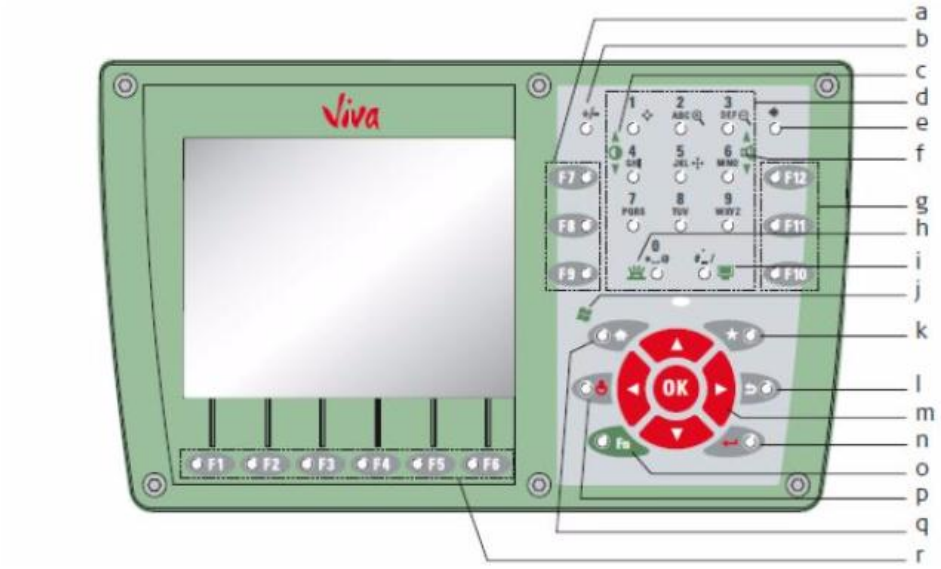
Last save date: 5 May 20155

Revisions

Date	Name	Changes

Background

The Total Station TS11 is used for measuring, calculating and capturing data. The user interface is operated either by the keyboard or by the touch screen with supplied stylus (the red stylus). The workflow is the same for the Keyboard and touch screen entry.



a) Function keys **F7** - **F9**
b) ± key
c) Brightness
d) Alphanumeric keys
e) Backspace
f) Volume
g) Function keys **F10** - **F12**
h) Keyboard illumination
i) Screenshot
j) Windows CE
k) Favourites
l) ESC
m) Arrow keys, **OK**
n) ENTER
o) **Fn**
p) ON/OFF
q) Home
r) Function keys **F1** - **F6**

- 1 -

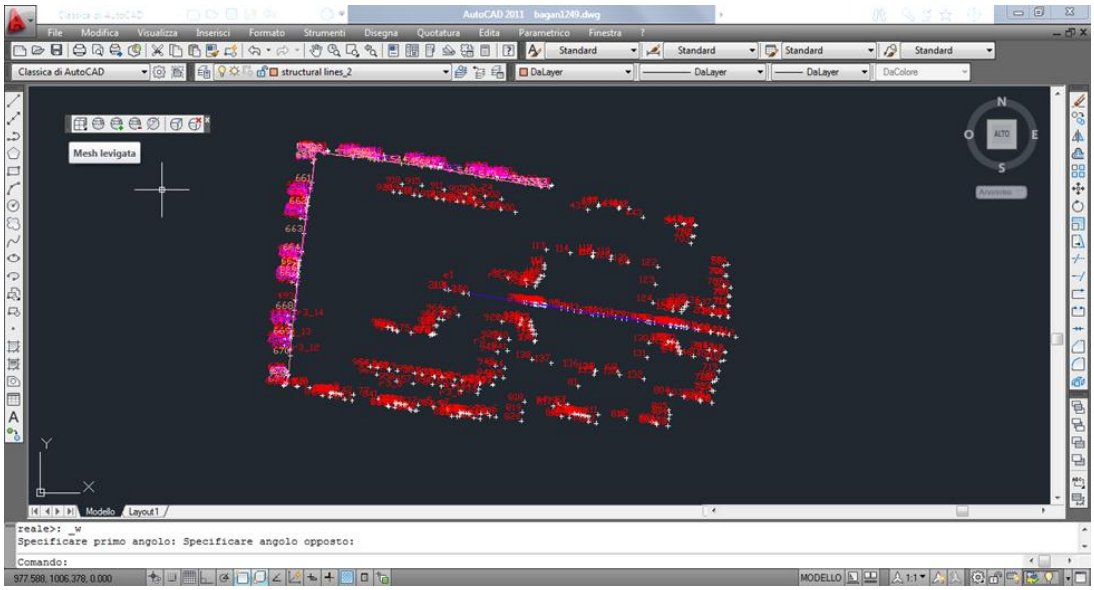


Figure 20 Image of the Total Station data translated into AutoCAD 2015.

2.3 Hand survey drawings

Hand drawings are useful along all the data processing phase to report the information of the building details coming from the hand measurements.

2.4 Global Positioning of site and floor plans

The GPS measurements can be used to geo-reference site and floor plans (considering that the GPS device indicates an average accuracy with a range of 3 meters). The points measured with the GPS device need to be opened in the ArchGIS –ESRI software. Once imported the shape file (.shp) of the points into ArchGIS it is possible to create a grid with the coordinates. The grid can then be imported in AutoCAD to geo-reference the site plan.

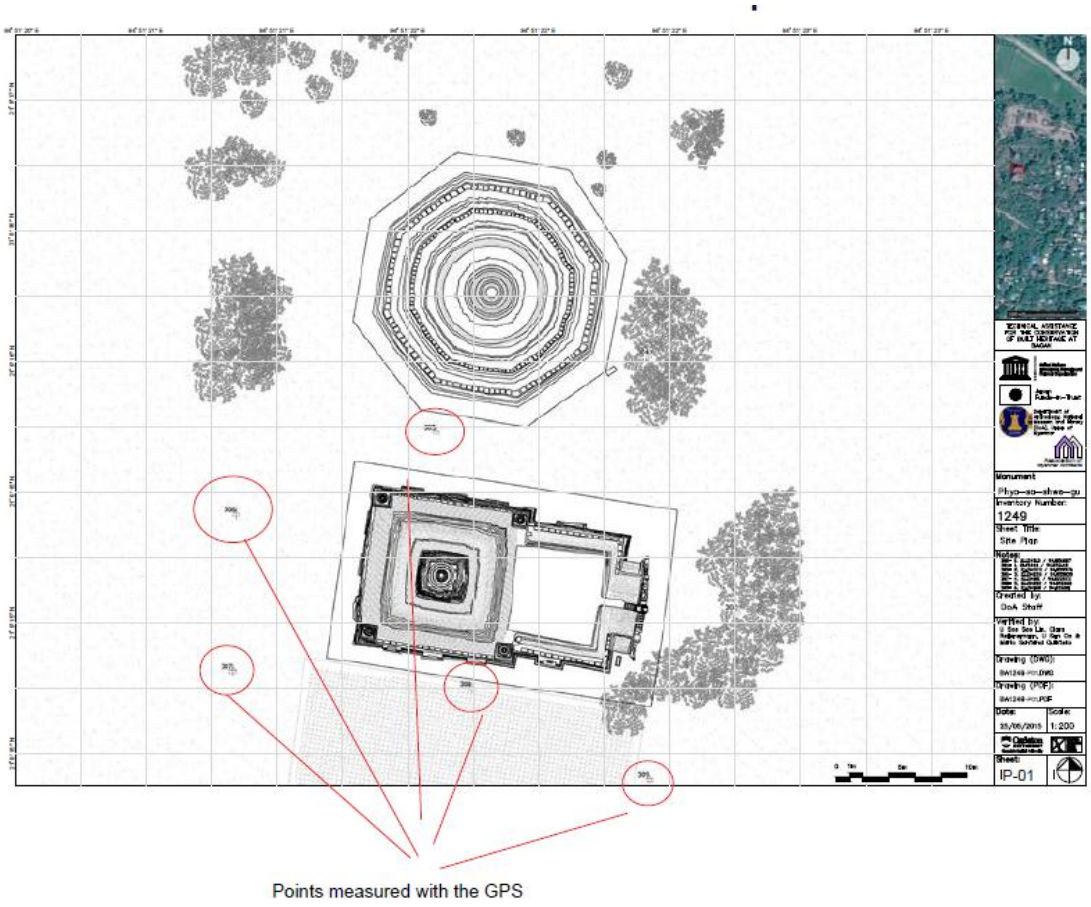


Figure 21 Survey network points measured with a GPS hand held device. The points have been used to geo-reference the site plan.

2.5 Photogrammetry

Photogrammetry models can be created, from the photo taken, employing the AgiSoft PhotoScan software. The model can be opened in Autodesk Recap and then exported into a compatible format into Autodesk AutoCAD 2015, where the model can be traced in order to produce line drawings from the point cloud. This process is described in the protocols: 2_Photoscan Protocol_CIMS Myanmar_2015 and 3_Autocad pointclouds Protocol_CIMS Myanmar_2015. This approach can be replicated for all the elevations, as well as the roof plans and cross sections.

Photogrammetry is capable to provide spatial (from the point cloud) and qualitative (from the photos) data. For these reasons it is a suitable recording strategy to be employed in the context of Bagan, where the monuments present a high damage level as well as irregular shapes.

Annex 3

3_Autocad pointclouds Protocol_CIMS Myanmar_2015.pdf

TECHNICAL ASSISTANCE FOR THE CONSERVATION OF BUILT HERITAGE AT BAGAN

Carleton University – Department of Archeology, National Museum (DoA)

Pointclouds in AutoCAD_Protocol

CIMS

Pointclouds in AutoCAD

Document Information

Document type:	Protocol	Author: Sarah	Ward, Davide Mezzino
Workgroup:		Creation date:	23 June 2013
		Last save date:	23 August 2015

Revisions

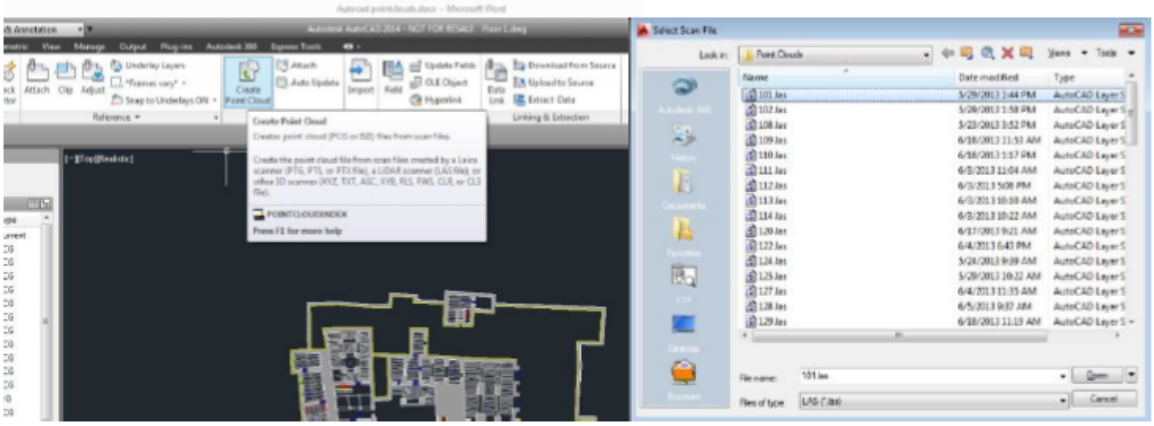
Date	Name	Changes

Importing Point Clouds into AutoCAD

AutoCAD Versions 2013 and higher allow pointclouds to be imported and manipulated. Files need to be saved as an las. or obj. file in order for them to imported.

Creating png. files

The Pointcloud menu is located in the menu ribbon under the Insert tab. Select "Create Point Cloud" and open the file you wish to import. Select create and wait for Autocad to indicate the file has been created.



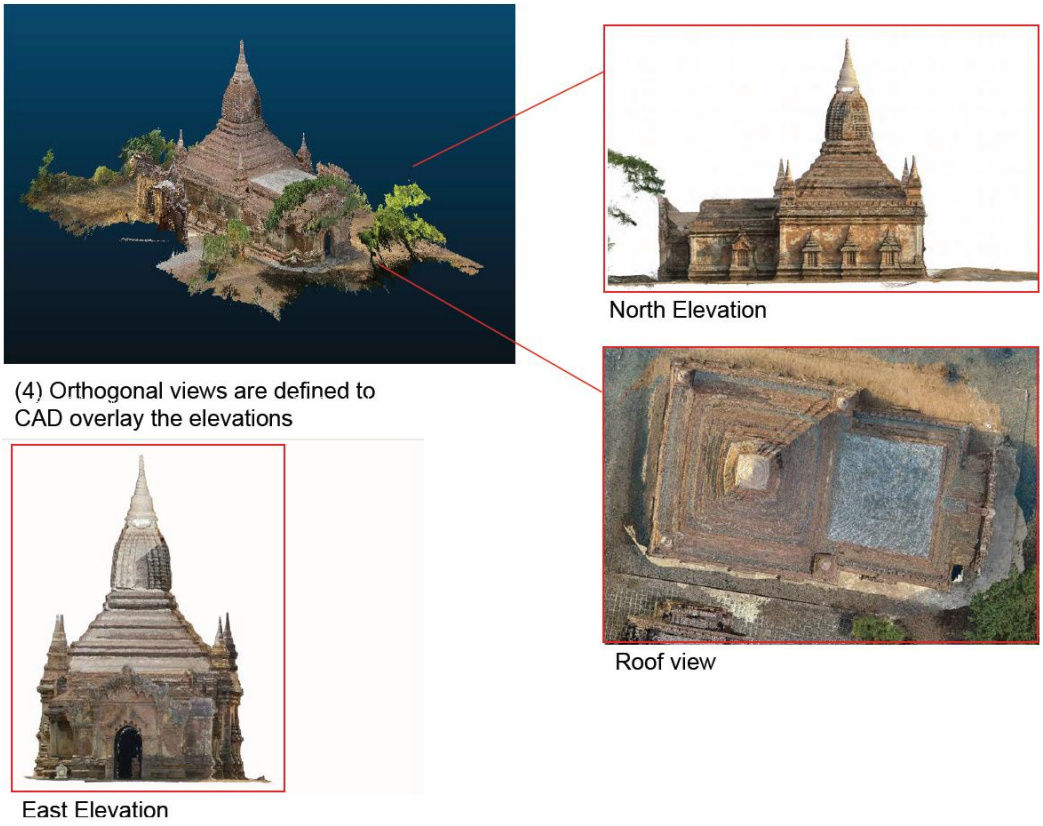


Figure 22 Example of the measured orthophotos that can be produced from the point cloud generated with photogrammetric technique.

a. AgiSoft PhotoScan to generate Orthoimages from a photogrammetric model

In AgiSoft PhotoScan is also possible to generate Orthoimages from the photogrammetric model. These Orthoimages can then be traced and imported in AutoCAD. This procedure can be particularly useful to generate elevations, cross sections and floor plans. Indeed, it is easy to trace an Orthoimage in AutoCAD rather than import, orient and trace a point cloud, generated from the photogrammetric model, directly in AutoCAD.

The process to create a photogrammetric model from the photos taken and to generate Orthoimages is fully described in the protocol: 2_Photoscan Protocol_CIMS Myanmar_2015.

Annex 2

2_Photoscan Protocol_CIMS Myanmar_2015.pdf

TECHNICAL ASSISTANCE FOR THE CONSERVATION OF BUILT HERITAGE AT BAGAN

Carleton University – Department of Archeology, National Museum (DoA)

TS11_Protocol

CIMS

Photoscan_Protocol

Document Information

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Last save date: June 24, 2015

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Date	Name	Changes
June 24, 2015	Davide Mezzino	PhotoScan Basics & Advanced Use

Background

Agisoft PhotoScan generates fully textured 3D models using 2D images. Following an automated work flow, the software aligns the images, calculates the geometry and builds the texture. Photos used to create the model can be taken from any position, given that the object is visible in at least 2 photos.

Taking Photos for PhotoScan(Photogrammetry):

Photos can be captured using any high resolution camera following some guidelines.

>Equipment:

Wide angle lens is better to capture images for photogrammetry than a telephoto lens. Avoid using fish eye lenses to minimize distortion. From the Morocco project, we learned that the best results are achieved by using a 50mm lens.

b. Orthoimages in AutoCAD

About how to insert and manage Orthoimages in AutoCAD please check the protocol: 4_Orthophotos in Autocad Protocol -CIMS Myanmar 2015.

Annex 4

4_Orthophotos in Autocad Protocol -CIMS Myanmar 2015.pdf

TECHNICAL ASSISTANCE FOR THE CONSERVATION OF BUILT HERITAGE AT BAGAN

Carleton University – Department of Archeology, National Museum (DoA)

Orthophotos in Autocad_Protocol

CIMS

Orthophotos in Autocad

Document Information

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Workgroup:		Creation date:	3 June 2015
		Last save date:	23 August 2015

Revisions

Date	Name	Changes

How to create a new UCS for each orthophotograph

Each unique elevation will require its own UCS (User Coordinate System) that will define the plane that each orthophotograph will be inserted onto.

• Choose two surveyed points in the AutoCAD file that are in line with the surface of the facade. In the Top view, draw a line between these two points.

1. Create a layer and name it UCS
2. "Orbit" to get a 3D view of the points
3. Type Pl on the command line
4. Click on bottom left point of your lower left control point
5. Then pick the bottom right point, though the line won't join the two points (this is defining the x axis)
6. Type on the command line: "UCS" "3p" (3-point)
7. snap on the first point (bottom left) and then the end point of the poly line (bottom right)
7. Type "@0,0,3" *enter* (the UCS icon becomes parallel to the plane you have defined)
8. Save this UCS by typing "DDUCS" and *enter*; name it "elevationX" (with X corresponding to the various facades, be systematic about it)
9. "Set Current" "OK"
10. Type "DDVIEW" *enter* "Present Views" "Top" " Set Relative to" "ElevationX" "Set Current" "Apply" *enter*

2.6 Record Photography

All the photographs taken have to be referenced in a key plan, in order to produce an accurate documentation of character defining elements and conditions of the structures recorded. The character defining elements[12] of Bagan's buildings come from the understanding of the physical character of a monument[13]. To grasp this awareness it is necessary to analyze: the historical context in which a building was built, who promoted its construction (i.e. which King of Bamar's dynasty), why was it built with certain shapes and decorative apparatus and how it was built (materials and construction techniques employed). According to these considerations, to identify and document the character defining elements of Bagan monuments the Nara-grid[14] can be used as reference.

Table 1 Nara Grid outline. Source: Safeguarding the spirit of an historic interior on the basis of the 'Naragrid' http://www.international.icomos.org/quebec2008/cd/toindex/77_pdf/77-j1F6-282.pdf Accessed on August 14, 2015.

ASPECTS of the sources (Related to documentation)	**DIMENSIONS of heritage**			
	Artistic	Historic	Social	Scientific
Form and design				
Materials and substance				
Use and functions				
Tradition and techniques				
Location and settings				
Spirit and feeling				

[12] In order to properly record a building it is necessary to understand its purpose and meaning. The first understanding comes from the function for which it was designed (i.e. the hall and the shrine, usually oriented in an east or north facing direction, the vestibule, the porch and the solid core for Bagan temples). Secondly, the analysis and study of activities, objects (for example Buddha statues) and decorative apparatus support the identification of the character defining elements.

[13] David Watt, *Surveying Historic Buildings*. Dorset, Donhead, 2010.

[14] The Nara Grid has been developed by the Raymond Lemaire International Center for Conservation (R.L.I.C.C) at the Katholieke Universiteit Leuven. It provides an evaluation scheme based on the Nara Document on Authenticity (Nara Conference on Authenticity in Relation to the World Heritage Convention, held at Nara, Japan 1994). This grid can be useful to understand and preserve tangible and intangible (craftsman's skills and workmanship) aspects of Bagan Built Heritage.

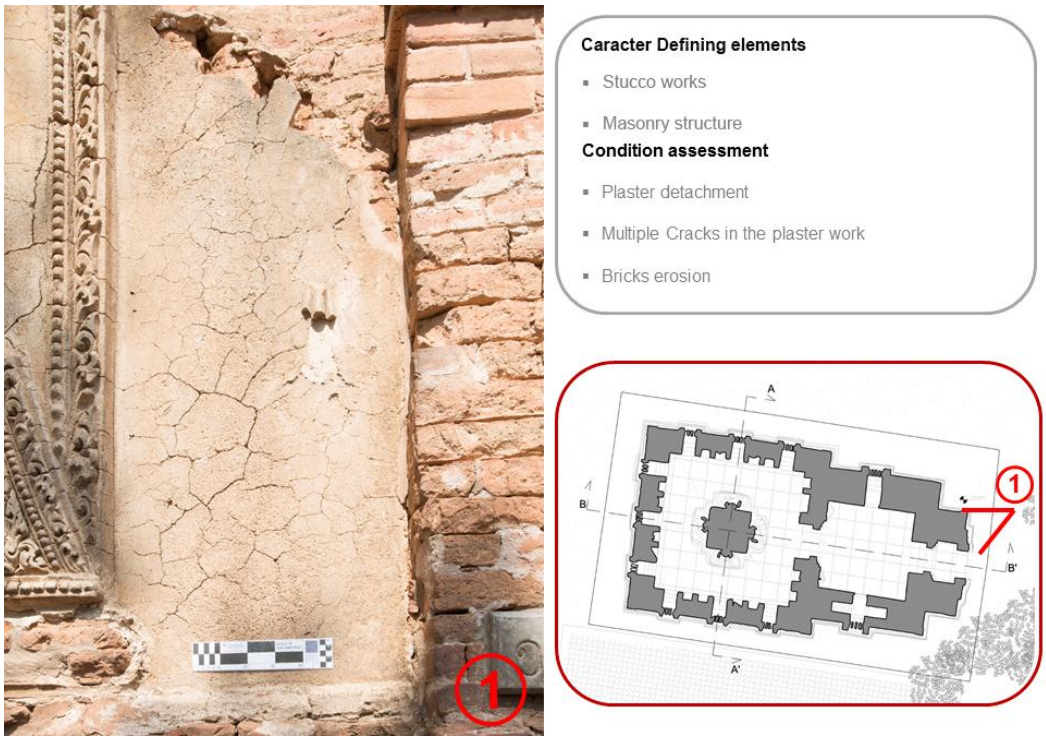


Figure 23 Example of record photography documenting character defining elements and conditions of the Phya-sa-shwe-gu temple. The image is referenced in a key plan.

High-dynamic-range photographs can be achieved by capturing and processing multiple photographs of a high contrast scene into a single image with details in both highlights and shadows, often using exposure bracketing, and then merging them into an HDR image.

Once the photos are shot, according to the rules reported in the paragraph 1.8 Record Photography, it is necessary to:

- Load photographs on Luminance-HDR[15];

Once the photos are loaded in Luminance-HDR it is necessary to follow these steps:

► Click on New HDR Image;
► Click on Next;
► Click on (+) icon;
► Select the bracketted images;
► Back on the HDR creation wizard, Click next ;
► Click Auto Align images;
► Click next;

[15]Luminance-hdr is a free software that can be downloaded at the following link: http://qtpfsgui.sourceforge.net

- Select Overlay;
- Click Save;
- Click Next;
- On the HDR Creation Wizard, Hit Finish.

Once these steps have been followed it is possible to create the HDR image by:

- Browse thru the previews of the different “Operators”;
- Check Result Image size;
- It is possible to play with other settings and get the desired image range;
- When ready click “Save as” to store a Jpeg image with the resulting photograph.

2.7 Panoramic Photography

Once the photos are taken according to the rules on the paragraph 1.9 Panoramic Photography, it is possible to process the photos in Hugin[16].

The following steps have to be followed:

- Open Hugin
- Load photographs on Hugin > Hit Load Images > browse and select all your images
- Select images
- Select the correct lens (Full Frame Fish eye)
- Rotate and align photographs > Hit align
- Align the panorama modify your panorama
- Go to Move/drag
- Use your move the image until it is correctly aligned
- Go to projection and select Equirectangular
- Go to Assistant
- Click Create Panorama
- Select the desired size of the projected panorama
- Select format of the image and quality and click OK

[16] The free software Hugin can be downloaded at the following link: http://hugin.sourceforge.net

Figure 24 Example of panoramic image.

The photos taken can also be processed in the software PTGui Prov9.0. Within this software, as in Hugin, it is possible to combine the different photos generating a quicktime 360 view as well as tiffs and raws original photographs. The PT Gui software for the creation of panoramic images can be downloaded at the following link: http://www.ptgui.com

Panoramic photographs provide an additional comprehensive visual understanding of the spatial context.

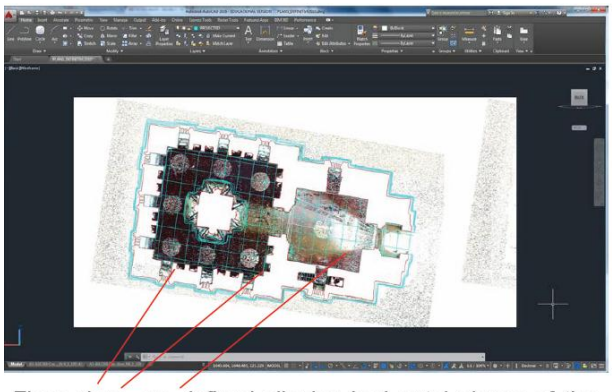
2.8 Measured drawings

A dossier of measured drawings can be produced from a combination of information collected from field notes and hand measurements, Total Station survey[17], Photogrammetry and Record Photography. For a comprehensive documentation elaborates should include the following graphic components:

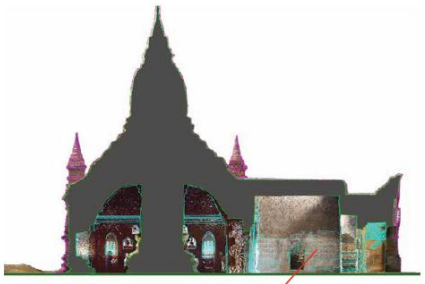
- Site Plans;
- Roof Plans;
- Floor Plans;
- Cross Sections;
- Elevations;
- Context 3D view (possibly).

The scale of all these components depends on the information accuracy required.

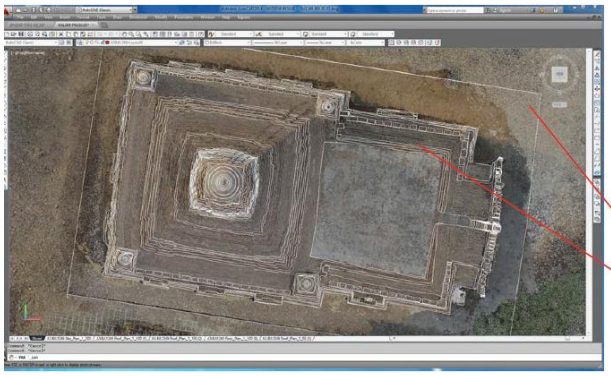
[17] The drawings produced in the field with the Total Station need to be refined in AutoCAD with the support of hand measurements and photographs.



Floor plans are defined clipping horizontal planes of the dense point cloud. Flooring is traced using projections.



Vertical cross sections are prepared clipping teh dense poitn cloud and tracing projections



Orthogonal projections fo the dense point cloud are traced to prepare line drawings of the temple

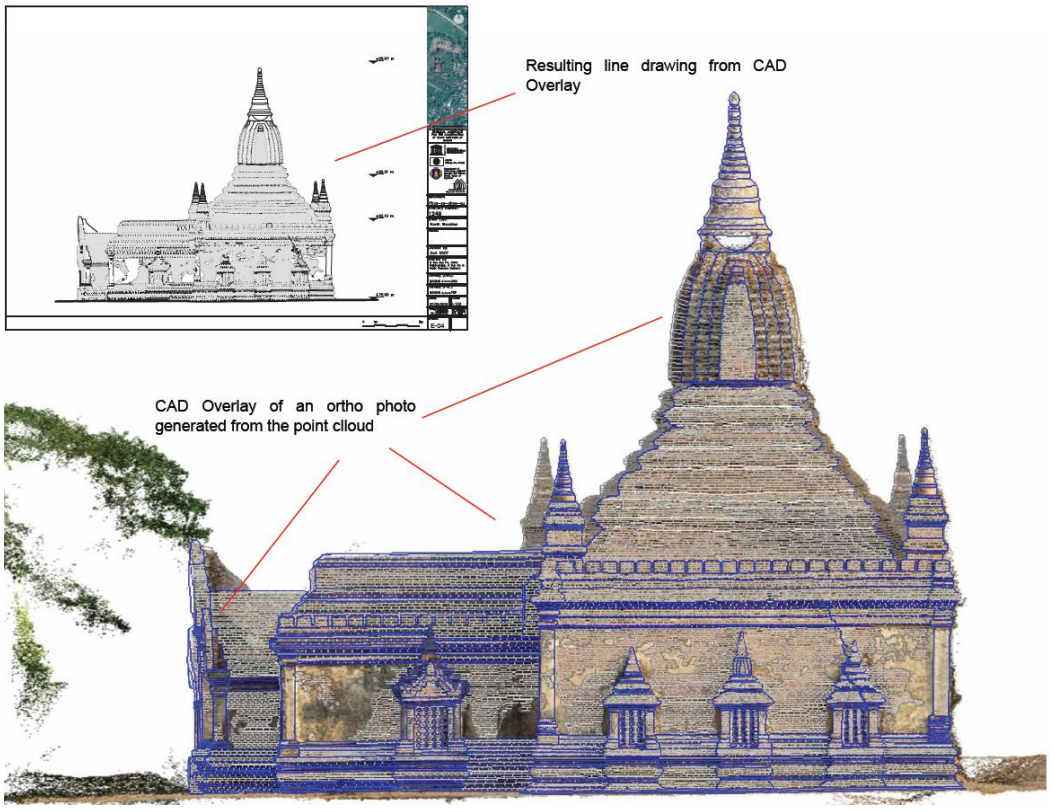


Figure 25 Example of measured drawings that can be produced using dense point clouds.

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Annexes

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Annex 1

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TS11_Protocol

Document Information

Document type: Protocol
Workgroup: Mario Santana Quintero, Davide Mezzino

Author: Davide Mezzino
Creation date: 02 May 2015

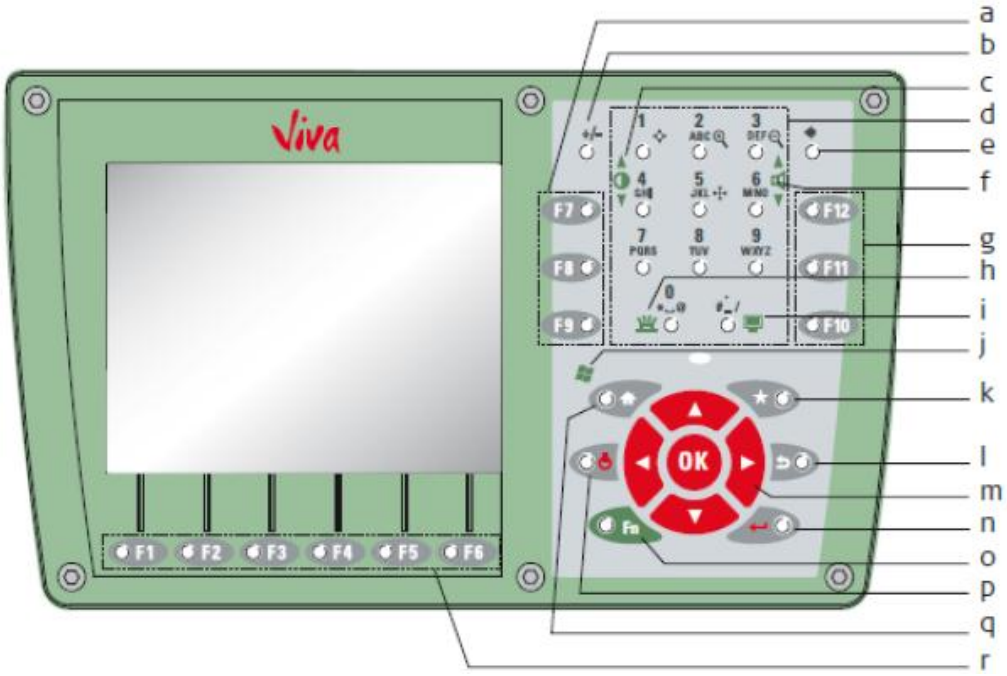
Last save date: 23 August 20155

Revisions

Date	Name	Changes

Background

The Total Station TS11 is used for measuring, calculating and capturing data. The user interface is operated either by the keyboard or by the touch screen with supplied stylus (the red stylus). The workflow is the same for the Keyboard and touch screen entry.



a) Function keys **F7** - **F9**
b) ± key
c) Brightness
d) Alphanumeric keys
e) Backspace
f) Volume
g) Function keys **F10** - **F12**
h) Keyboard illumination
i) Screenshot
j) Windows CE
k) Favourites
l) ESC
m) Arrow keys, **OK**
n) ENTER
o) **Fn**
p) ON/OFF
q) Home
r) Function keys **F1** - **F6**

Equipment

The necessary equipment for a proper use of the Total Station are:

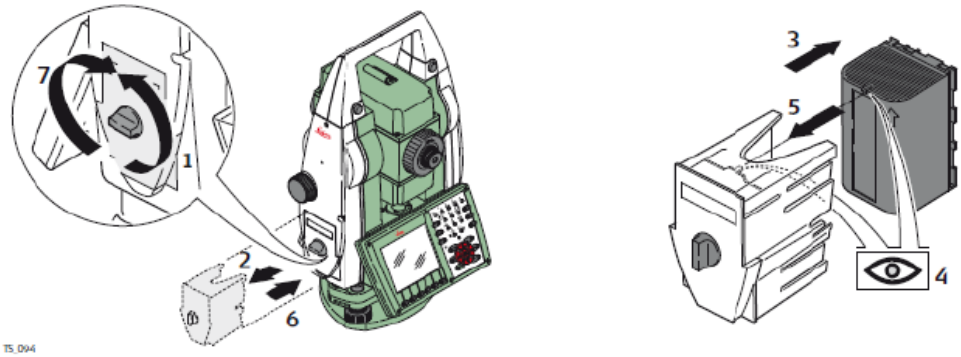
- Tripod;
- Total Station;
- Batteries;
- Prism (mirror);
- Tape;
- Targets;
- Notebook;
- Pen.

Operating principles

Batteries

Batteries

Change battery step-by-step



Step	Description
1.	Face the instrument so that the vertical drive screw is on the left. The battery compartment is below the vertical drive. Turn the knob to the vertical position, opening the lid of the battery compartment.
2.	Pull out the battery housing.
3.	Pull the battery from the battery housing.
4.	A pictogram of the battery is displayed inside the battery housing. This pictogram is a visual aid to assist in placing the battery correctly.

Step	Description
5.	Place the battery into the battery housing, ensuring that the contacts are facing outward. Click the battery into position.
6.	Place the battery housing into the battery compartment. Push the battery housing in until it fits completely into the battery compartment.
7.	Turn the knob to lock the battery compartment. Ensure that the knob is returned to its original horizontal position.

Levelling

To level the Tripod and the Total Station follow these steps:
1. Take the tripod, keep its legs together and loosen the clamping screws, let the legs drop out as you pull the stage up to your chin and retighten the clamping screws.
2. Spread the legs open to form a stable shape. Place the feet so that they won't slip. Place the tripod approximately over the point. Placing your foot over the point and moving the tripod over your foot can help. Sight the point on the ground through the hole in the tripod stage and moving the whole assembly about the centre of the stage up with the point.

Figure 1 Point on the ground on which the tripod has to be placed.

3. Place the instrument carefully on the tripod. Check the tripod is stable, the stage roughly level and the plummet is over the point. Secure the instrument tribrach to the tripod with the central fixing screw. The screw should be tightened firmly.

4. Drive the plummet to the centre of the mark with the tribrach foot-screws. Use 2 of the foot screws by turning your thumbs out or in together to move the plummet onto the point. The 3rd screw will provide the motion to move at right angles to the first movement.
5. With the plummet centred on the point the instrument is now levelled by adjustment of the tripod legs. Working on each leg in turn, slacken off the clamping screw and slide the leg to bring the instrument bubble in line with its centre circle. Retighten the clamping screw securely before adjusting the next. Measure and record the height of the instrument.
6. Switch on the Total Station by pressing the red button  on the side and hold for 3 seconds;
7. Wait, the laser plummet will be activated automatically, and the Level/Plummet screen appears. Otherwise, press FNC from within any application and select Level/ Plummet.
8. Make sure the red lower laser is directly on top of the “Instrument Position”, this is done by elevating two legs with your hands and putting on top of the point;

Figure 2 Image depicting the red lower laser directly on top of the "Instrument Position".

9. Make sure that the instrument is in a comfortable height for you to reach and measure;

10. Now use the legs to level, using the upper water level, when the bubble reaches the center, the electronic level will be activated, now you can use the electronic level.

Figure 3 Example of how to use the footscrews to level the Total Station

Center the electronic level of the first axis by turning the two footscrews. Arrows show the direction of rotation required.

Figure 4 Image of the electronic level on the total station.

11. Before starting to work, make sure again that your lower laser is directly on top of the "Instrument position", if not move the device by unscrewing the Total Station in the tripod, be very careful, level again if needed;
12. When ready, press "OK".
13. Take the height of the instrument by placing the holder for height meter and measuring with the height meter, write down this number somewhere.

Before staring any other operation take into consideration the following 3 main points:

- The instrument have to be stable and safe, clear from wet, dust, wind and traffic. Make sure the instrument is clamped to the tribrach.
- The Total Station has to be vertically centered over the point.
- Levelling the Total Station. Keep an eye on the bubble, it will move off centre over time. Use the foot screws to bring it back to level, but don't forget if you adjust the level you will need to check the centring.

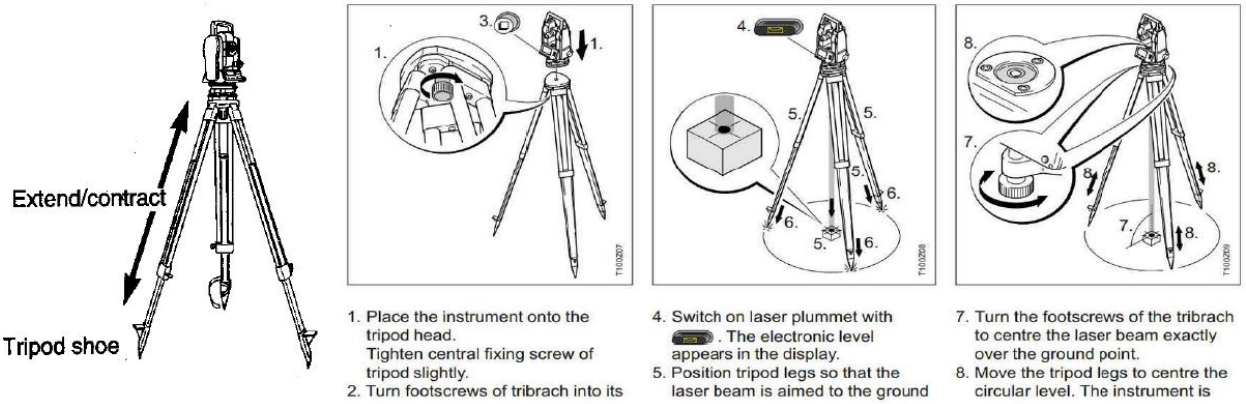


Figure 5 Different steps of the levelling phase.

Small adjustments can be made by carefully unscrewing the central mounting and sliding the tribrach back over the mark. Once the bubble is almost in the middle of the centre the instrument has to be levelled using the electronic level. For this operation the following steps have to be followed: Main Menu > Instrument > TPS settings > Level bubble and comp (compensator). During this operation the tribrach, the tripod and the underground should be stable and secure from vibrations or other disturbances.

Figure 6 Images presenting two screenshot of the total station while levelling using the electronic level.

First set up

After levelling the instrument, go on the Main menu > Jobs and Data > New Job . In New Job there are the following options:

- Name: (digit the name of the project)
- Description: (digit the description of the project)
- Creator: (digit the name of the creator)
- Device: (choose between Internal memory or SD card)

To change from number to letter and vice-versa press F6 Num for number, Alpha for letter.

Once inserted the description and features of the new job go back in the main menu > Go to work > Set up > OK > Set orientation (i.e. orienting the Total Station towards North) > OK. Station point from > job

Figure 7 Sreenshot of the Total Station while setting the orientation.

Figure 8 Measuring the instrument height with the tape.

In job:

- Job: (select the job name that has been created)
- Point ID: 101 for example
- Easting: 1000.00 m
- Northing: 1000.00 m
- Elevation: 100.00 m
- Instrument height: (measure the height instrument with the tape)

Then, store > OK

Go back in the main menu > Go to work > Survey >

- Point ID: 201 (for example)
- Target height: 0.000 m

Press 'star' and activate the laser, click on laser beam on.

Then  > go with the total station on the target and press > Meas (F1).
In the 'Map' folder it is possible to visualize what we are surveying.

Figure 9 Screen shot of the total station screen. It is underlined the Map folder where it is possible to visualize the points, lines and areas surveyed. It is also underlined (in green) the Code folder where it is possible to personalized the parametes of the points/lines/areas that we are measuring.

In the 'code' folder it is possible to set up the parameters of the points/lines/areas that we are measuring.
To create a new code go on the 'Code' folder > Code: > New >

- Code: (digit the name of the code)
- Description: (digit the description of the code)
- Code group: (click > New and create a new code)
- Code type: (choose between point, line[1], area)
- Linework: (once set up everything if you need to draw a line select 'begin line' and start to draw once you finish remember to select 'End line' before measuring the last point of your line).

Followings set up

After levelling the instrument, go on the Main menu > Go to work > Set up > OK > Known back site.

[1] For the command line you can personalize your line giving style, colour, etc.

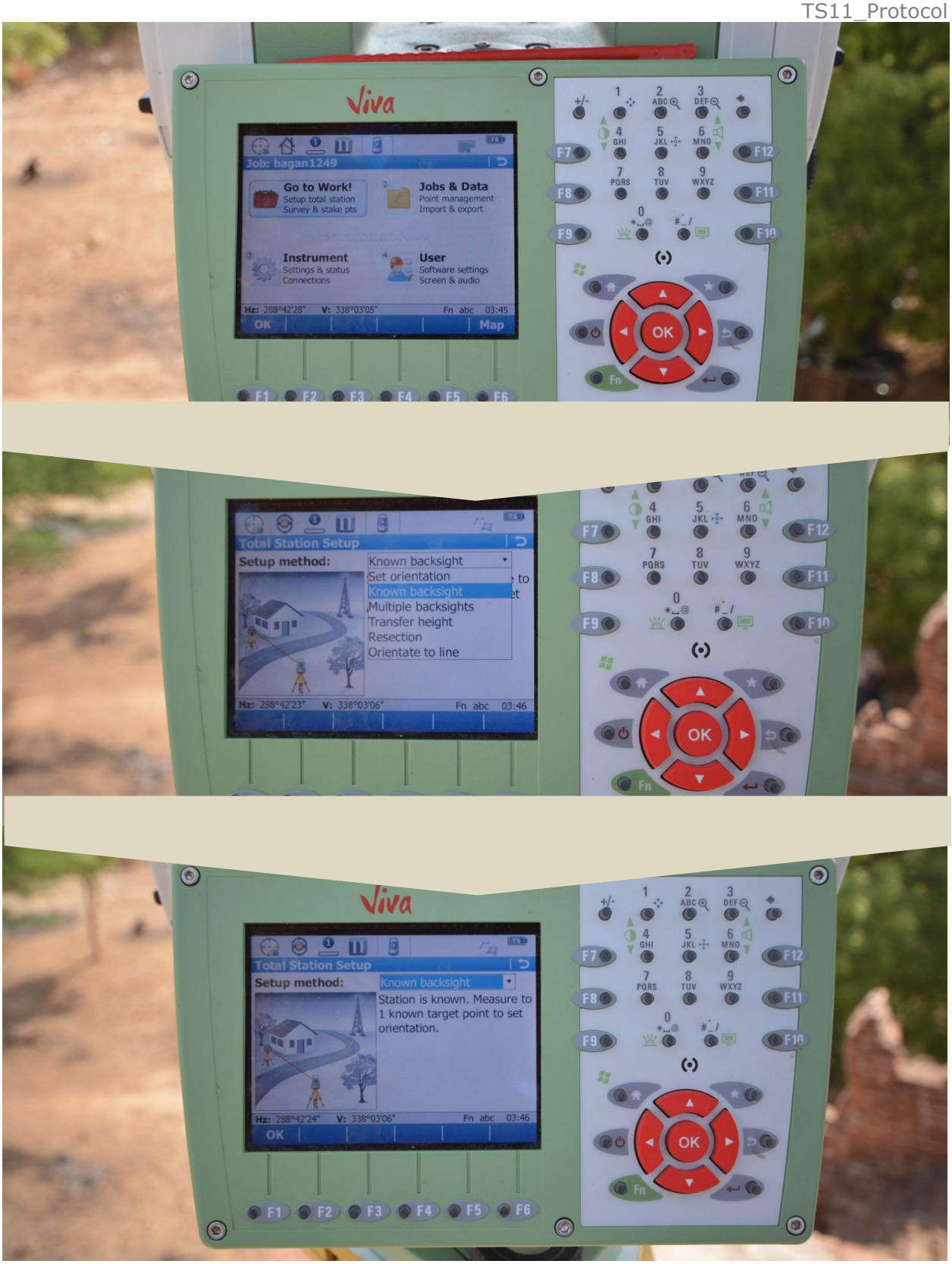


Figure 10 Images presenting the workflow of the set up.

In the point ID insert the number of your point (already in your survey network).

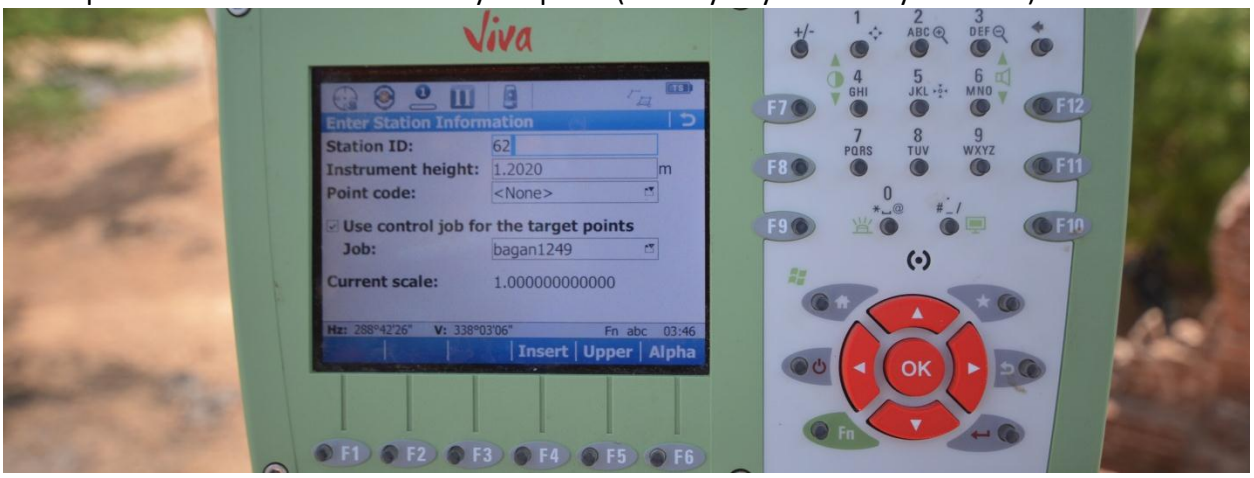


Figure 11 Screenshot of the Total Station while digiting the Station ID.

Then, measure the high of the Total Station with the tape.

Figure 12 The measurement of the height of the instrument.

Insert the numeric value in ‘instrument height’.
Insert the other known point to be measured digit its identity ID and select it for the list of point available (pick it selecting it from the list) and press OK.
Digit the height of the point to be measured.

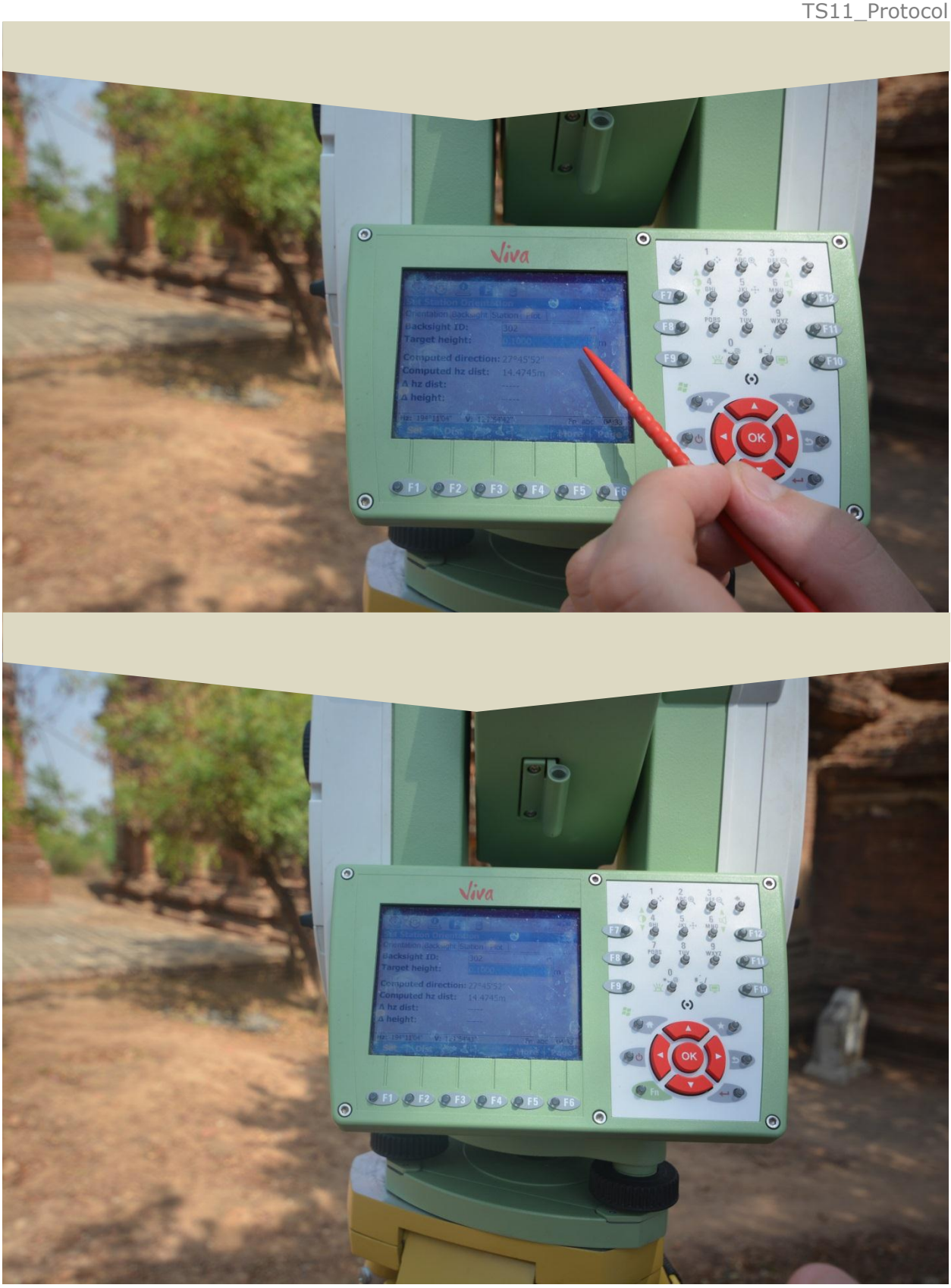


Figure 13 Workflow to set up the Total Station. Screenshot presenting how to insert the backsight point.

If you are measuring a point with the prism remember to select it (click on the second icon up on the right).

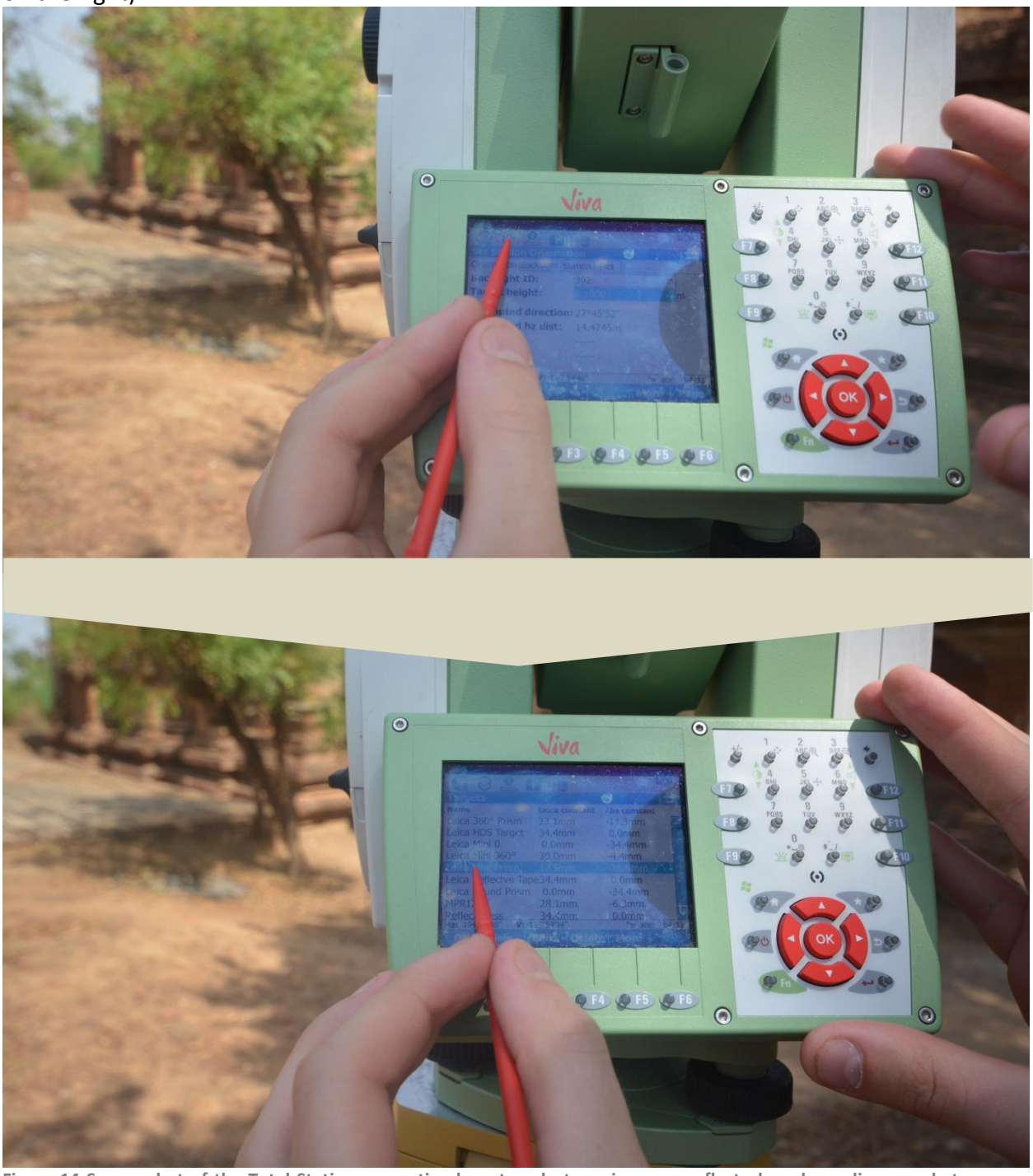


Figure 14 Screen shot of the Total Station presenting how to select a prism or a reflectorless depending on what you are going to measure.

Select the kind of prism you are using.
Click on star and then laser beam off.

Figure 15 Measurement of a point using the Leica TS11 and a Leica Mini Prism.

Measure the distance with the total station > Dist checking the error, if the error is fine click Set.

Figure 16 Workflow to set up the TS station using a known backsight

Once set up the total station it is possible to draw lines and areas, measure targets or other points to be added in the survey network.

To draw lines for floor plans, elevations or cross sections, go on the Main menu > Go to work > Survey > Code > Code: > New > Rename the code.

Figure 17 Workflow to draw lines with the Total Station.

Feature the code according to what are you going to draw (type of line, color, etc.).
If your code (layer) is already existing go on Code> Code: > select your code from the list and press OK.

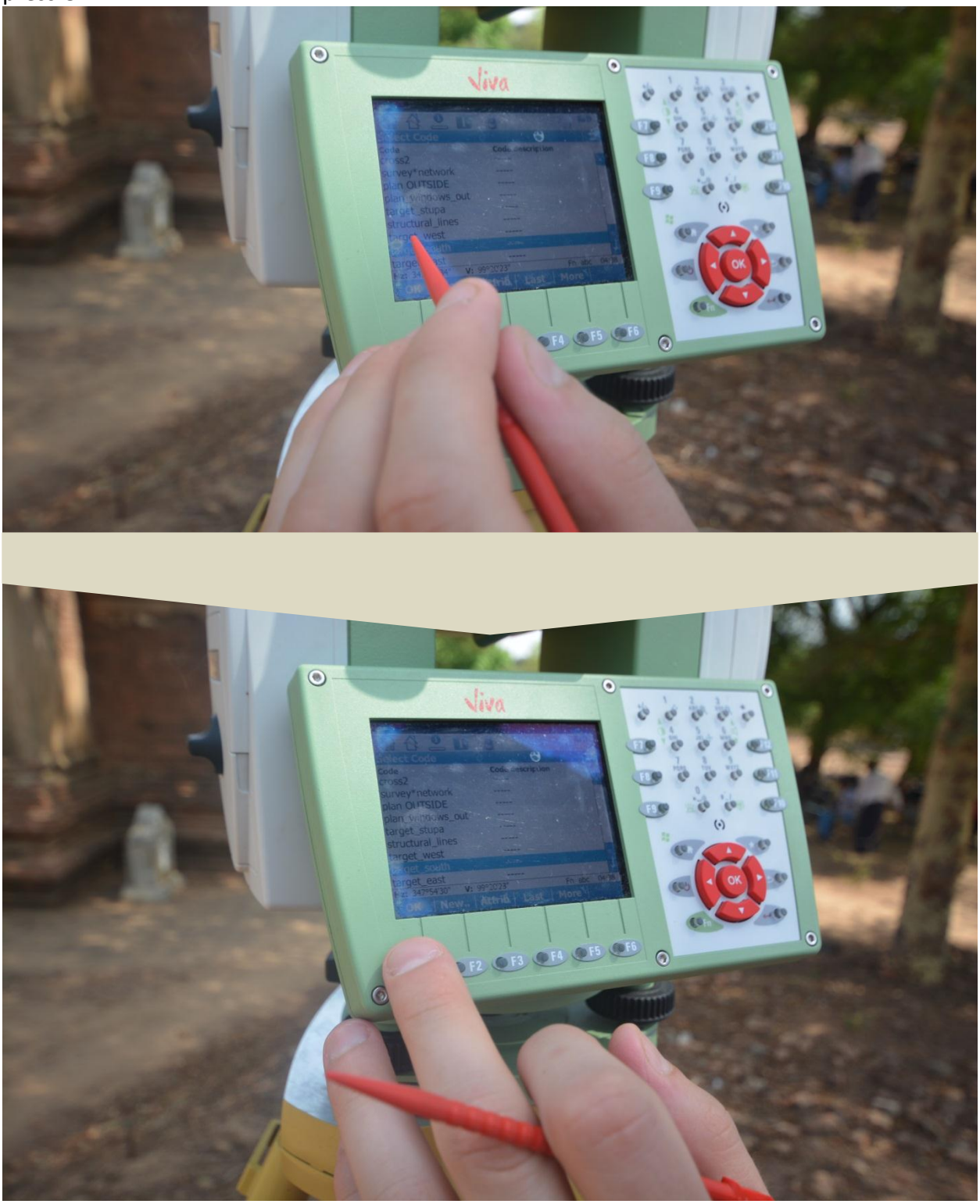


Figure 18 Workflow to draw in an existing code.

To start draw go on code> Linework > Begin line. If you want to finish your line go on Code > Code: > Linework > End line.

If you are measuring targets, go on Code and in the section Point ID digit the name of your point. In Target height give 0.000 and in Code: the code (layer) in which you want to visualize it (ex. target_north façade).

Figure 19 Workflow for measuring targets.

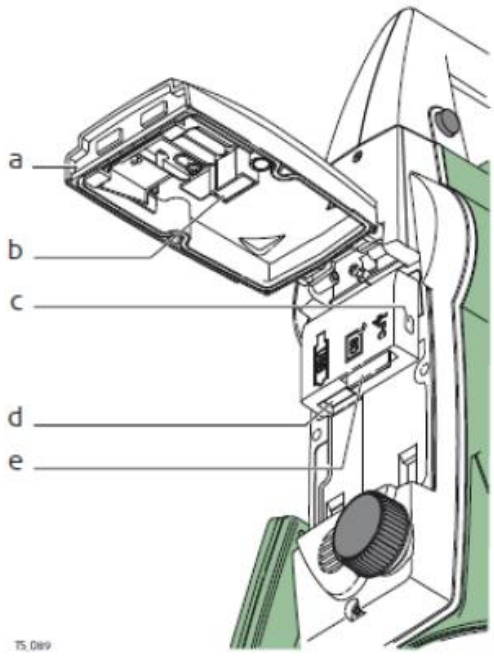
Because it is a point leave the Linework unselected (---------).

Once you have set all the parameters point on the target and measure the target with the total station pressing ‘Measure’.

Figure 20 Workflow of target's measuring.

Data Downloading

Open the compartment lid.



a) Compartment lid
b) USB stick cap storage
c) USB device port (mini AB OTG)
d) USB host port for USB stick
e) SD card port

Insert the USB stick in the USB host port.

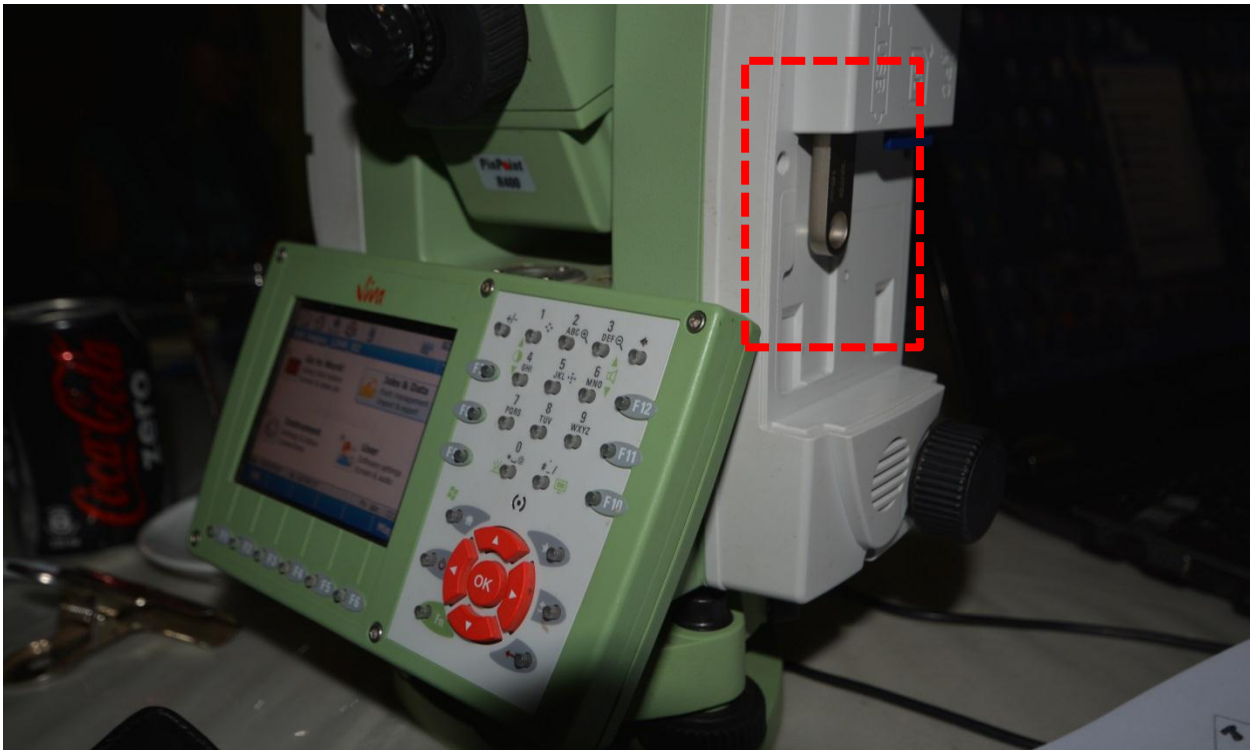
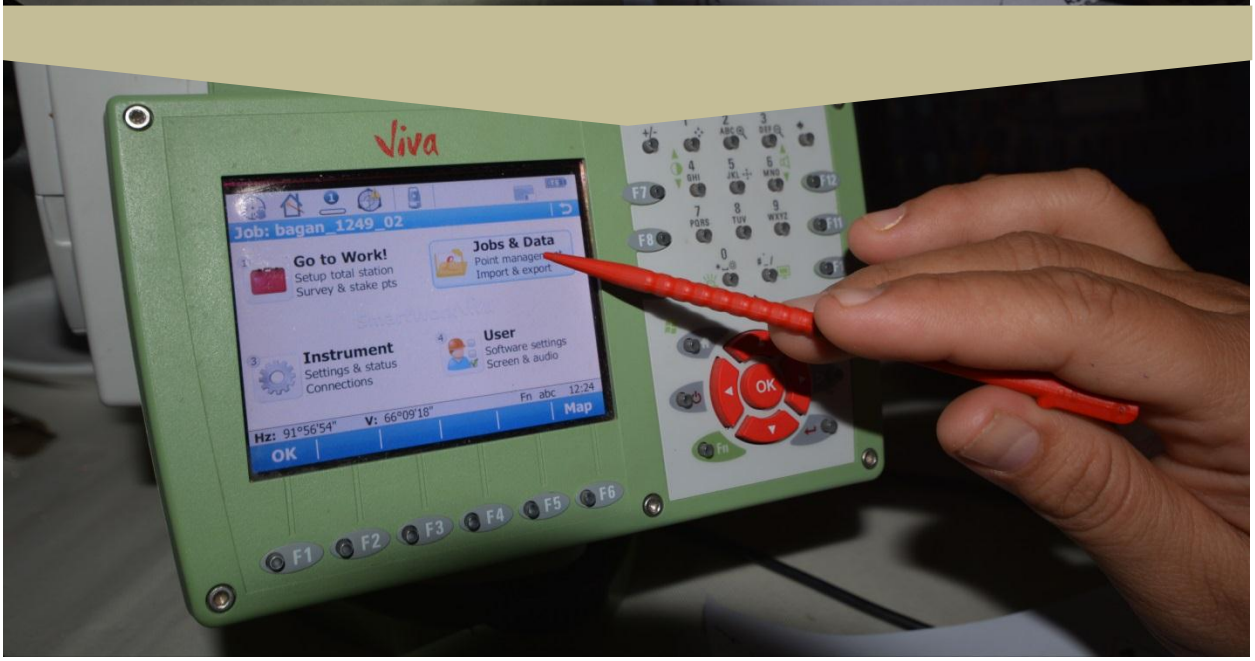


Figure 21 Location of the ISB hot port where it is possible to insert the USB stick.

Go in the main menu > Jobs and Data > OK > Export & copy data..> Export DXF data (file readable in AutoCAD) >

- > Folder: (select folder in which you want to export your data)
- > Export to: USB stick
- > Job: (select the name of the job)
- >File name: (name of the job)



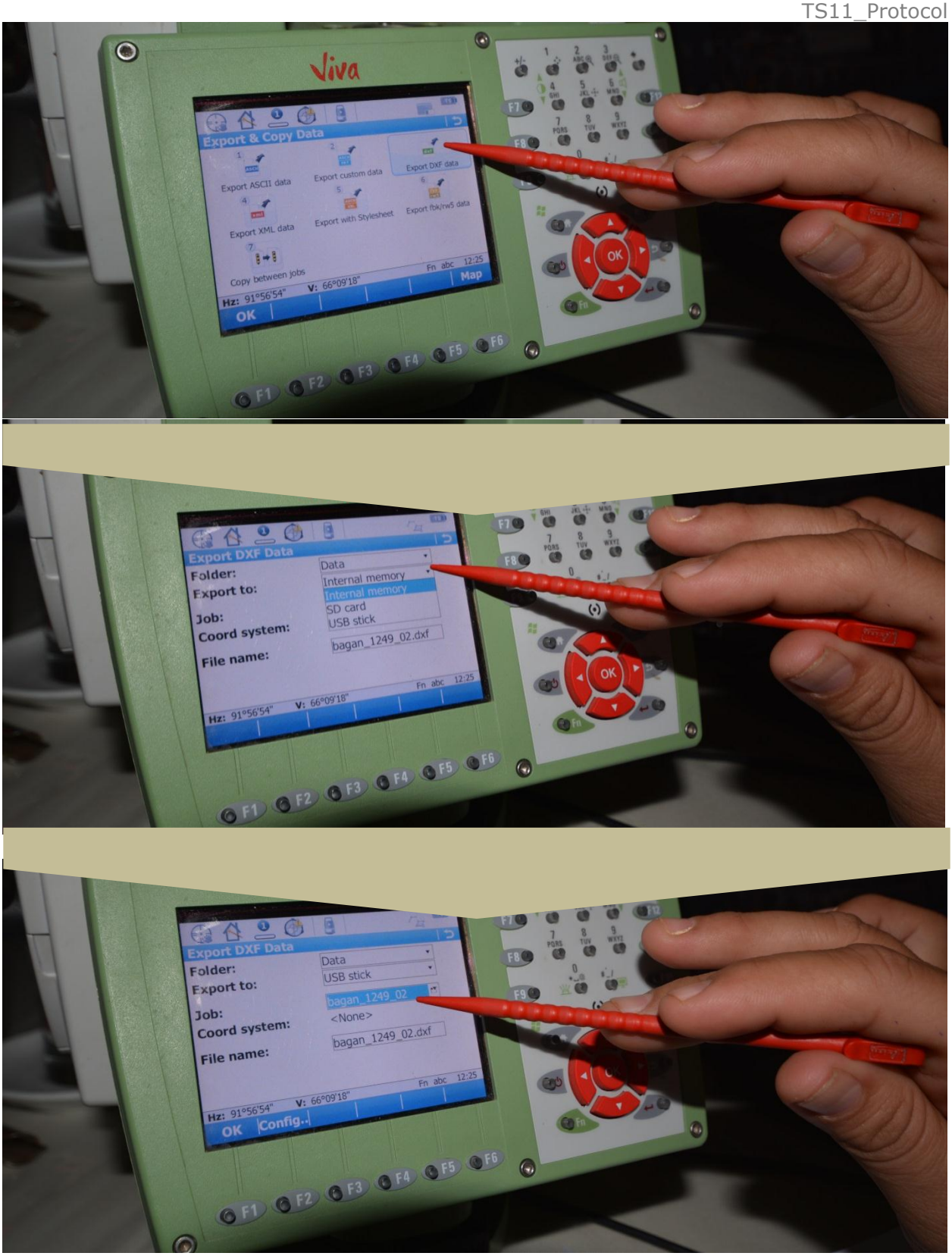
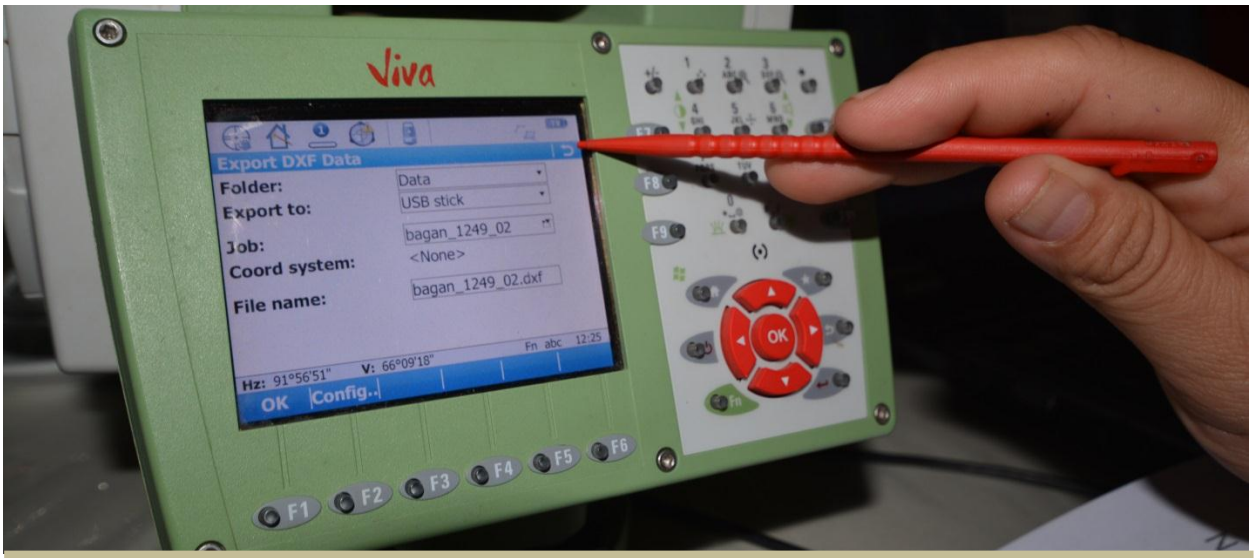


Figure 22 Workflow of the data export in the DXF format.

Then go back and click on 'Export ASCII data' to download the point list and their coordinates in a .txt file > Select the folder > Press OK[2] and the data will be exported to the USB stick.

Once the process is finished press NO.



[22] In 'Config..' you have different options.

- EXP > Export to DXF layer (so it maintains the features of the code of each points/lines/areas). to choose what to export (points/lines/areas).
- DXF > Export lines > as polylines > OK
- Labels > you can choose if have information about Point ID, coordinates, etc.


Viva
Export ASCII Data
Folder: Data
Export to: USB
Job: bagan_1249_02
Coord system: <None>
Example: P,E,N,H
Output file to write: bagan_1249_02.txt
Hz: 91°56'54" V: 66°09'18"
OK Config.. Filter.. CrdSys..
F1 F2 F3 F4 F5 F6


Export ASCII Data
Folder: Data
Export to: USB
Job: bagan_1249_02
Coord system: <None>
Example: P,E,N,H
Output file to write: bagan_1249_02.txt
F1 F2 F3


Export ASCII Data
Folder: Data
Export to: USB
Exporting data...
72%
Output file to write: bagan_1249_02.txt
Hz: 91°56'54" V: 66°09'18"
OK
F3 F4 F5 F6

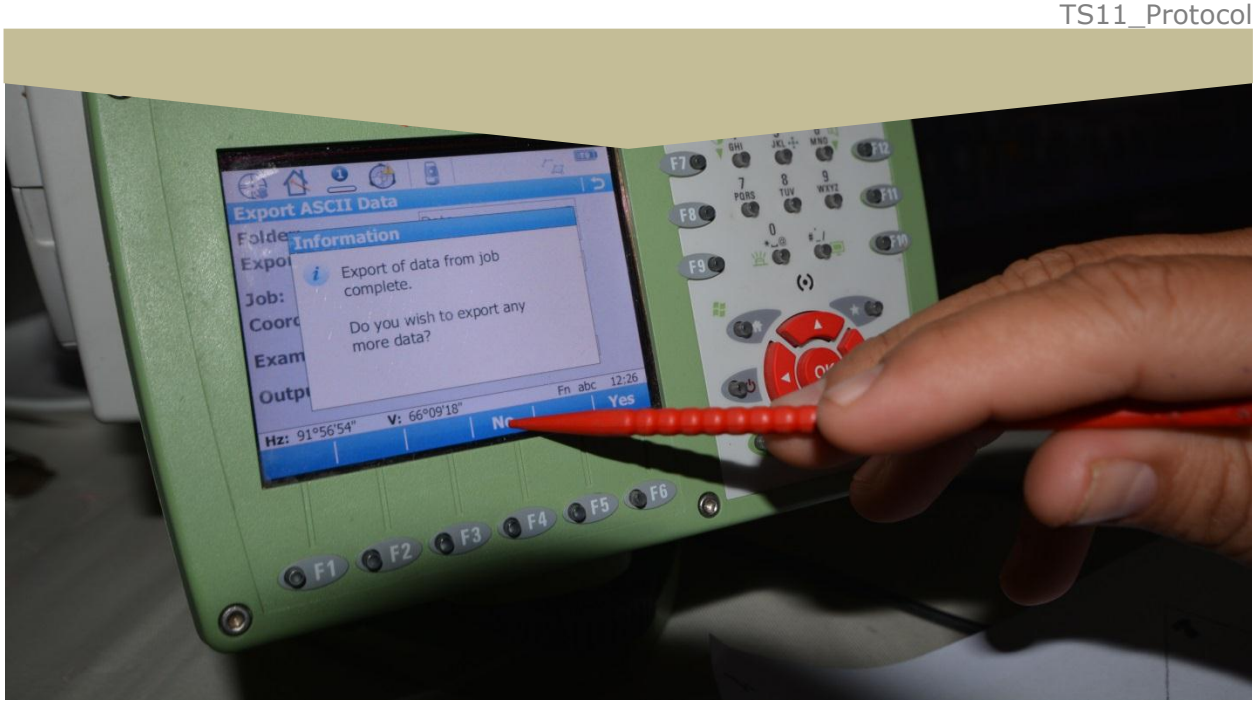


Figure 23 Workflow of the data export in the ASCII format.

Go back in the main menu and extract your USB stick.

Figure 24 Image presenting how to extract the USB stick from the USB host port.

Once finished everything turn off the Total station pressing  > Turn off.

Import Data to AutoCAD

Insert the USB stick with the DXF data downloaded from the Total Station > Open from your computer the USB stick > Copy the folder in which you saved your DXF file (i.e. Data folder) in your computer > Open the DXF file with your AutoCAD version. Select the folder >right click > Open with > Open with your AutoCAD version.

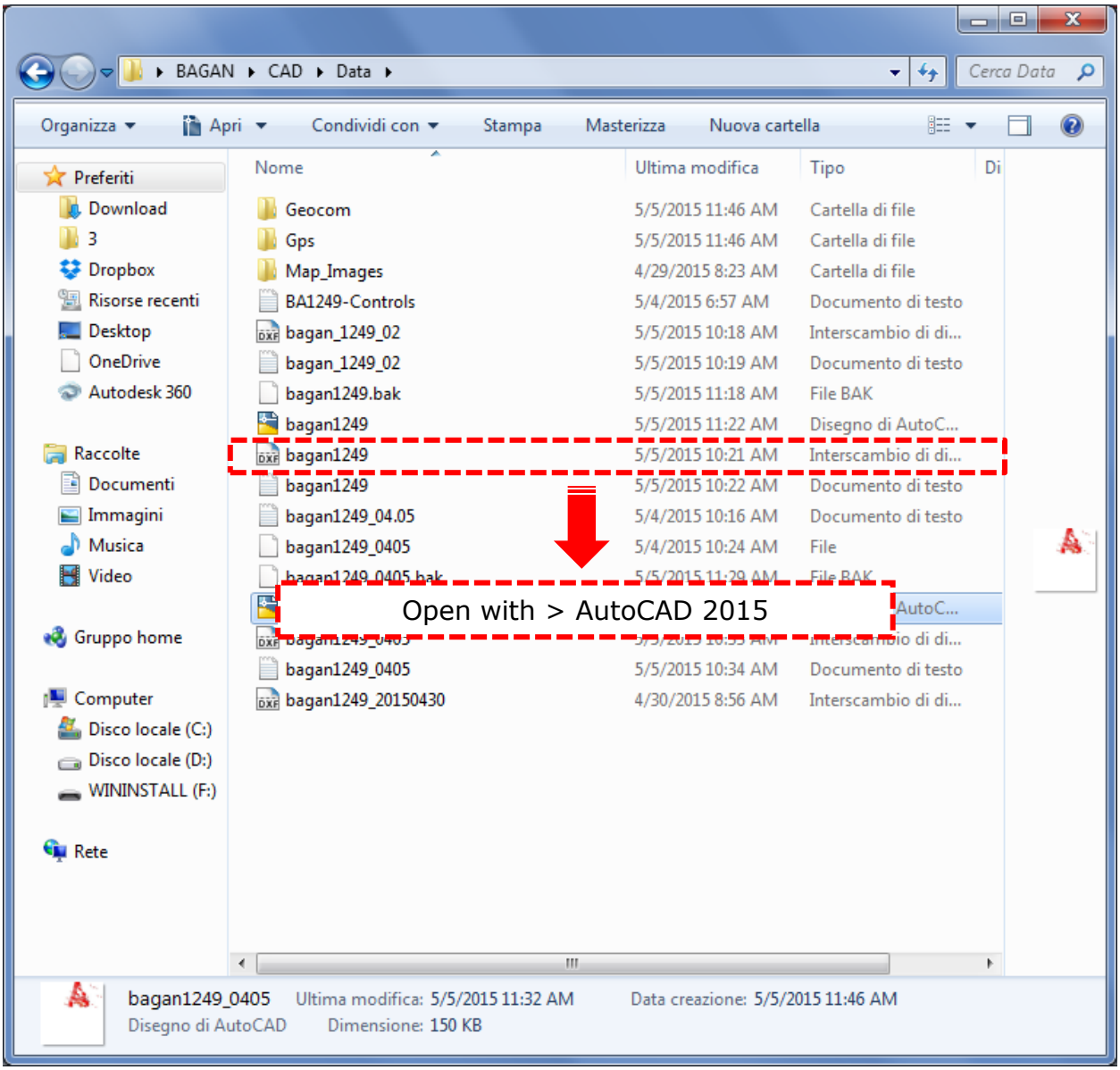


Figure 25 How to open the DXF file with your AutoCAD version.

Once you open your file it is possible to visualize the points/lines/areas you have measured.

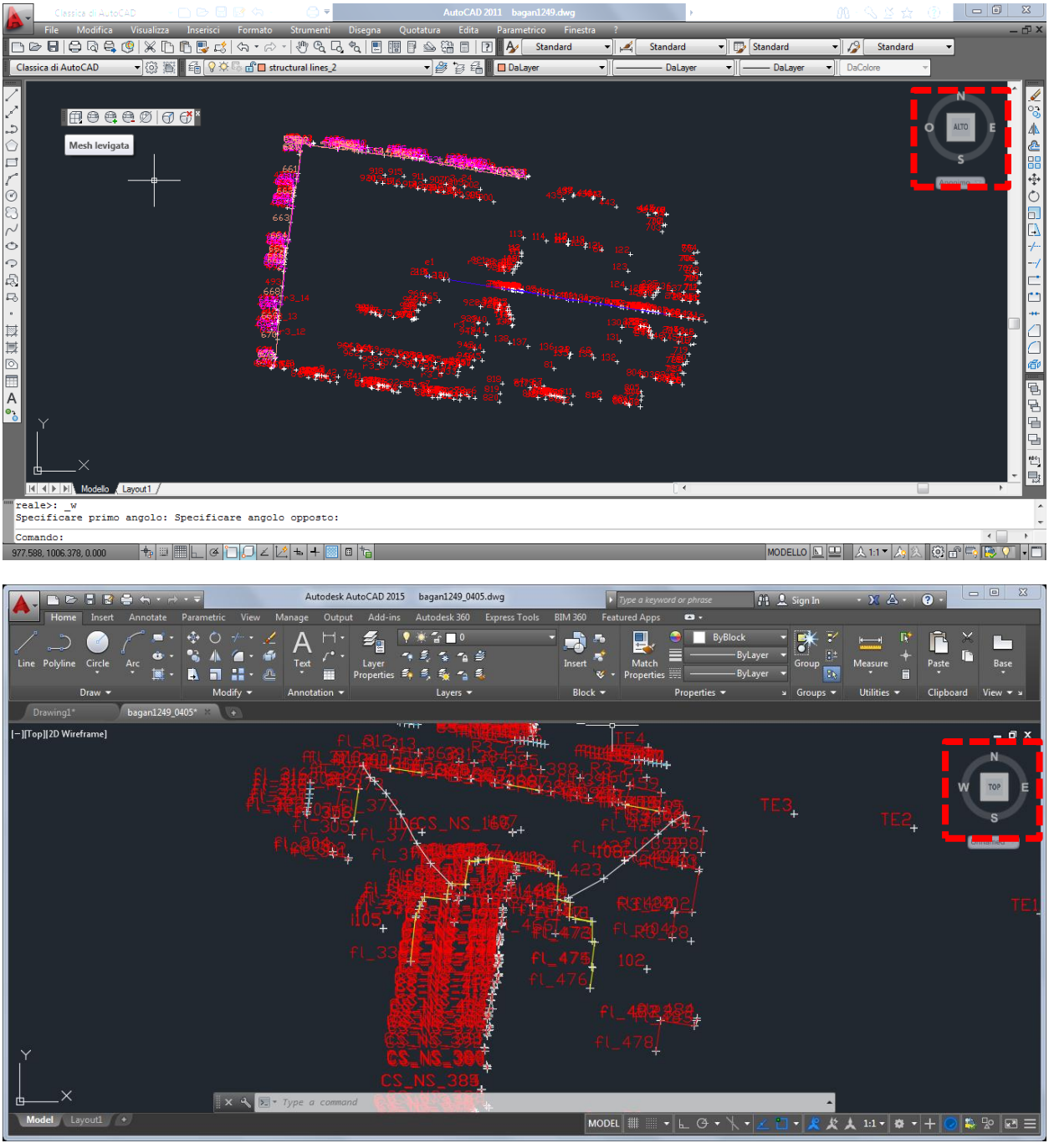


Figure 26 Visualization of Points and lines from the Total Station opened with AutoCAD 2015. Visualization in 2D.

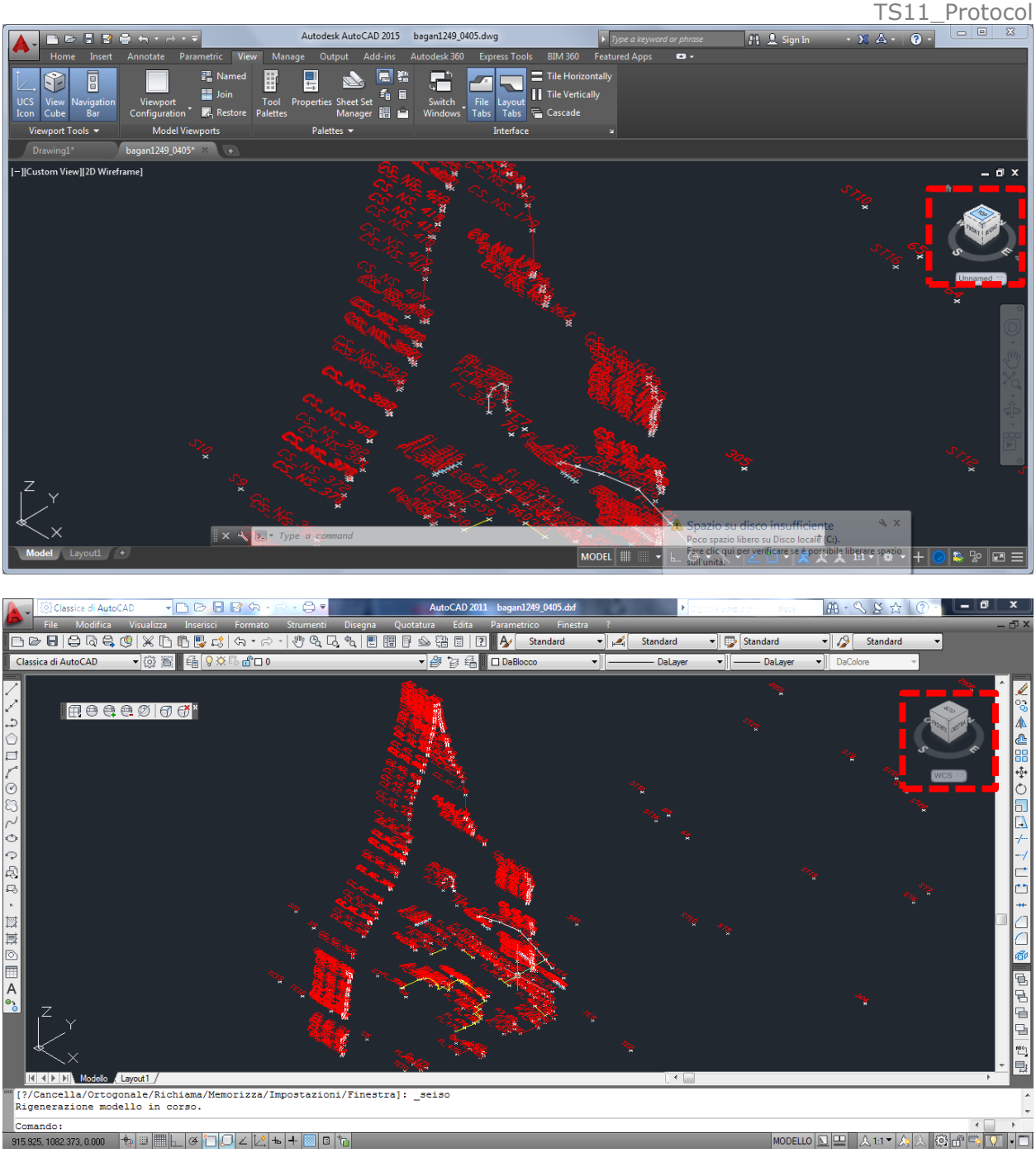


Figure 27 Visualization of Points and lines from the Total Station opened with AutoCAD 2015. Visualization in 3D.

It is possible to visualize the data in 2D and in 3D editing the View settings.

In AutoCAD 2015 using 'PIVOT' and the box up on the right it is possible to move the point cloud in 3D.

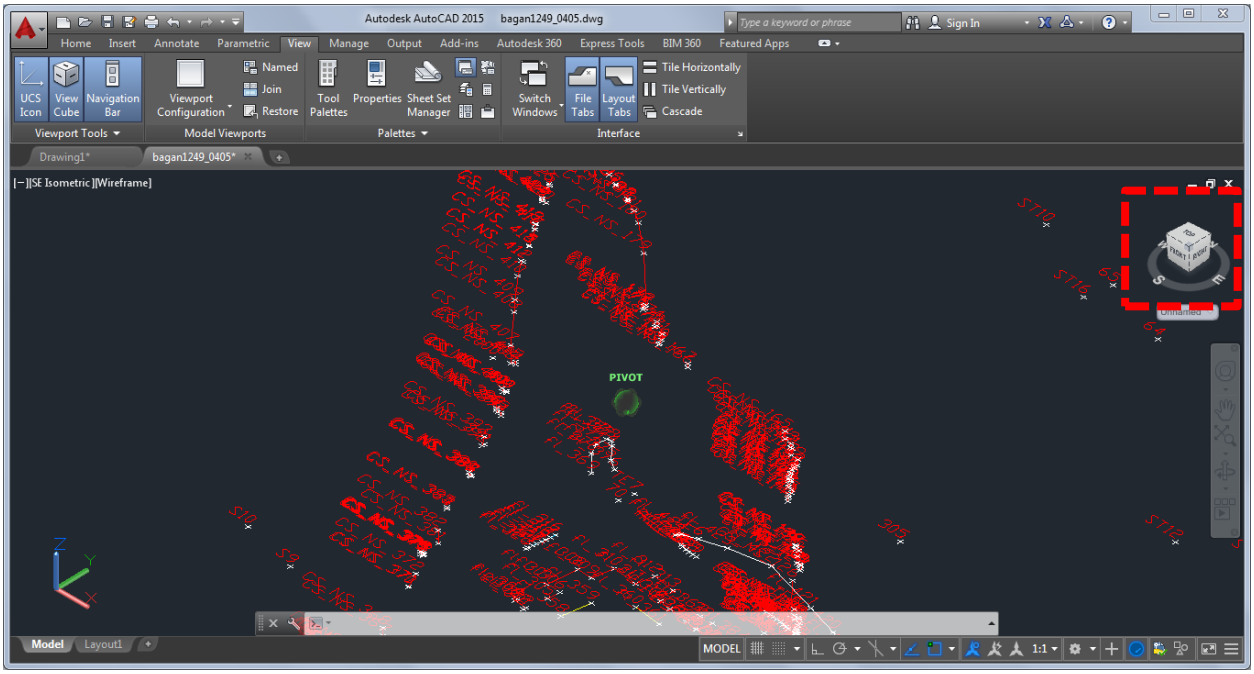


Figure 28 Screen shot of the DXF file from the Total Station opened in AutoCAD in a 3D view.

With these data it is possible to draw floorplans, cross sections, elevations. The same data can then be used to orient and match the points clouds using the measured targets.

Annex 2

2_Photoscan Protocol_CIMS Myanmar_2015.pdf

Photoscan_Protocol

Document Information

Document type: Protocol
Workgroup:

Author: Zeynep Ekim, Davide Mezzino
Creation date: July 23, 2013
Last save date: June 24, 2015

Revisions

Date	Name	Changes
June 24, 2015	Davide Mezzino	PhotoScan Basics & Advanced Use

Background

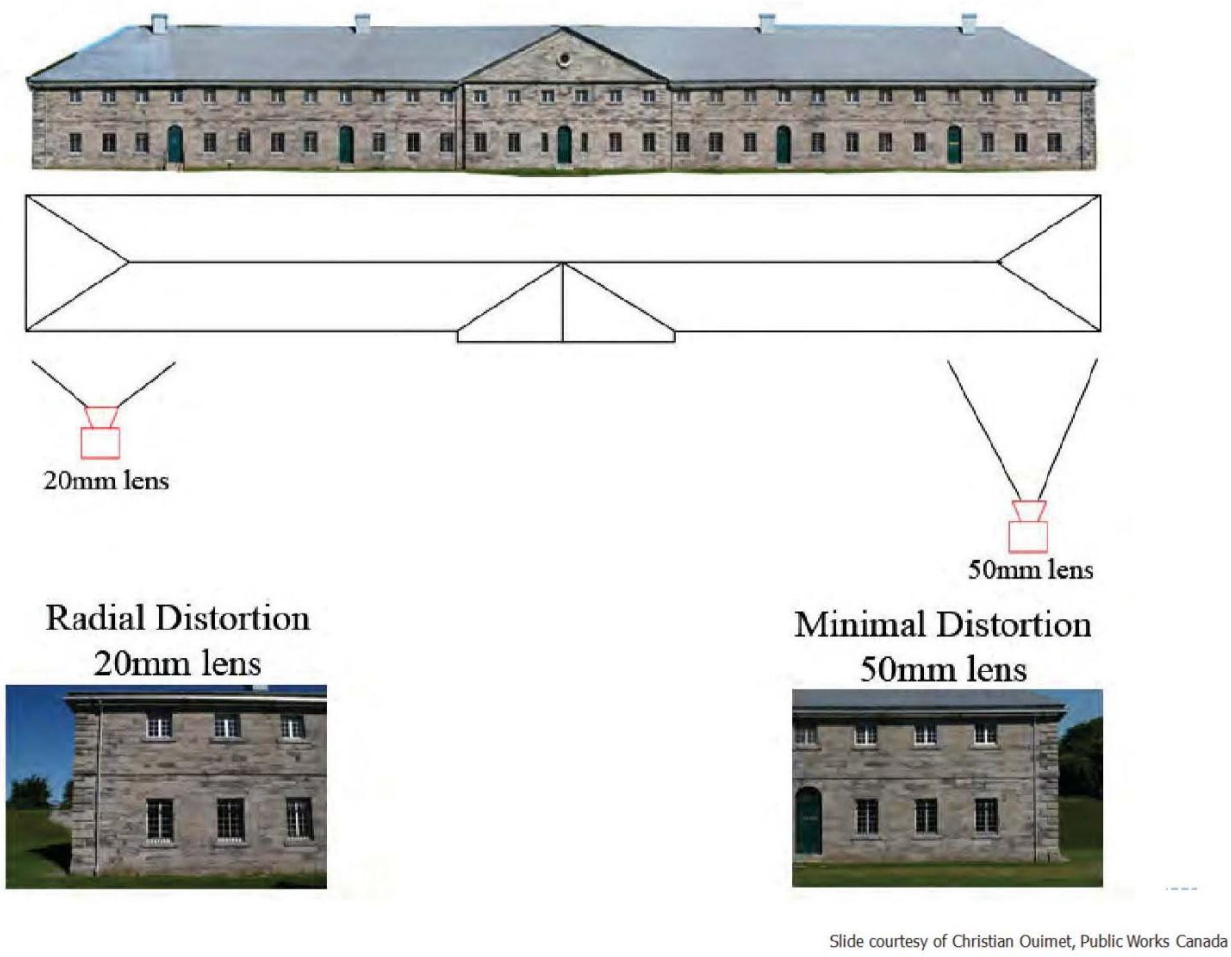
Agisoft PhotoScan generates fully textured 3D models using 2D images. Following an automated work flow, the software aligns the images, calculates the geometry and builds the texture. Photos used to create the model can be taken from any position, given that the object is visible in at least 2 photos.

Taking Photos for PhotoScan(Photogrammetry):

Photos can be captured using any high resolution camera following some guidelines.

>Equipment:

Wide angle lens is better to capture images for photogrammetry than a telephoto lens. Avoid using fish eye lenses to minimize distortion. From the Morocco project, we learned that the best results are achieved by using a 50mm lens.

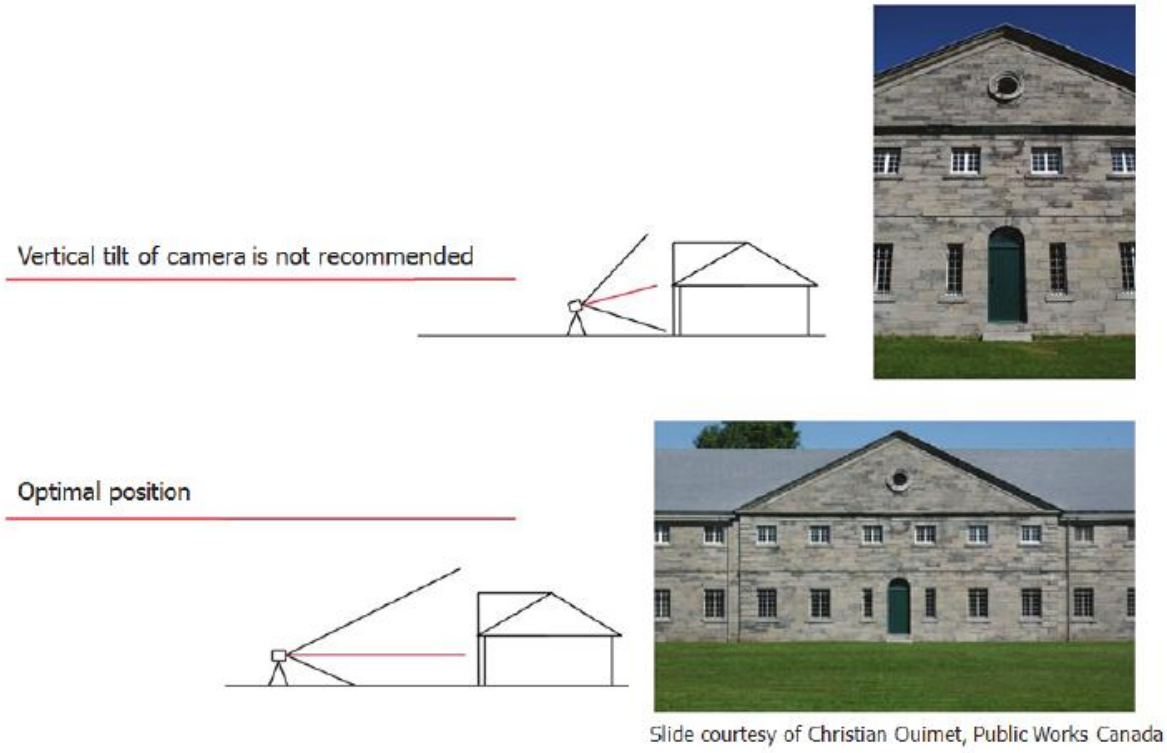


Slide courtesy of Christian Ouimet, Public Works Canada

>Position:

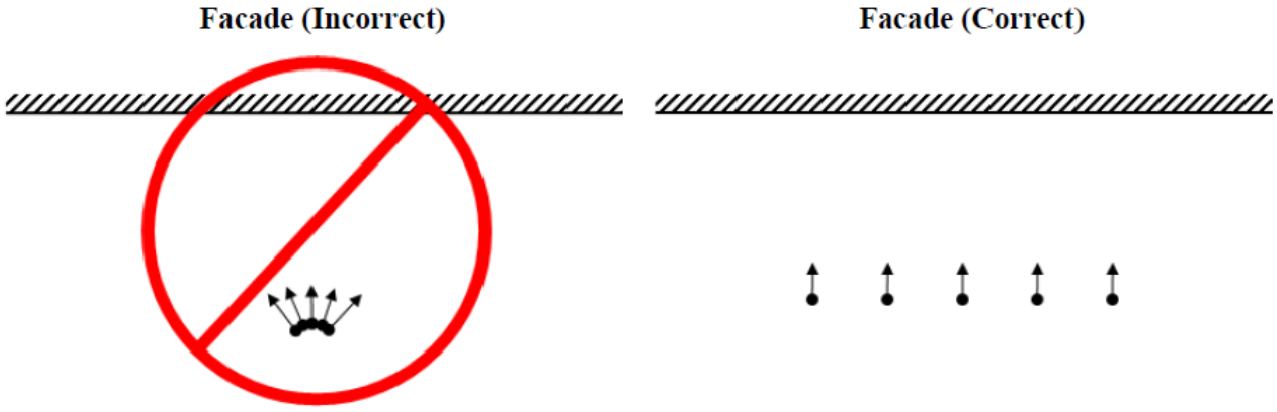
When you are taking the photos, be sure to move around the object. Do not pan. Photos should have 60-80% overlap.

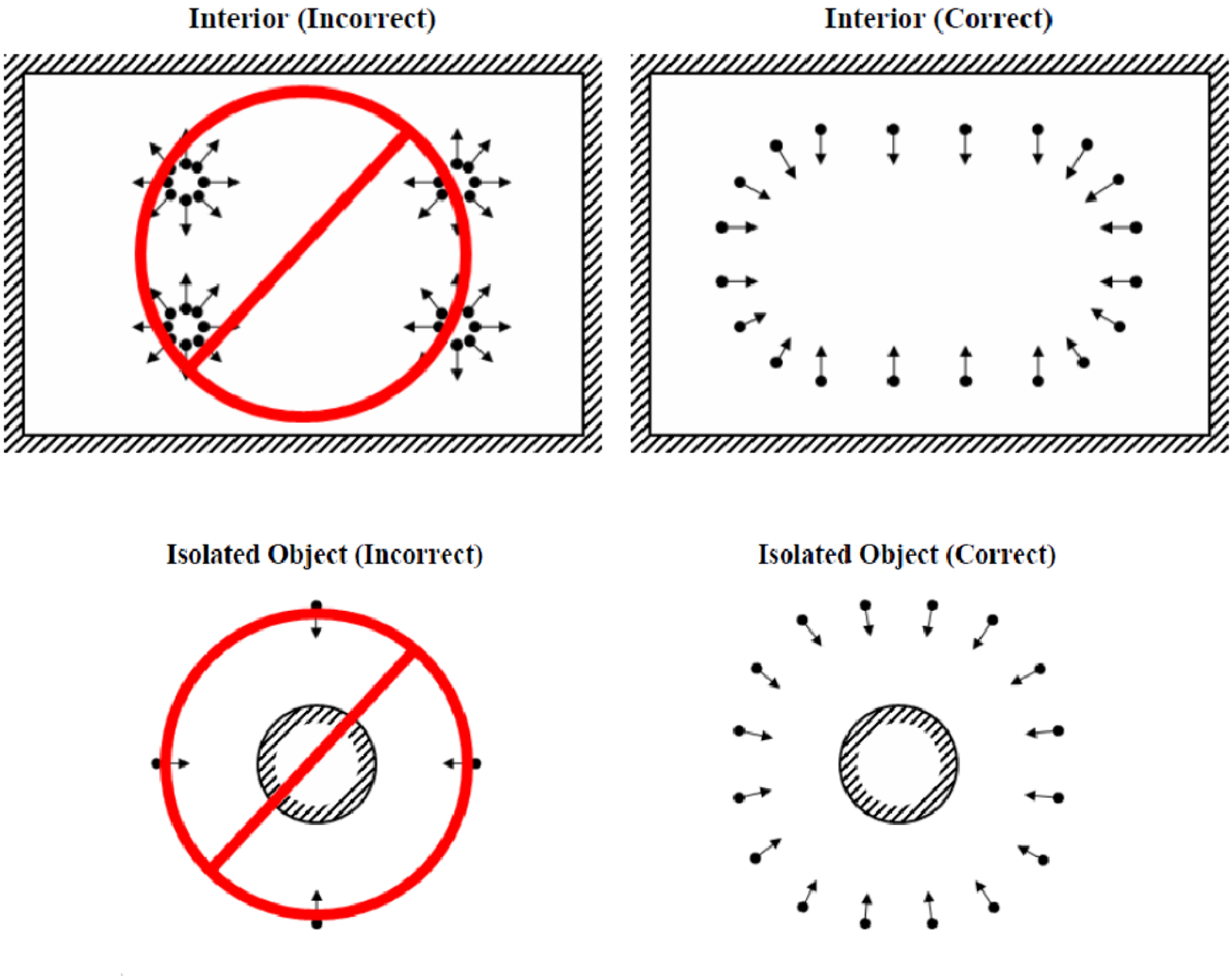
Vertical tilt is not ideal but can be used to capture the surface in tight areas. However, head on shots are preferred if you have the space to back up.



Slide courtesy of Christian Ouimet, Public Works Canada

TIP: Spending some time to plan out the shoot is very useful. Establish your starting point and walk clockwise around the object, taking two steps between each photo capture. This will allow you to have a consistent overlap between each photo.





>Good Practice:

-Make sure you have a lot of overlap between you photos. A good practice is to take 3 photos of each surface. More photos is better than not enough photos.

-Avoid blurry images.

-Set the focus so that all parts of the photo are sharp. Use a tripod in poor lighting conditions.

-Any basic photography and lighting rule apply to taking photos for photogrammetry. Better photos= better photogrammetric model.

-Avoid flat and shiny surfaces. Textured planes are ideal for photogrammetry.

-Make sure there is homogenous illumination.

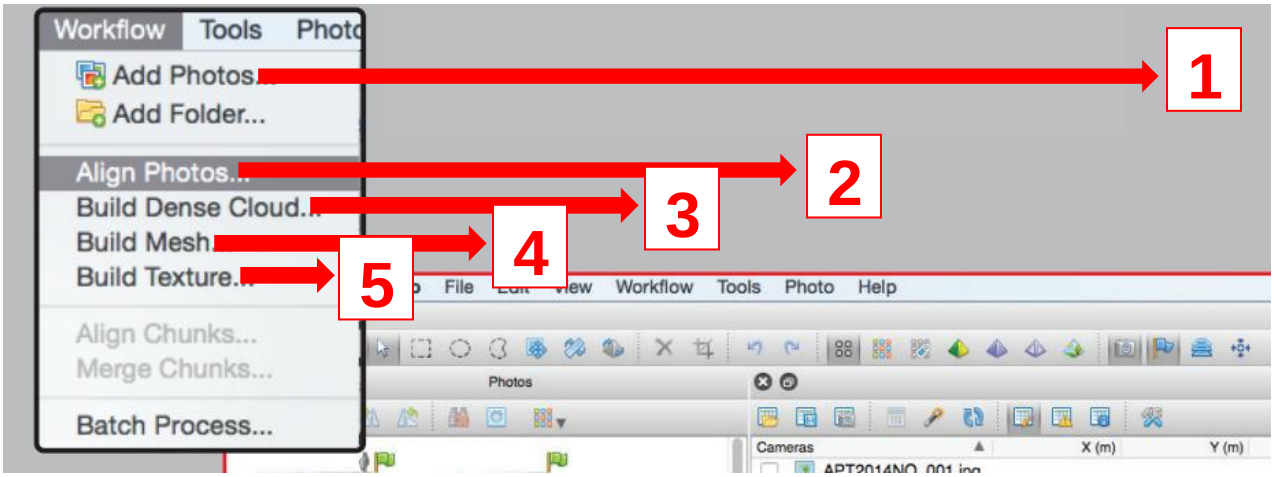
-Avoid lens flares , moving objects and obstructions in the foreground.

-Prefer to take pictures on a cloudy day, rather than a bright sky.

-Do not crop or modify your photos. Photoscan warps, crops and modifies your images when it is aligning the photos. As long as you have sharp images under good lighting conditions, minimal blurry with a lot of overlap, you will get good results.

PhotoScan Workflow:

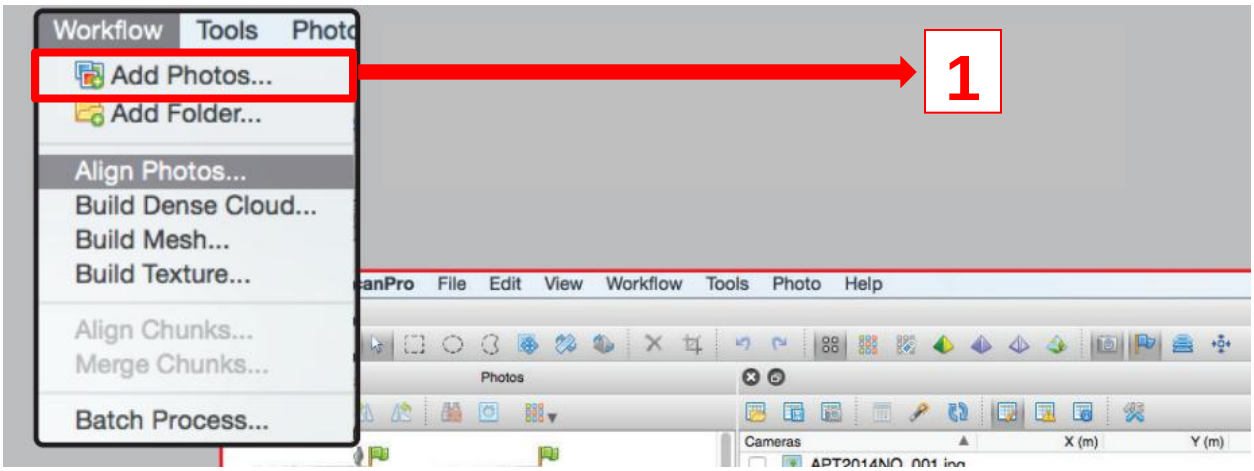
PhotoScan follows a 5-step Workflow to create the 3d model: Add Photos, Align photos, Build Dense Cloud, Build Mesh and Build Texture.



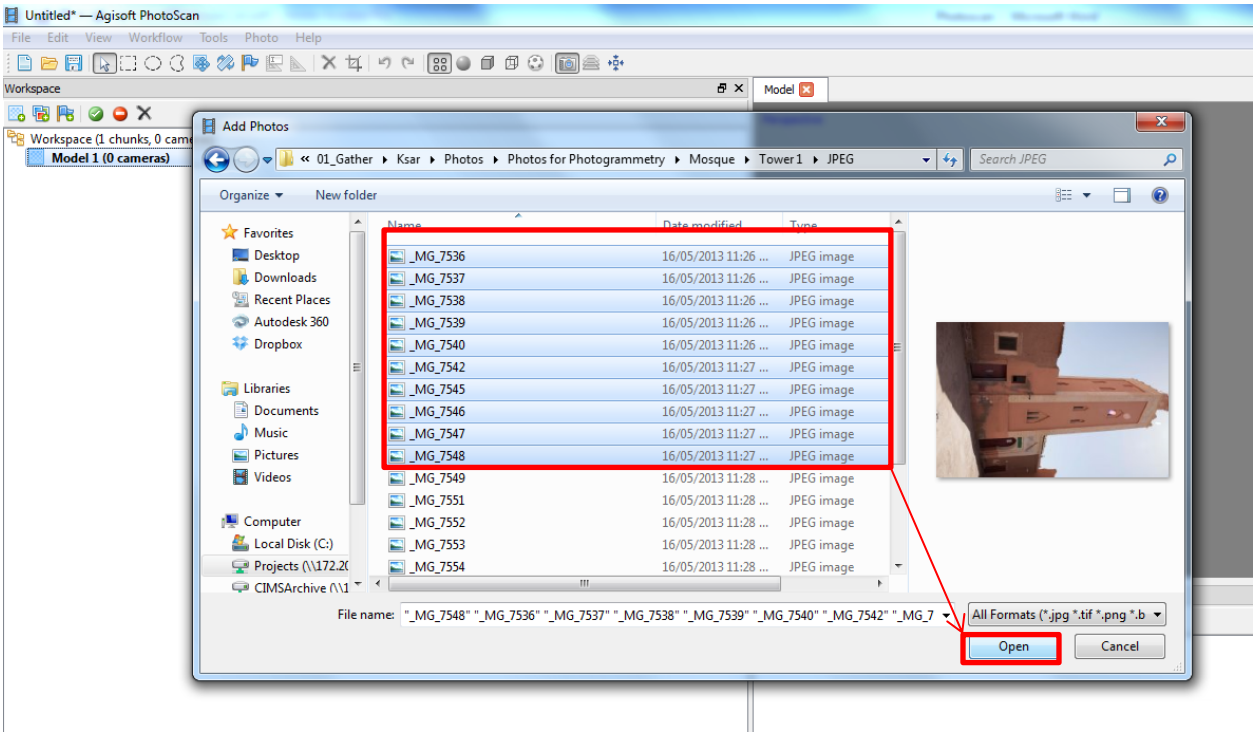
To start open Photoscan and create a new “Chunk” by clicking  . Give the chunk a name. (ex: Model 1.)

Adding Photos:

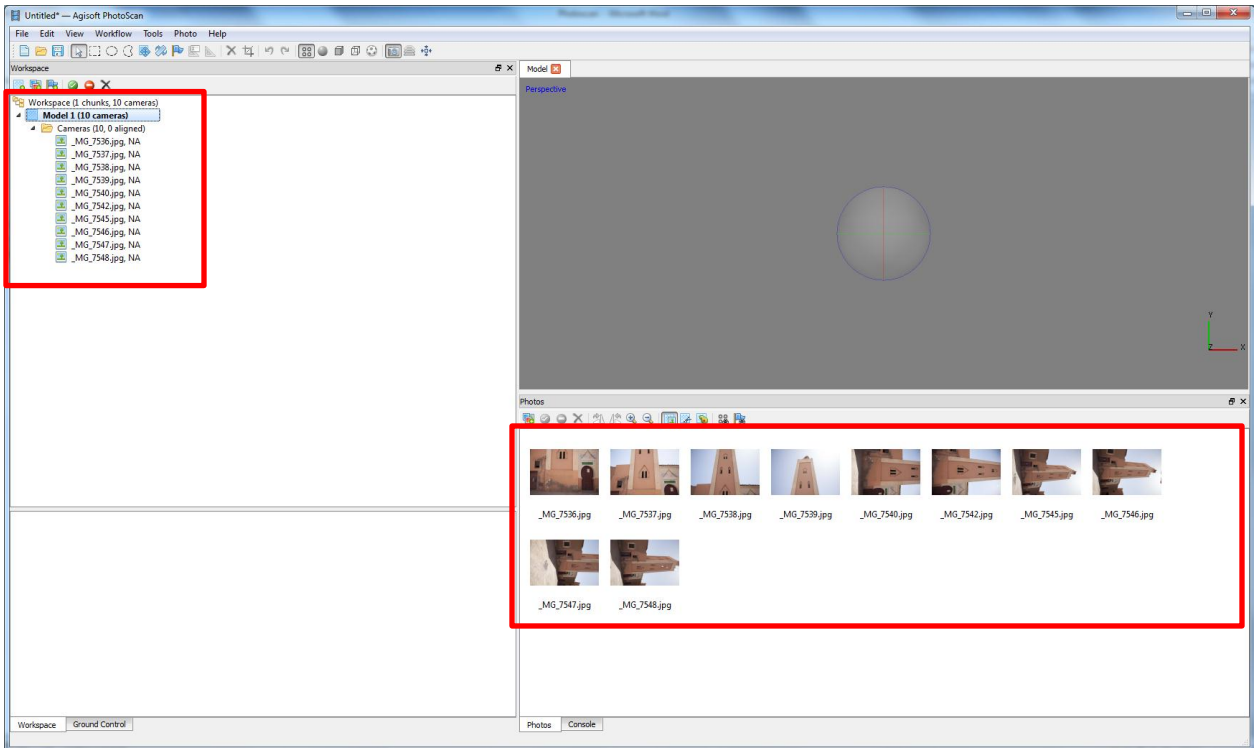
To load or add photos to your photoscan project select Add photos command under the workflow menu or click  on the toolbar.



Select your photos from the directory that opens up (PhotoScan accepts JPEG, TIFF, PNG, BMP, PPM, Open EXR. Images in other formats will not appear in the dialog box).



Selected photos will appear in the workspace when you click open.

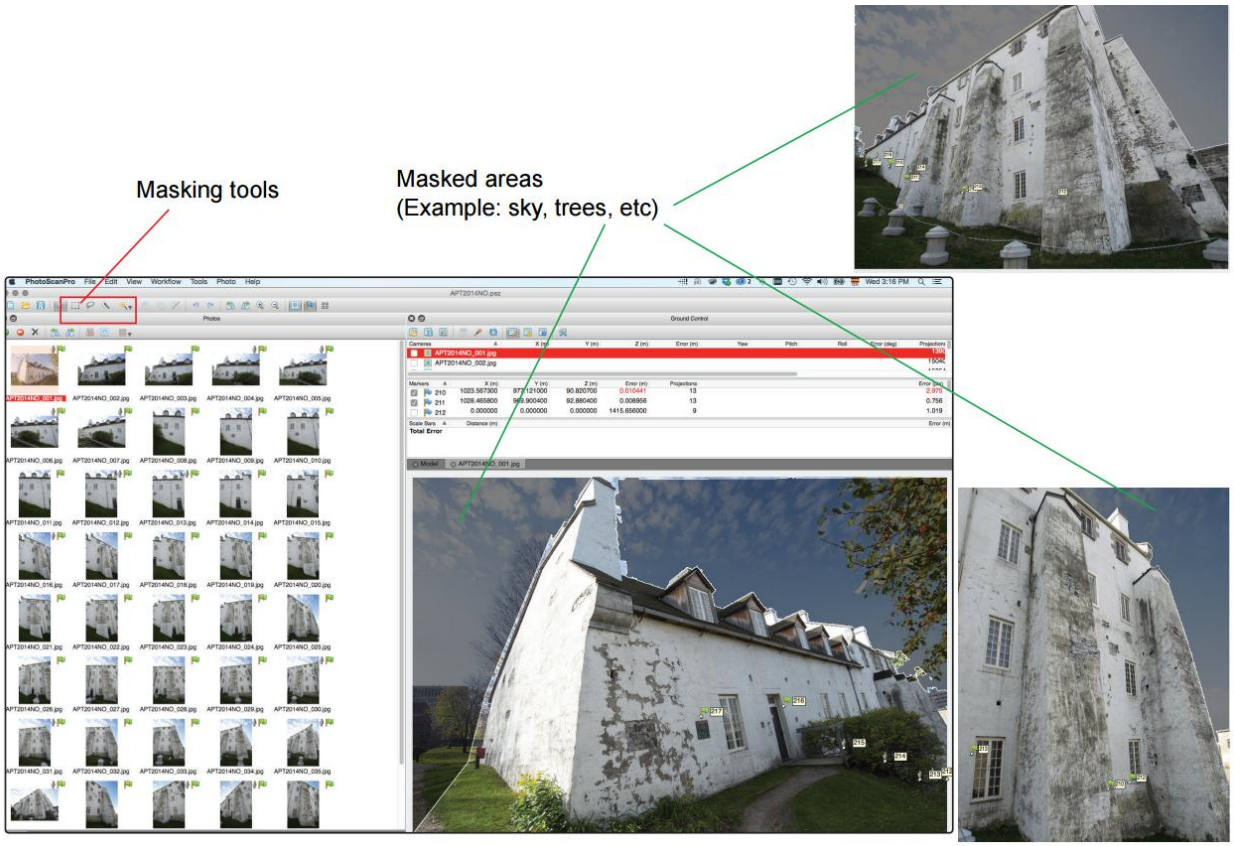


Here you can delete the photos that you don't want to use when creating the model or add more photos to the project repeating the same process. To delete a photo(s), right click on it and choose ``remove photo``.

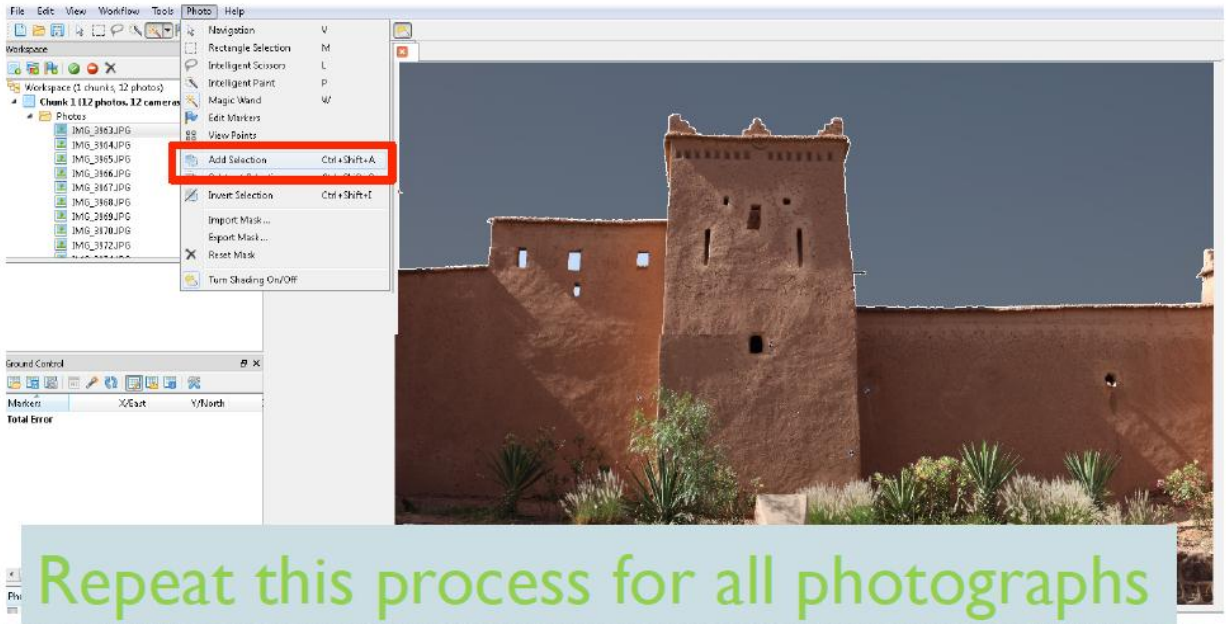
Cleaning Up/Masking:

If there are a lot of noise in the geometry due to sky, vegetation etc. you can use masking tools to mask them out.

Double click on the image you want to edit. Masking tools will appear on the top left corner.

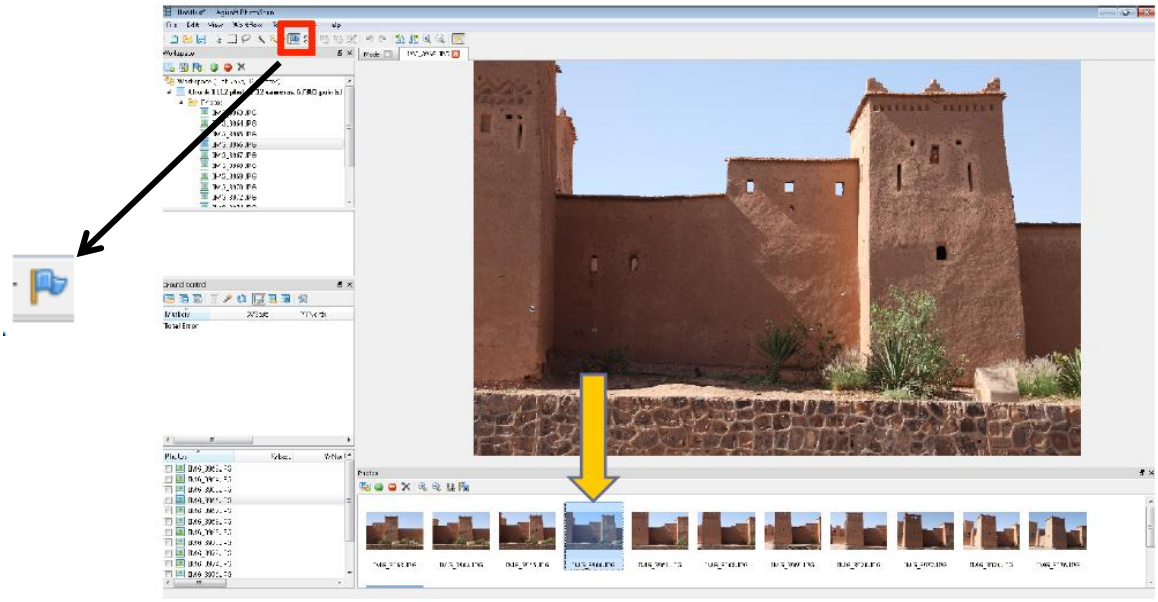


You can use the magic wand to select the sky or similar areas. When you have the area selected you can mask the area using Photo>Add Selection (Ctrl+Shift+A) . Repeat the process in every photo to eliminate the noise. You can use the lasso tool to select the vegetation or any source of foreground noise.

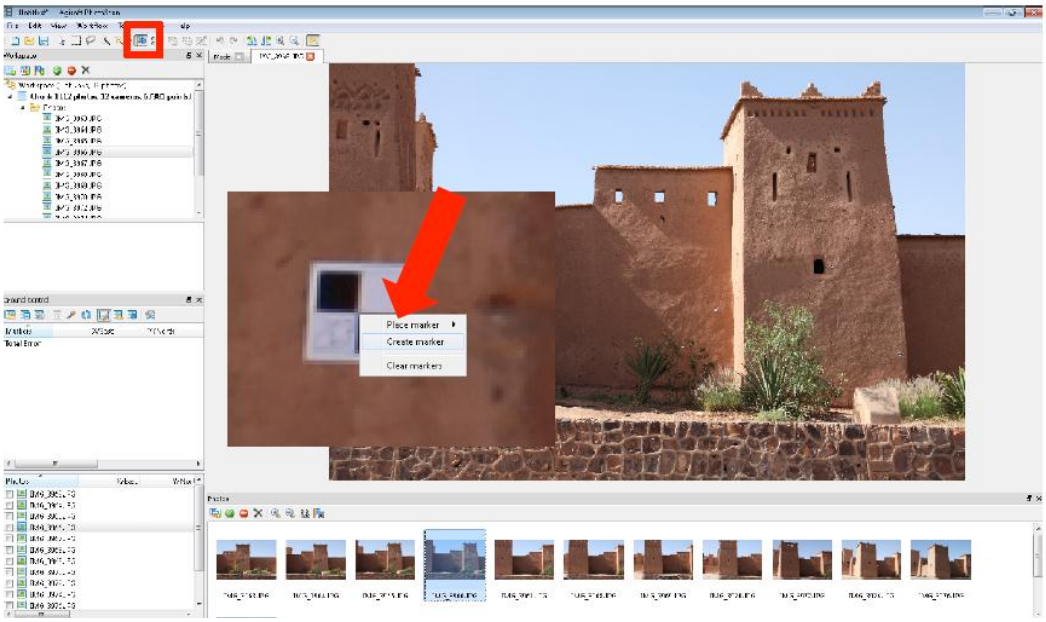


Adding Control:

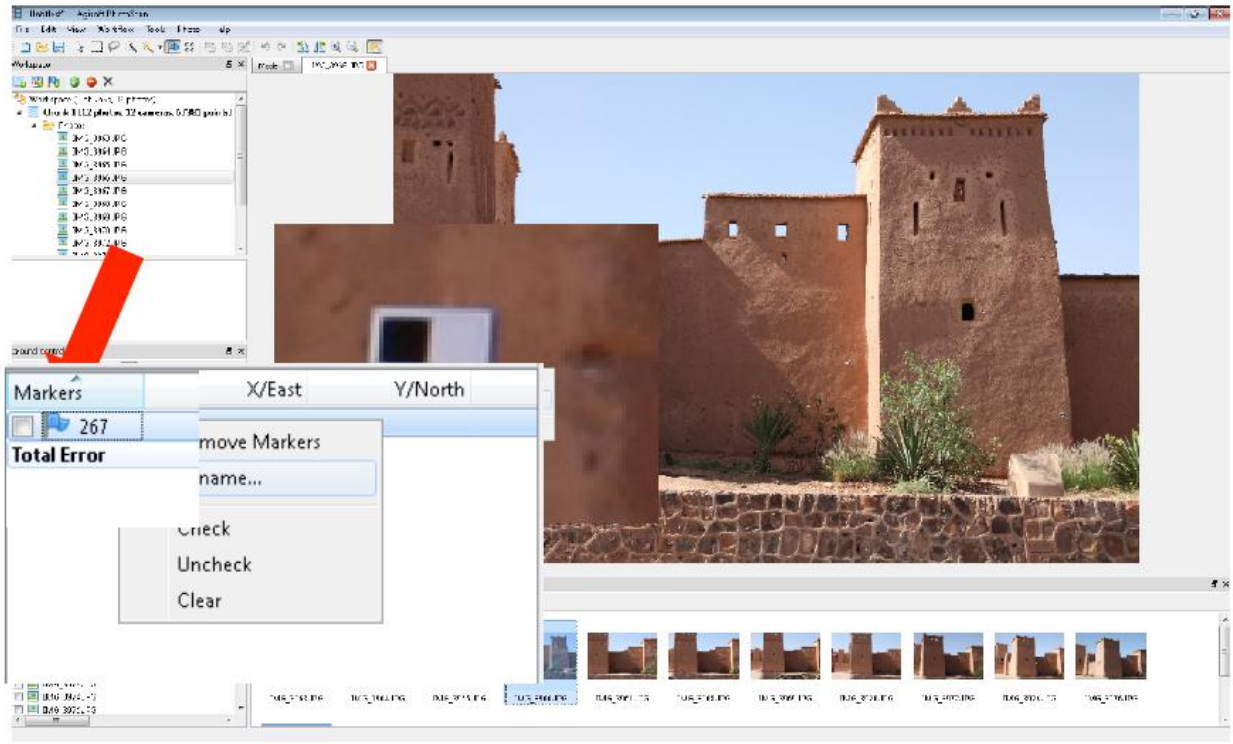
You can add control points (measurement) using the “marker” tool. Before you add the control, make sure you have your survey data and all the control points you need in a text file. You can also manually input these points.



Double click on the picture you want to put a marker in, and select the “marker” tool. Zoom into the corner or the target you want to put a marker on and right click. Select create marker. You can adjust the location of the marker by dragging it.

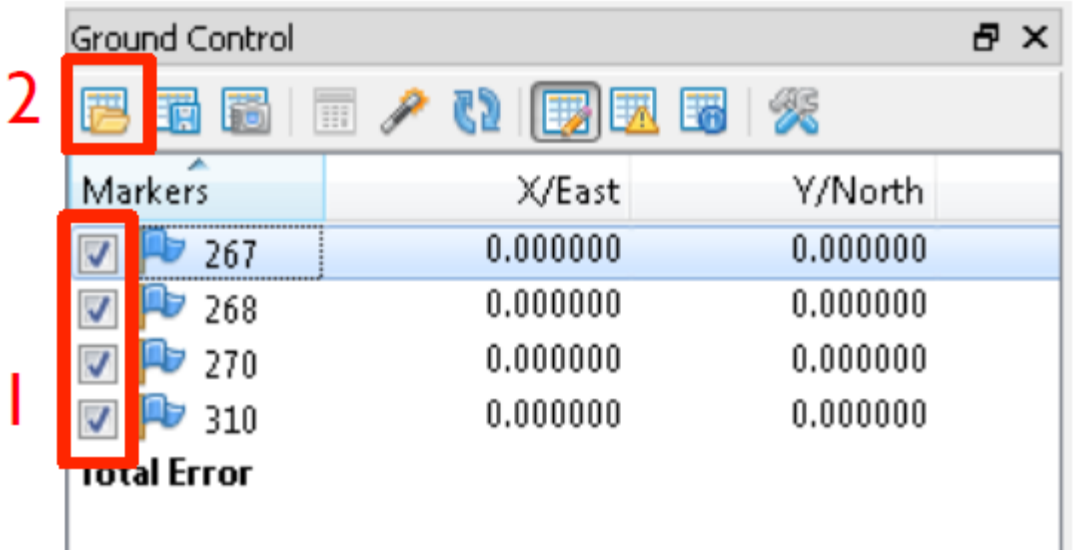


Rename the marker to match with the name in the text file.

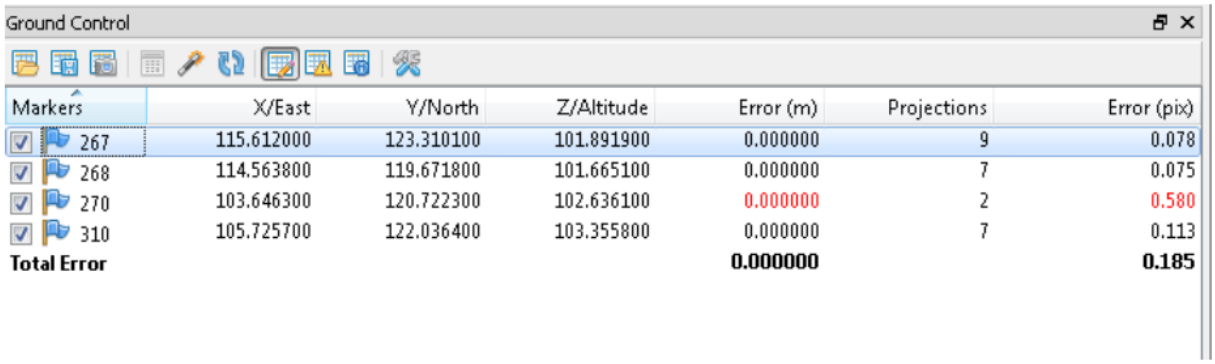


You should check and refine the position of each marker to make sure they are in the right spot. Repeat the process in as many photos as you want, but make sure that you have each marker in at least three photos. (Avoid marking targets in more than 5 photos.) If you want to remove a marker, right click on it and select “remove marker”. When you select the same point in two photos, PhotoScan will automatically create “suggestion locations” in other photos. They won’t be in the exact location of that control point/target and they will be grey colored. Markers are not active unless they are blue. Drag them to their proper location and they will turn blue.

Once all markers are set, renamed and their positions are checked, you can import your control point data (ground control data). In the ground control pane on the left check all the boxes beside the control points. Click the “import” button. Browse for the file you need.

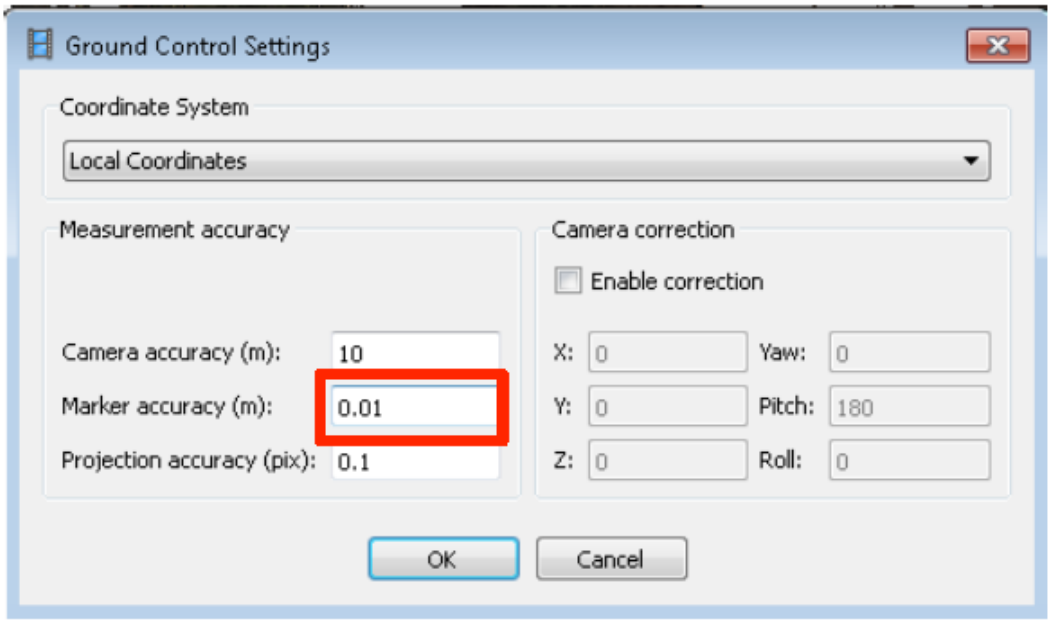


When the coordinates for the points are imported they will appear next to the control point labels.



If the error (m) or the error (pix) is bigger than 0.05m or according to your survey accuracy, there are a couple of things you should adjust. (It is rare that the error is less than 50mm right away so don't stress out.)

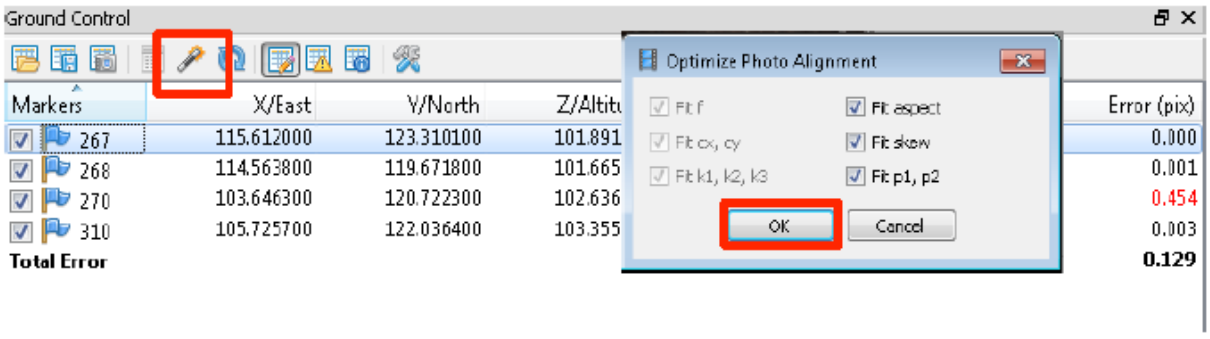
First click on the settings button and change the marker accuracy to 0.01 or to the accuracy of your survey. (For the Morocco project we used a marker accuracy of 0.02).



If the error is still not good, check the location of each marker and adjust them. Check the names of the points in case you mislabelled them. Checks if the x and y coordinates are flipped.

(Errors cannot be 0m or 0pixels. If it is that means there is something wrong).

If you are making changes in the positions of the control points, click the "refresh" tool each time to check the results of the move. As the control points are used to rescale and orient the generated model, you should calibrate the model, using the "optimize button.  In the dialog box that appears uncheck "fit aspect", "fit skew" and "fit p1,p2" When the optimization is finished, the error value should drop.



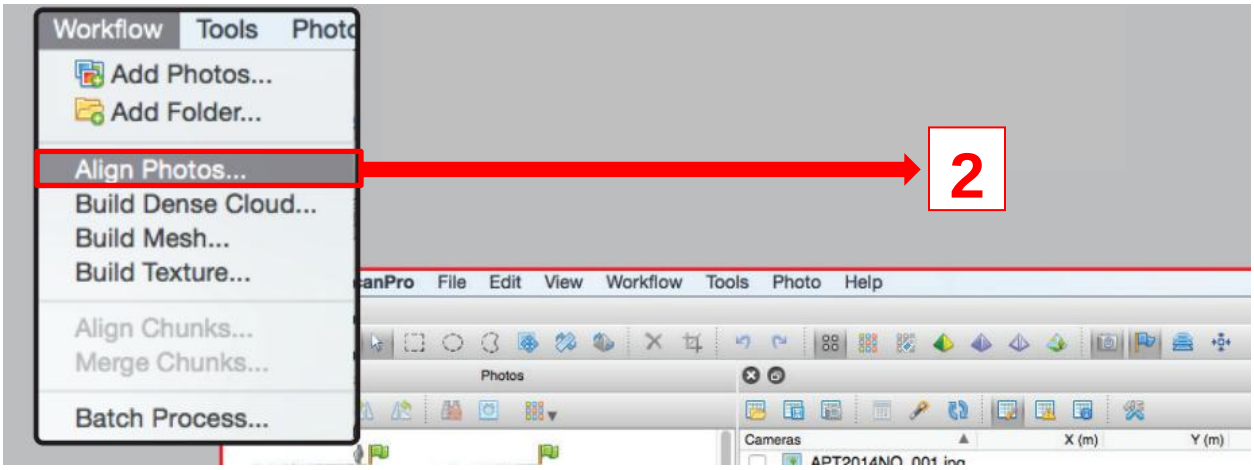
If you are happy with the error values you can continue to building the texture.

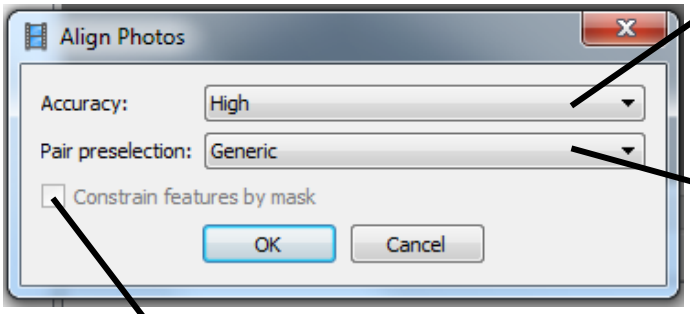
If you have added masks to your photos, rebuild the geometry to refine your model.

Aligning Photos:

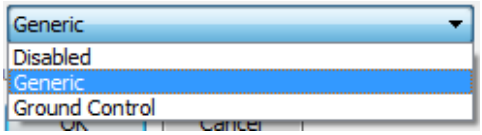
Now you need to align your images. During the alignment PhotoScan finds the camera position of each image and creates a point cloud.

Under the Workflow menu, click on Align Photos





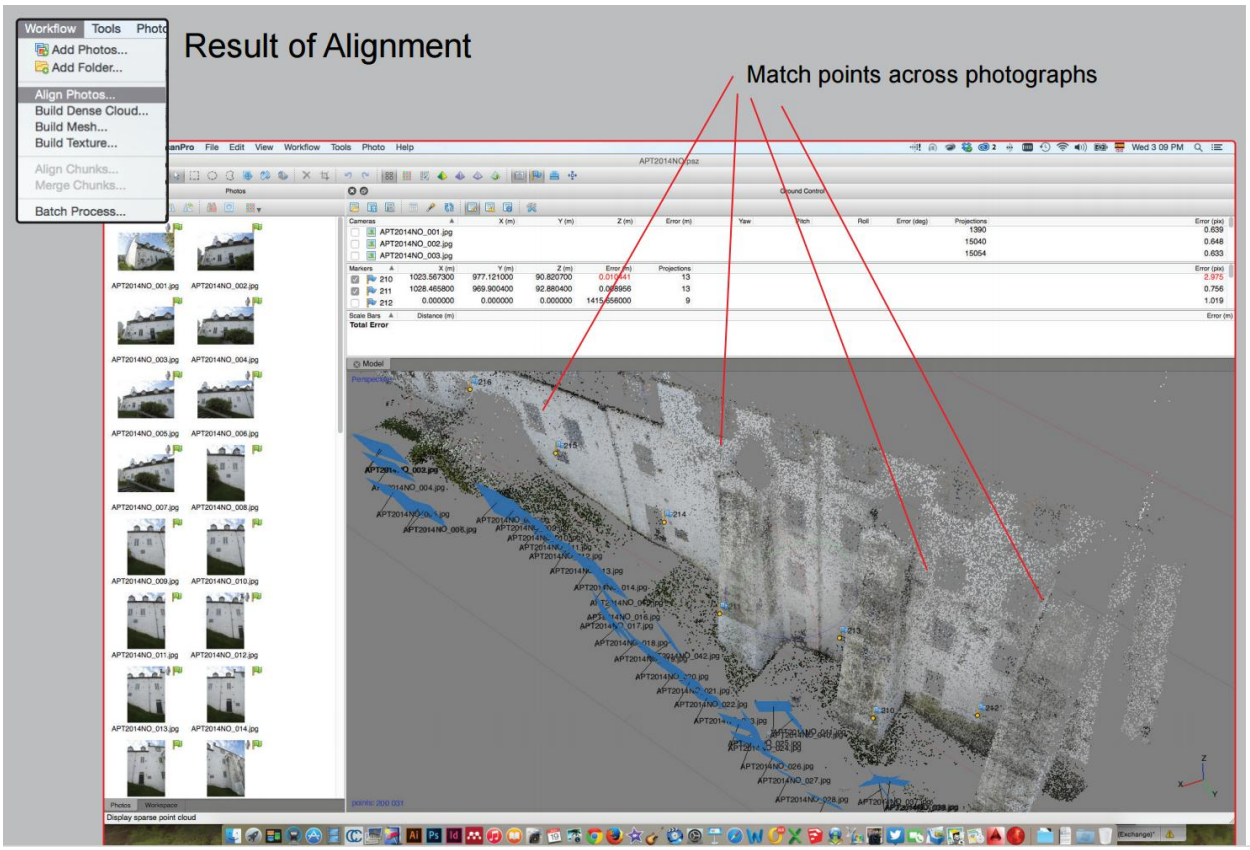
Higher accuracy will provide better camera estimates. **Lower accuracy** will create rough estimates in a shorter period of time.



The tool to select which process the software should use when matching features on each photo. If you choose **Generic,** the software will first try to match the features in the smallest scale and compare the results in the bigger scale. If you choose **disabled** the process will be shorter but the results may not be the best. In the **Ground Control** option the alignment of each pair is done using the measured camera positions (if available).

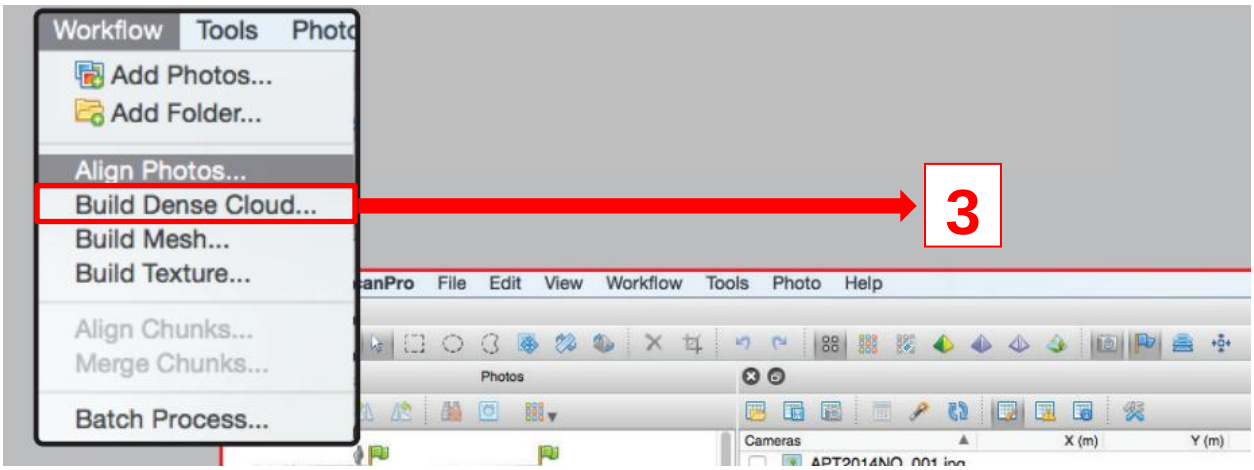
If you select this box, the masked areas will be discarded. Scroll down to find more about masking.

When the alignment is done, the process dialog box will disappear and the result is a sparse point cloud with camera locations.

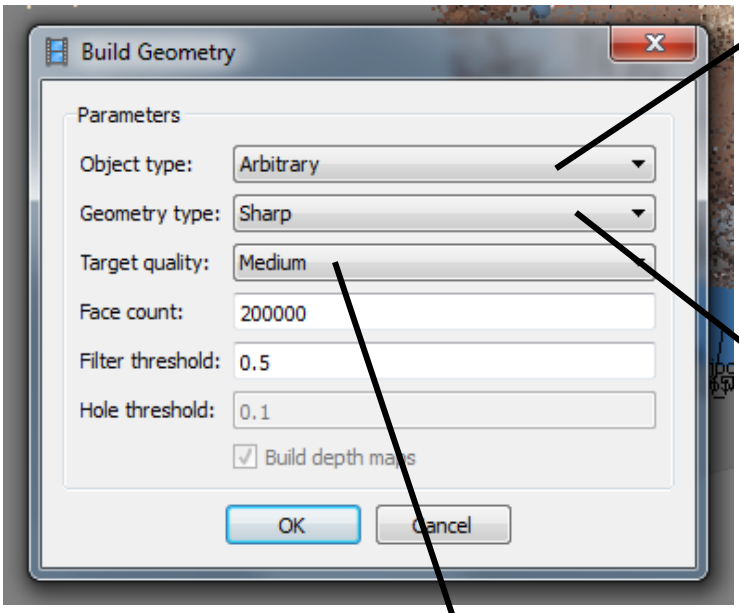


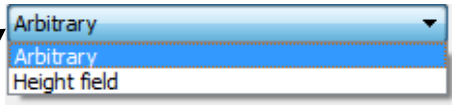
Build Dense Cloud:

The third step of the work flow is to calculate the geometry of the model. Under the workflow menu select ``Build Dense Cloud``.

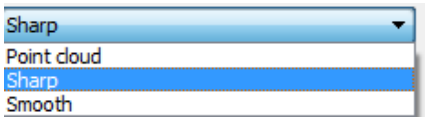


Select you desired parameters in the dialog box that appears.

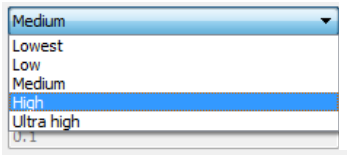




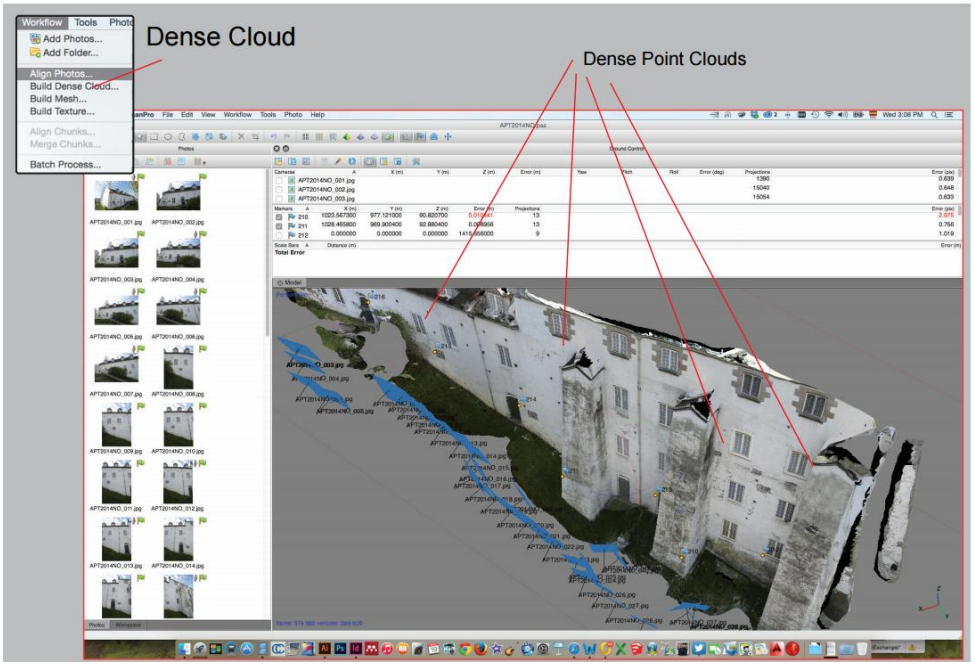
Arbitrary: Select this if you are working with buildings or statues. Uses more memory.
Height Field: Should be used if you are modeling terrains or planar surfaces. Uses less memory.



Choose **sharp** to get more accurate results without introducing hole patching features. **Smooth** creates a bubble around the model and fills in any gaps and holes.

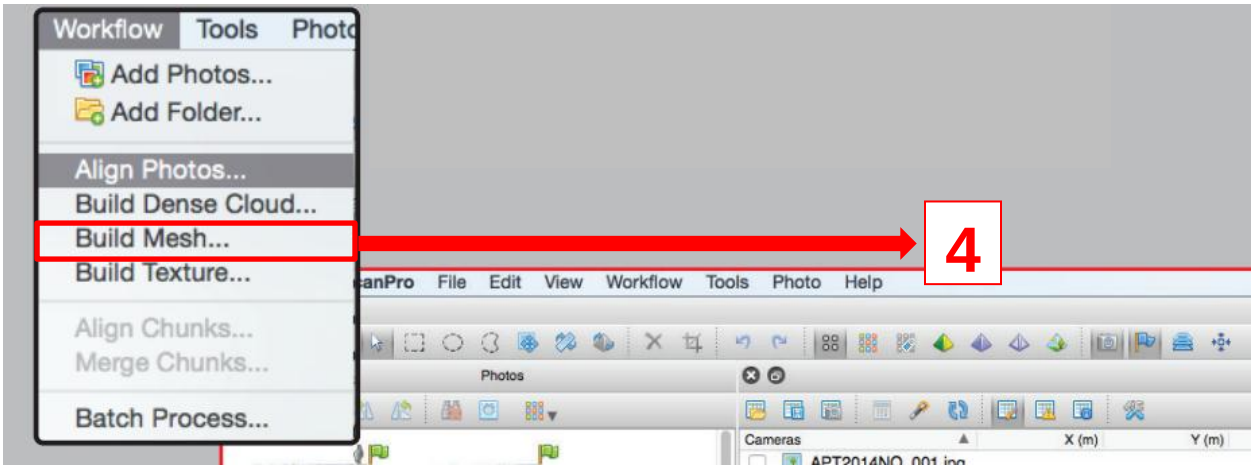


If you have more than 5 images in your model choose medium. High target quality takes too long but creates better results. Medium is not too bad though. If you have time choose high.



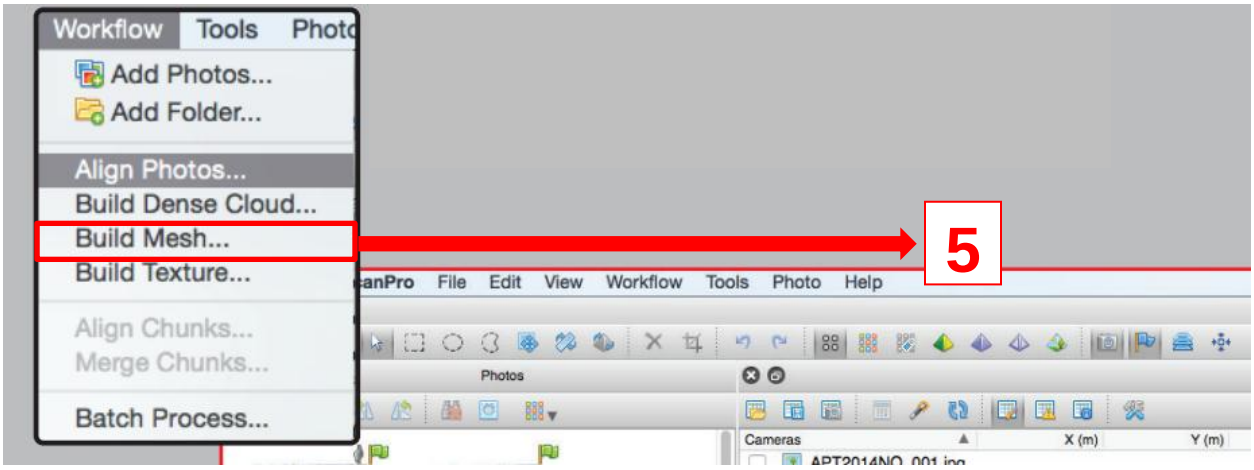
Building Mesh:

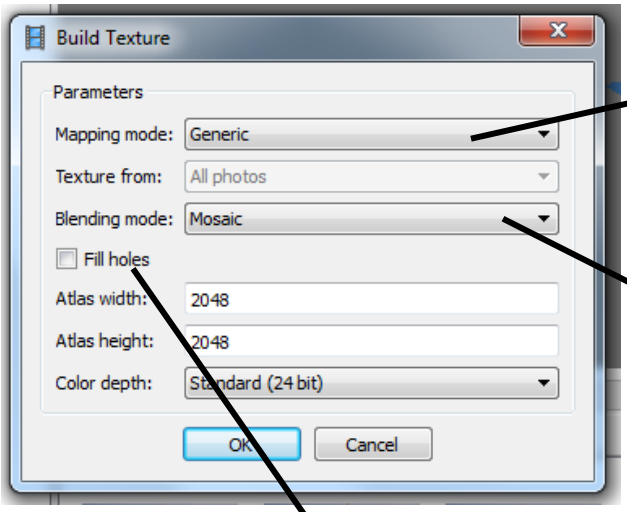
The fourth step of the work flow is to generate a mesh of the model. Under the workflow menu select ``Build Mesh``.



Building Texture:

The fifth step of the work flow is to create a texture of the model. Under the workflow menu select ``Build Texture``.

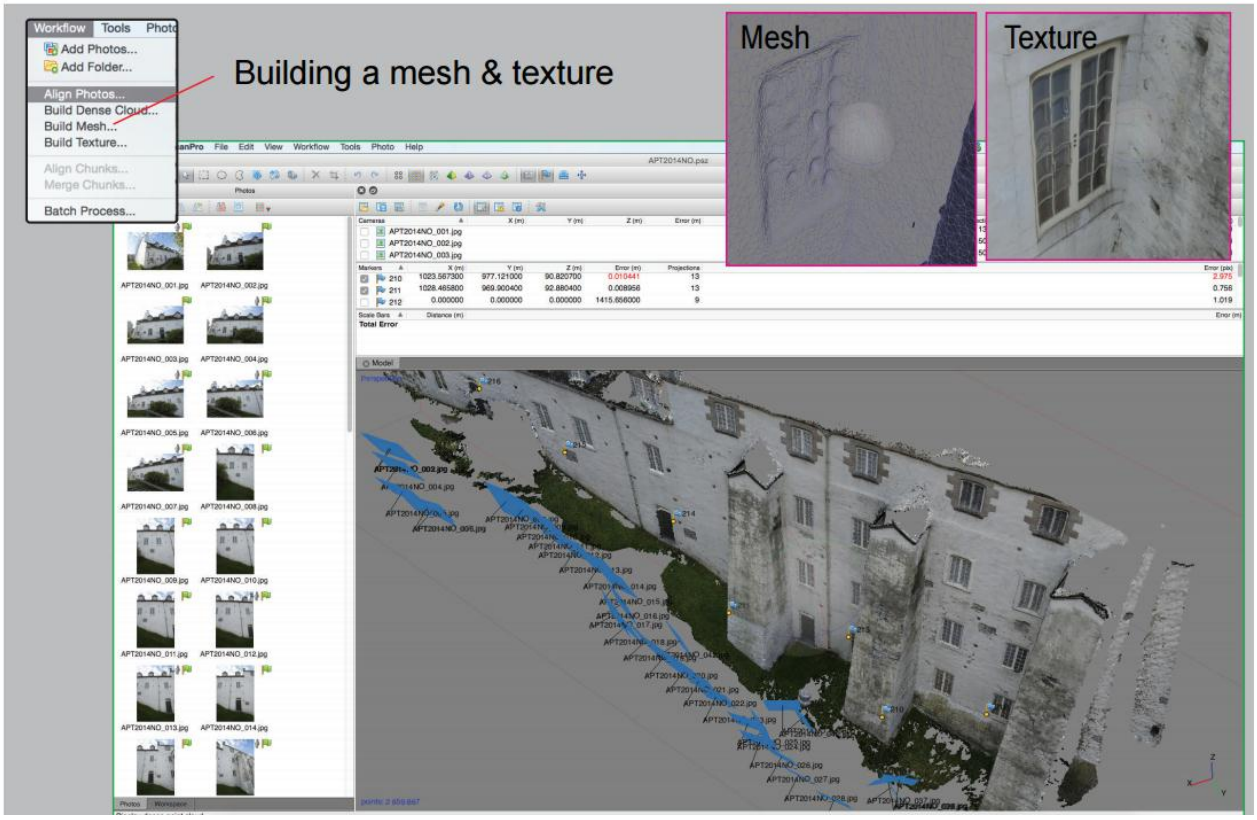




Mapping Mode determines how the texture of the object will be created.
Generic: program tries to create a uniform texture using all photos.
Single Ortho photo: creates the texture using only one photo. The photo can be chosen from the list.
(You can also disable all the other photos except the one you want to use in the workspace and use generic mapping mode).

Blending Mode determines how pixels are going to combined with one another.
Average: uses an average value for pixels from individual photos for blending.
Mosaic: this mode doesn't mix pixels but uses a more appropriate pixel from each image, thus creating a better texture for the model.

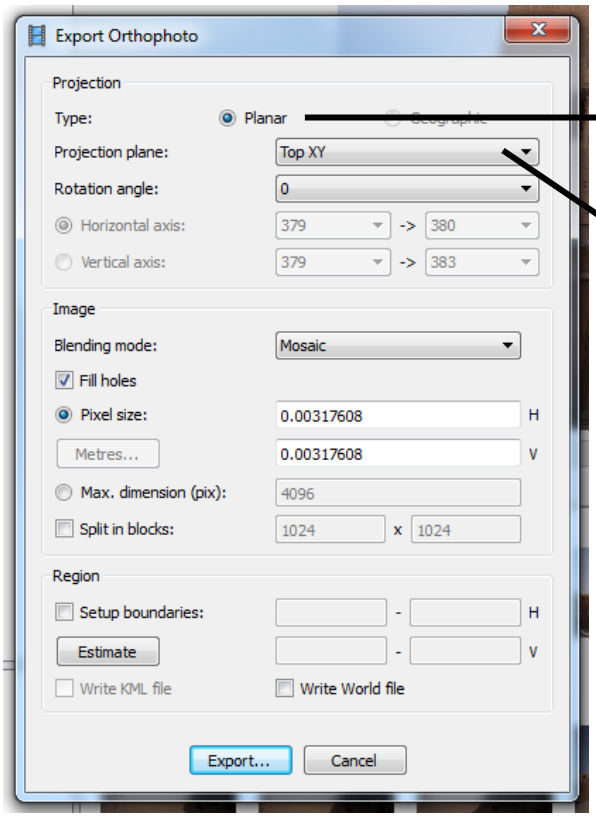
Check this to create a more complete, ortho photo like texture.



Exporting

>Orthophoto:

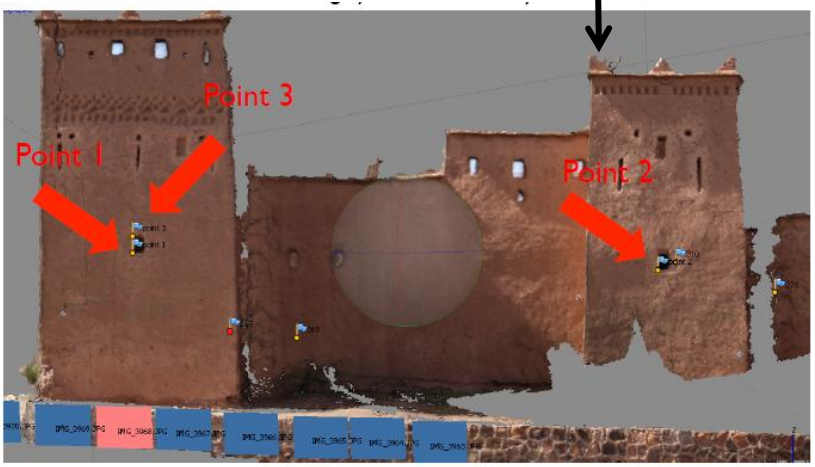
To export an orthophoto of a specific surface or view of your 3d model, go to File>Export Orthophoto>Export "JPEG/TIFF/PNG". In the dialog box, choose the following:



Choose **Planar** to create a regular orthophoto.

You need to define the projection plane. If you are exporting an orthophoto of the plan view, you can simply select Top XY.
If you are exporting an orthophoto of a specific elevation view, the best way is to use the "markers"

Exit the dialog, and put three new markers. These will define your coordinate system of the projection plane.



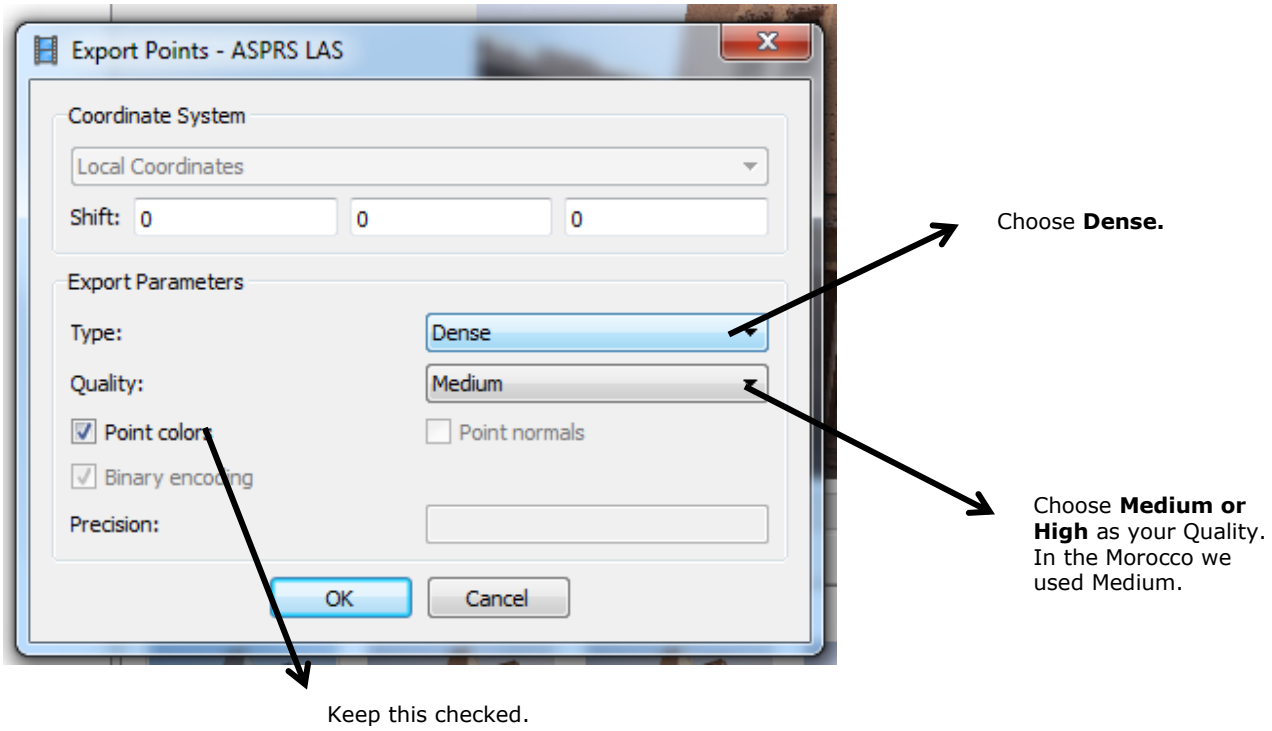
Point 1 should be roughly horizontal with point 2 and roughly vertical with point 3.

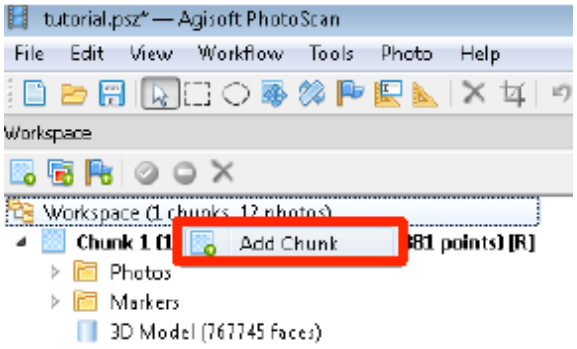
When you have your markers placed, go back to the export dialog box and choose “Markers” as your projection plane. Choose the appropriate points for your horizontal and vertical axis.

Choose “Mosaic” for the blending mode. (it is the way the software chooses the colors from the different photographs.) Keep “Fill Holes” checked. Click export to choose the location you want to save.

Export Point Cloud:

To export point cloud, select export points from the File menu. Choose the destination folder and choose the file type. To export for AutoCAD choose ASPRS LAS. Choose your export parameters and hit OK.





ADVANCED USE: SPLITTING PROJECTS INTO CHUNKS:

For very large file with over 50 photos you can split the project into chunks. This would allow you to modify and handle the models easily and would prevent the program from crushing.

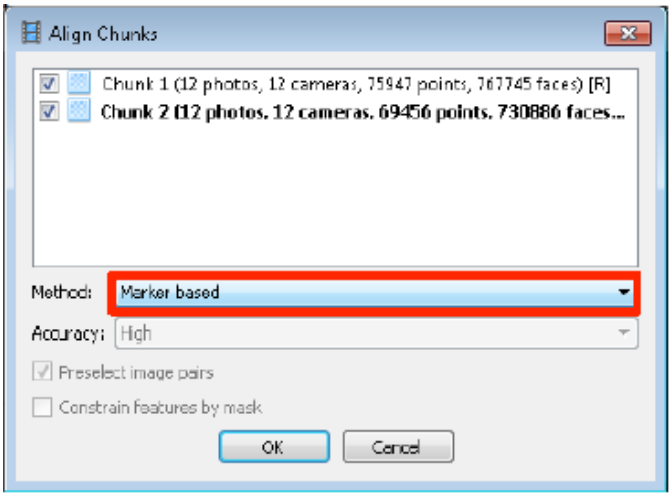
To add a chunk, right click on the workspace on the left side of the screen.

Once a new chunk is added you need to "activate" it to be able to work with it. Right click on the chunk and select "Set Activate". Now you can add photos, create geometry, built texture in this chunk.

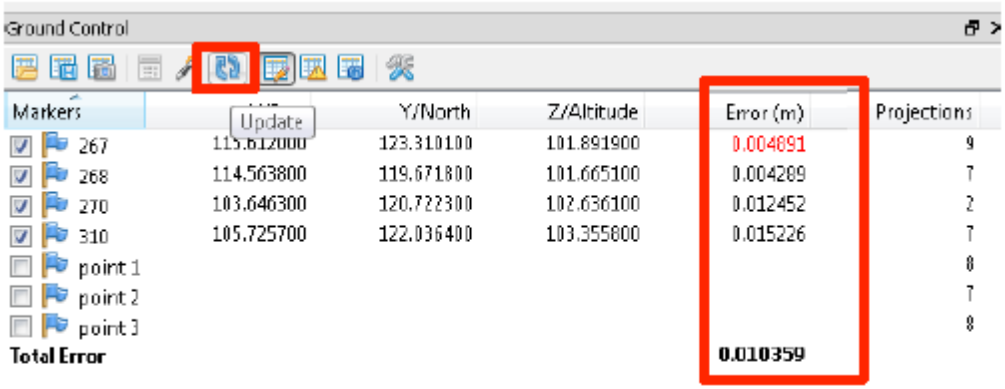
When you have two or more chunks with build geometries, you can align these chunks using control points.

Select "Align Chunks" from Workflow menu.

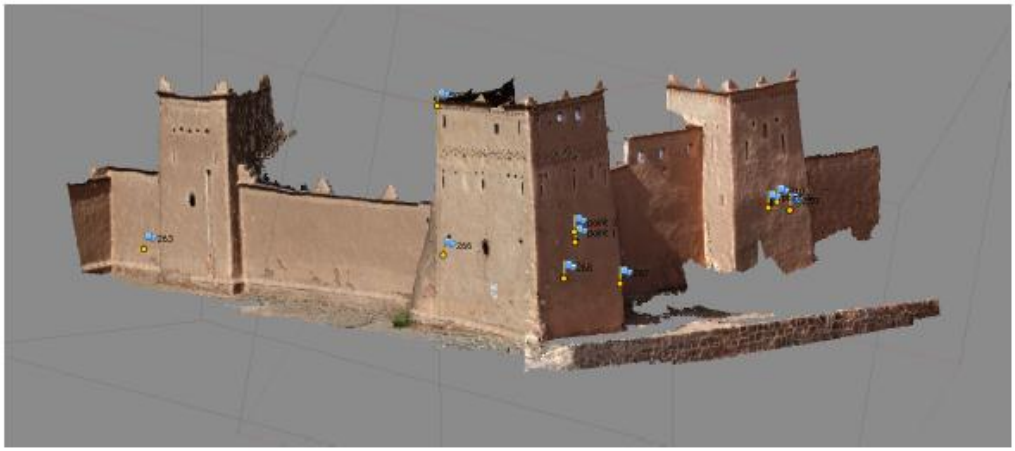
From the dialog box, choose "Marker based" for Method, as you have ground control in all chunks. Set the accuracy as "High". Click OK.



All of your chunks should now be aligned. But you still need to go into each one and check the ground control. You will notice that the error is 0 in the chunks that were not active during the alignment process. Click on update button.



In order to see the aligned icons go to the viewing pane, and click the icon “show aligned chunks”.



Annex 3

3_Autocad pointclouds Protocol_CIMS Myanmar_2015.pdf

Pointclouds in AutoCAD

Document Information

Document type:	Protocol	Author: Sarah	Ward, Davide Mezzino
Workgroup:		Creation date:	23 June 2013
		Last save date:	23 August 2015

Revisions

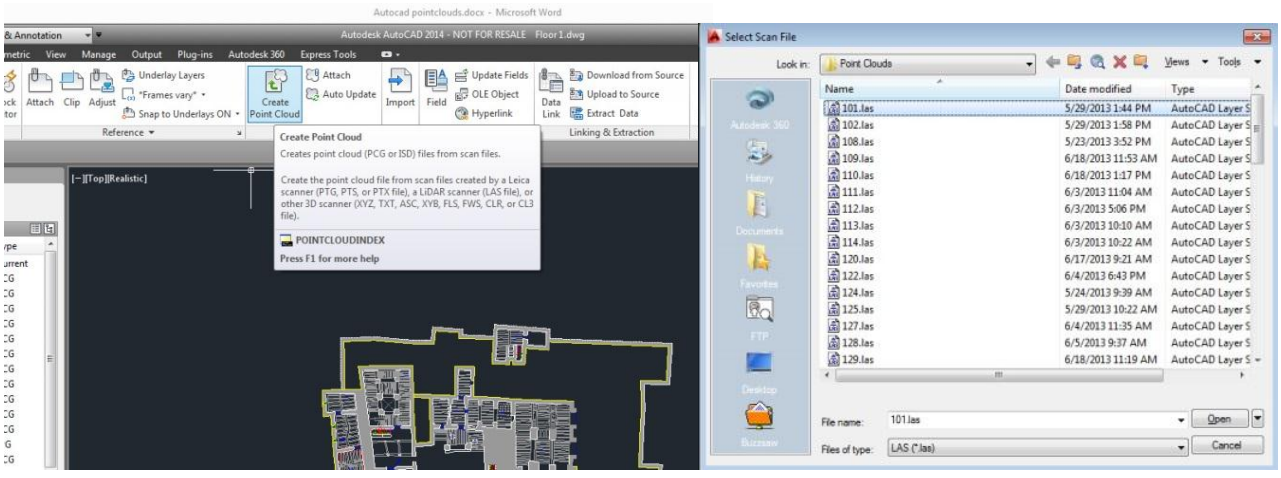
Date	Name	Changes

Importing Point Clouds into AutoCAD

AutoCAD Versions 2013 and higher allow pointclouds to be imported and manipulated. Files need to be saved as an las. or obj. file in order for them to imported.

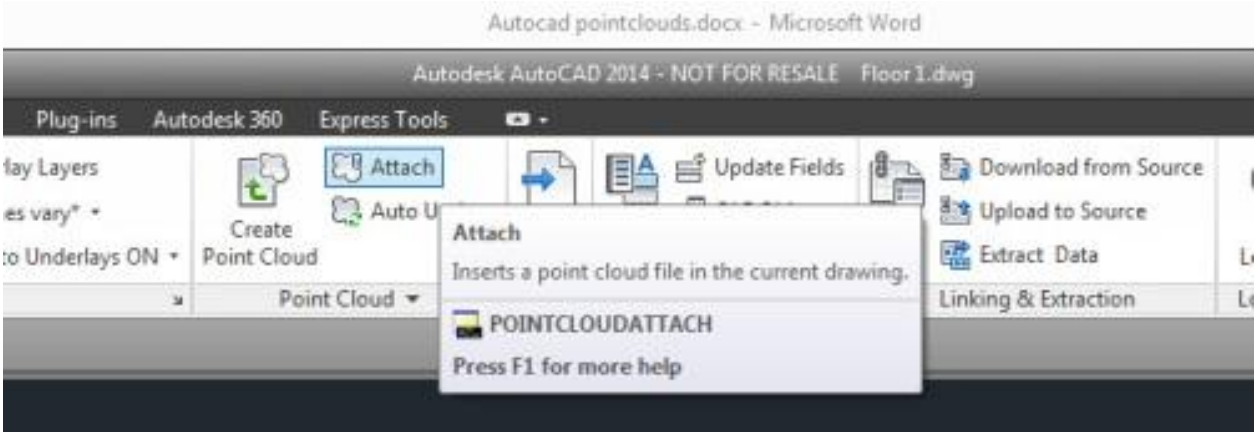
Creating png. files

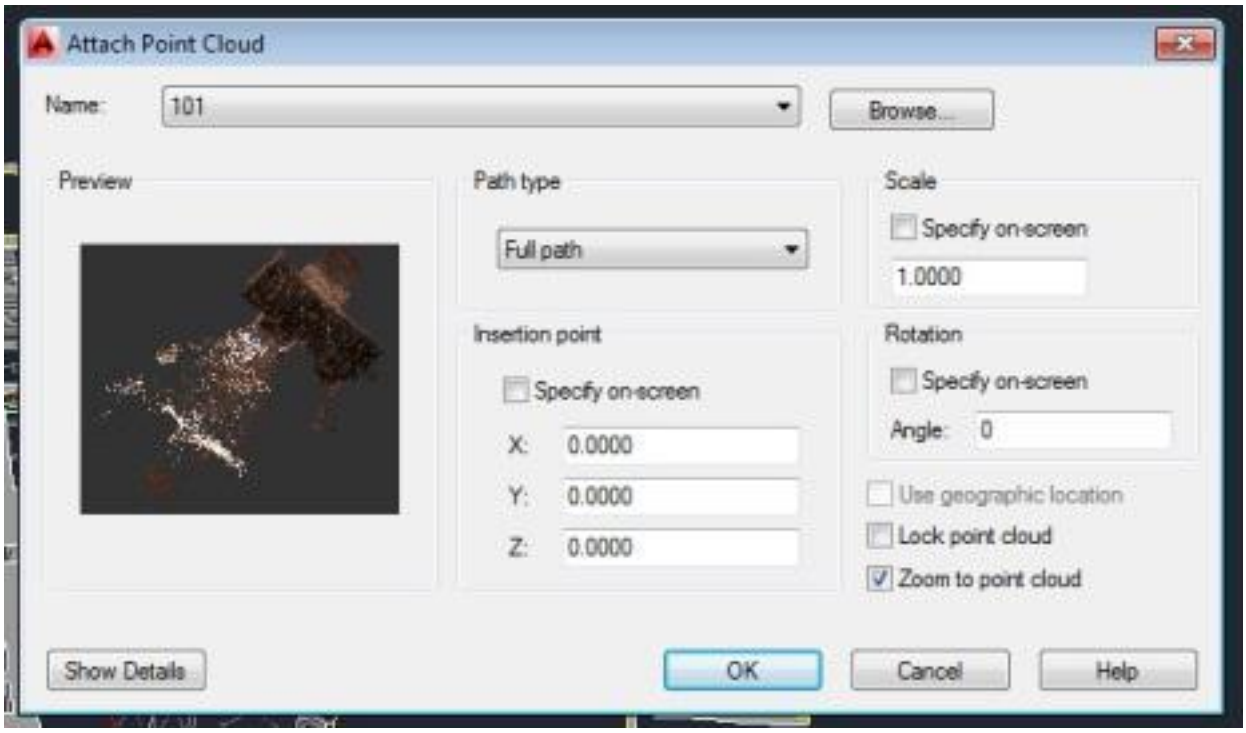
The Pointcloud menu is located in the menu ribbon under the Insert tab. Select “Create Point Cloud” and open the file you wish to import. Select create and wait for Autocad to indicate the file has been created.



Inserting png. files

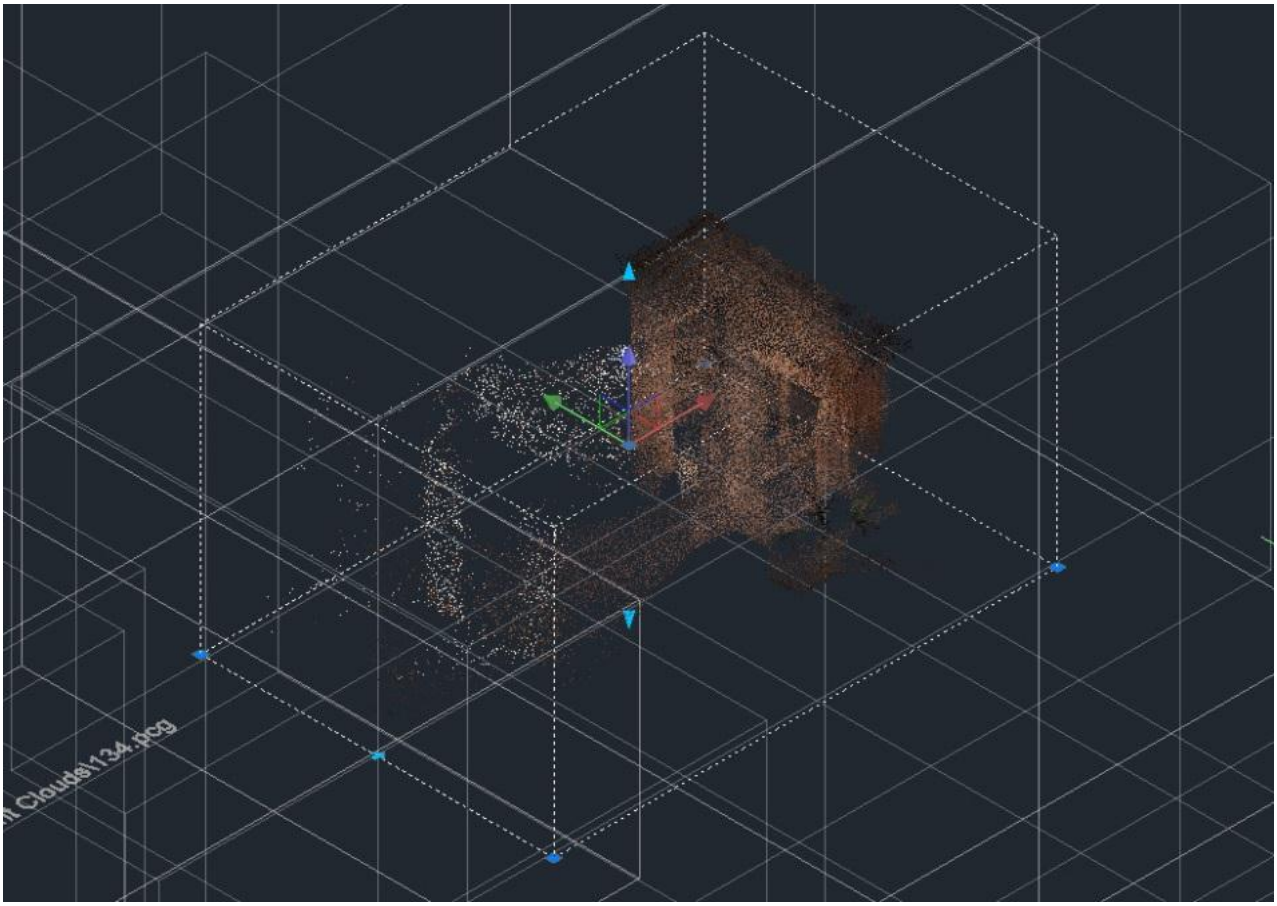
Once the file has been create, select “attach” under in the pointcloud menu and select the png. file you wish to attach. If the file is geo-referenced and it is to be inserted at its exact location, ensure that in the attach menu the insert point is (0,0,0). Also ensure that the ucs in model space is set to “World.”





Manipulating Point Clouds

Once the pointcloud is inserted, it can be manipulated in numerous ways in order to accommodate various drawing types. The command “pointcloudclip->”clippingbox” allows the pointcloud to be clipped in all directions permitting better interpretation for drawing plans, sections and elevations. The height and width of the clipping box can be adjusted by selecting the corners or blue arrows. Orienting the pointcloud in 3d space allows better control of the clipping box.



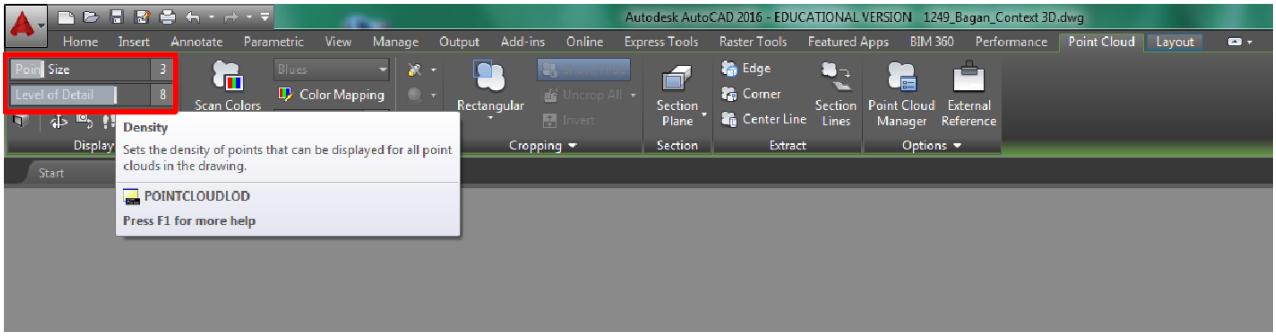
Pointcloud Density

In order to better view the pointcloud, ensure the pointcloud density is at 100%. The command “pointcloudpointmax” will allow you to set the pointcloud density to the maximum of 15000000 points.

]

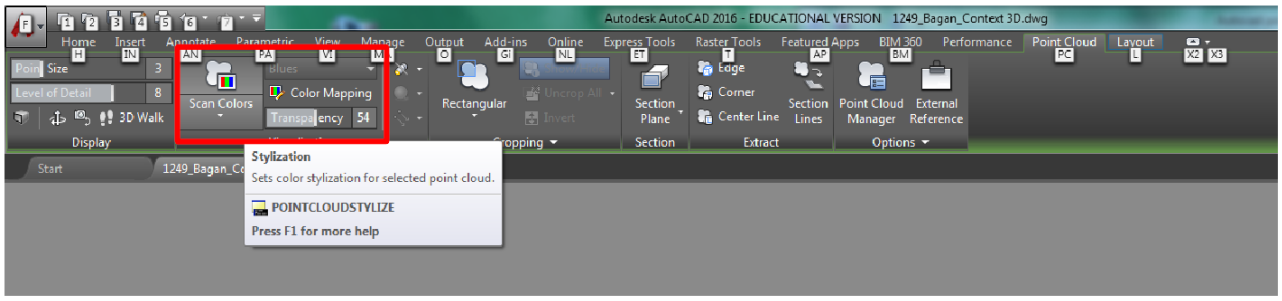
Pointcloud Resolution

The point cloud resolution can be regulated in the section 'Display' with the point size bar (where 10 is the biggest point size and 1 is the smallest point size) and with the level of detail bar (which range goes from 1 to 10).



Pointcloud visualization

The point cloud visualization can be regulated in the section 'Visualization' using the command Scan Colors, and regulating the Transparency.



Annex 4

4_Orthophotos in Autocad Protocol -CIMS Myanmar 2015.pdf

Orthophotos in Autocad

Document Information

Document type:	Protocol	Author:	Davide Mezzino, Crystal M. Hanley
Workgroup:		Creation date:	3 June 2015
		Last save date:	23 August 2015

Revisions

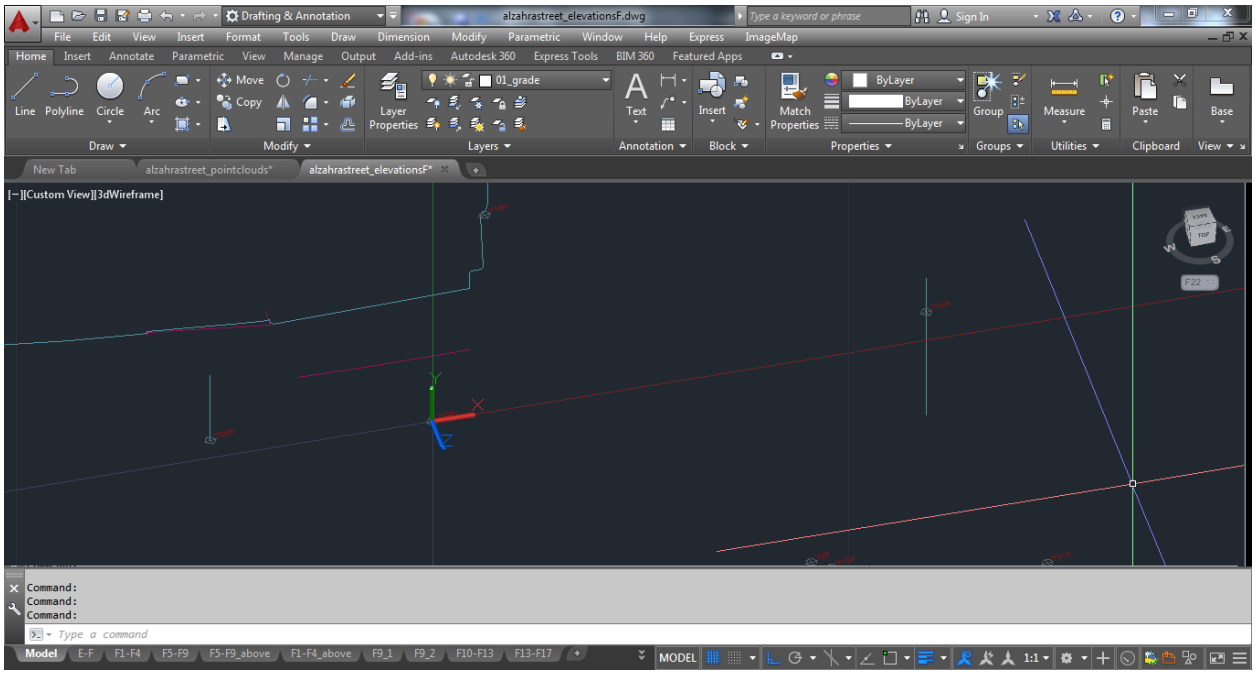
Date	Name	Changes

How to create a new UCS for each orthophotograph

Each unique elevation will require its own UCS (User Coordinate System) that will define the plane that each orthophotograph will be inserted onto.

• Choose two surveyed points in the AutoCAD file that are in line with the surface of the facade. In the Top view, draw a line between these two points.

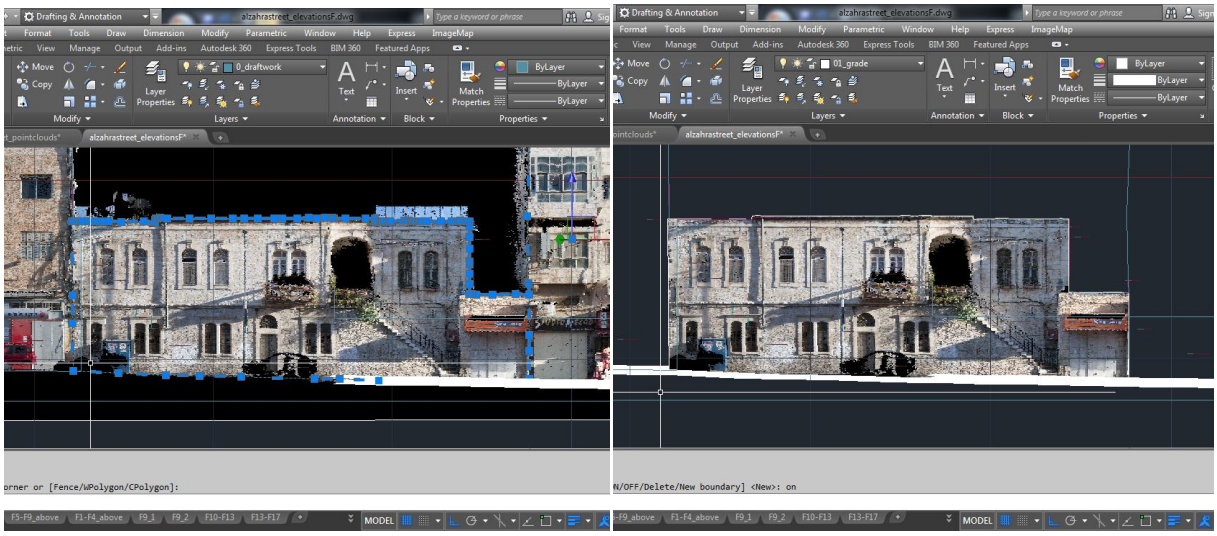
1. Create a layer and name it UCS
2. "Orbit" to get a 3D view of the points
3. Type Pl on the command line
4. Click on bottom left point of your lower left control point
5. Then pick the bottom right point, though the line won't join the two points (this is defining the x axis)
6. Type on the command line: "UCS" "3p" (3-point)
7. snap on the first point (bottom left) and then the end point of the poly line (bottom right)
7. Type "@0,0,3" *enter* (the UCS icon becomes parallel to the plane you have defined)
8. Save this UCS by typing "DDUCS" and *enter*; name it "elevationX" (with X corresponding to the various facades, be systematic about it)
9. "Set Current" "OK"
10. Type "DDVIEW" *enter* "Present Views" "Top" " Set Relative to" "ElevationX"
"Set Current" "Apply" *enter*



How to import and orient an orthographic image

- Next, import the orthographic image that corresponds to this UCS view
- Insert > Attach Image > *select tif file created in PhotoScan*
- for the moment place the image without applying a scale to it
- once the image is arbitrarily placed, type "align"
- there will be a prompt for the first source point...choose one of the surveyed points on the image
- then there will be a prompt for the first destination point...choose the actual survey control point that corresponds to the point on the image
- do the same for the second point
- when the prompt for the third point appears, press enter to dismiss it
- then there will be a final prompt asking to scale the image based on these selected points. Type "y" for yes.
- the image will then be scaled based on these points and placed directly on them in the AutoCAD file
- it is good practice to lock this layer so that the image retains its position and scale
- carefully trace the extents of the image (the parts of the image that you want to appear in the final document) with one single polyline. If you have multiple polylines, you can connect them with the Ploy line Edit command
- next type "imageclip"
- choose the image
- then choose the polyline
- the image will be cut with the polyline as its boundaries

- if the polyline needs to be edited later, type "imageclip" and select the image again and either turn it off, or create a new boundary polyline.



From this point, the image can be measured and traced as necessary.

Annex 5

5_Laser Scanning Protocol_CIMS Myanmar_2015.pdf

Laser Scanning Protocol

Document Information

Document type:	Protocol	Author:	Mikael Sydor, Davide Mezzino
Workgroup:	CDMICA, Mario Santana Quintero, Davide Mezzino	Creation date:	1 August 2012
		Last save date:	23 August 2015

Revisions

Date	Name	Changes
25 August 2010	K. Wurts	Adapted from ScanStation 2 Field Setup Protocol
01 August 2012	M. Sydor	Rewritten to expand and include new equipment.
01 August 2012	D. Mezzino	Revisited version

Background

This protocol explains the principals and use of two kinds of scanners<

1. the ScanStation2
2. and the ScanStation C10.

They both operate on the same principals. They send out a laser beam, when it contacts a surface and reflects back the length of time is measured. This is used to compute the distance to that point. The scanner calculates its position, the angle of the lens and the distance to locate that point in 3d space. This method of laser scanning is called “Time of Flight.” The resulting data is millions of points in 3d space, called a Point Cloud.

During the scanning operation, 360 photographs are taken, these photos are used to assign colour the points. The density and colour of these points can be displayed, resulting in a convincing 3d representation of the scanned information. However, no geometry is created; the information is recorded as simply points in space. Other methods may later be used to process the data for use in different ways (such as creating a mesh, or extracting information for use in a BIM model.)

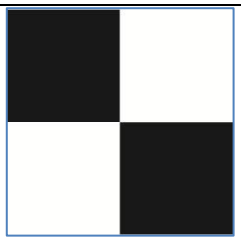
Just as a camera, the laser scanner can only record within its line of site. Meaning that only what is visible from the scanner will be recorded.

Site Selection

In most cases, scans from multiple positions will be required to capture the entire building or site. In order to ensure that these scans will be complete and also be able to be fitted together (registered) some careful preparation is required.

When choosing stations, 1_be aware of occlusions both from objects in front (ie. A tree blocking a face), and also occlusion created by the building itself (ie. mouldings blocking other parts of the window, or recesses in walls.)

There are two ways of registering scans together, and both require preparation on site.
1-The first is with targets that the operator places in the site,
2-the second is by using high resolution fixed details.
In both cases, they must be common between multiple scans. The targets are preferable because they are more accurate (registered by the software, and not by hand.) They are also more easily identifiable after the scan is complete. There are three options for different targets:

	HDS Bracketed Target	HDS Sticker Target	Black and White
			
	Large (~6”) targets manufactured by Leica for use with surveying and laser scanning equipment.	Smaller (~3”) stickers, made by Leica, affixed to surfaces to be scanned.	Pattern printed by operator on regular paper (no precise scaling required)
Advantages	Easier to see from further away, easier to target, highly precise. Tilts (incliner-pendere) and pans(ruotare-muovere) so they are more easily viewed from every angle (while maintaining the precise centre	Easily acquired by laser scanner at close range. Highly precise.	Inexpensive and simple to produce a large number.

	point.)		
Disadvantages	Cannot be left set-up over multiple days, CIMS only has a limited number.	Expensive if only used once, may harm (danneggiare) some surfaces, when viewed at a sharp angle they are less precise.	Far less precise for scanner to target, may be damaged by site conditions.

Depending on the site conditions and the number of scans required, the operator may choose (or use all) of these targeting options. However, high resolution fixed details scans should also be completed as a back-up (conferma – corroborare) to the targets. Targets have the risk of not being registered properly by the scanning software, of being accidentally moved between scans, and also of being mislabelled. In any of these cases, a back-up is essential.

There are several things to consider when choosing scanner locations, target placement and fixed details for high-res scans. Work-out (esercitarsi – risolvere) the scanner and target placements before you start scanning, sometimes seemingly complicated set-ups can be simplified with enough fore-thought (preparazione mentale).

Scanner Placement:

- Try to choose as few scans as possible, without compromising any information.
- Scanning from the corners of a building, instead of face-on will usually make it easier to fill in details and match up targets between scans.
- Consider scanner height, sometimes setting the scanner up very high, or very low will permit you to scan around objects.

Target Placement:

- There must be a minimum of 2 common targets between scans, 3 is better. Consider using even more if there is a chance they might not work properly (i.e. windy day, threatening townsfolk, etc.) The more targets, the better: when registering the scans, some targets can be dropped if their error is too great.
- The wider the angle between targets, the more accurately they will register. Consider targets behind the scanner.
- When scanning an entire perimeter (i.e. of a building) keep in mind that you will be registering to both the previous scan, and the next scan (which means you might need 6 or more targets in your view.)
- If possible, use the total station to survey your targets. This will create a network which makes registering your scans easier.

Fixed Details:

- Choose details that will not move, or be obscured in later scans.

- They do not necessarily have to be part of the building/site being scanned. (ie. a lamp-post visible from multiple scans.)
- Choose areas that have distinct details that can be located visually. Flat flaces or even round surfaces are impossible to choose a specific point from.
- Some examples: edge of a roof, top of a power pole, church spire.

Field Notes

Once these placements have been decided, make detailed field notes and sketch drawings with all of the information.
Minimum Data for the Field Book:

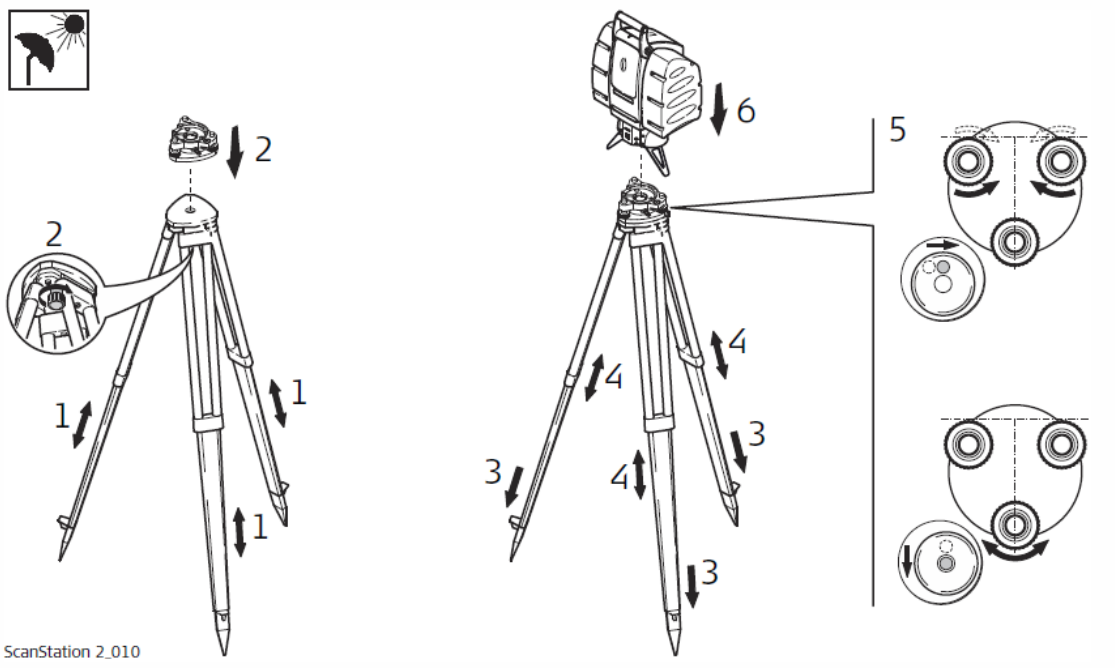
i. Location and Date
ii. Names of the Scanner Operators
iii. Station locations: shown on a sketch or map drawing
iv. Target names and locations
v. Locations of higher resolution scans of fixed details
vi. A sketch of the area with location of stations and targets

- Other possible information:
  i. Known coordinates
  ii. Exact measurements of the targets from the known coordinates
  iii. Weather concerns
  iv. Interference concerns

Scanner Setup – ScanStation2

These instructions are provided to serve as a reminder for use in the field.

- Set up the tripod and make sure it is level. Ensuring that it is level at this point is important for the future levelling of the Scanner.
- Install the Tri-Bracket. Ensure that the lock is open and ready for the Scanner. Use the dials on the Tri-Bracket for fine adjustments only, large adjustments should be made with the tripod legs.
- Carefully place the scanner on the Tri Bracket. Lock the tri-bracket.



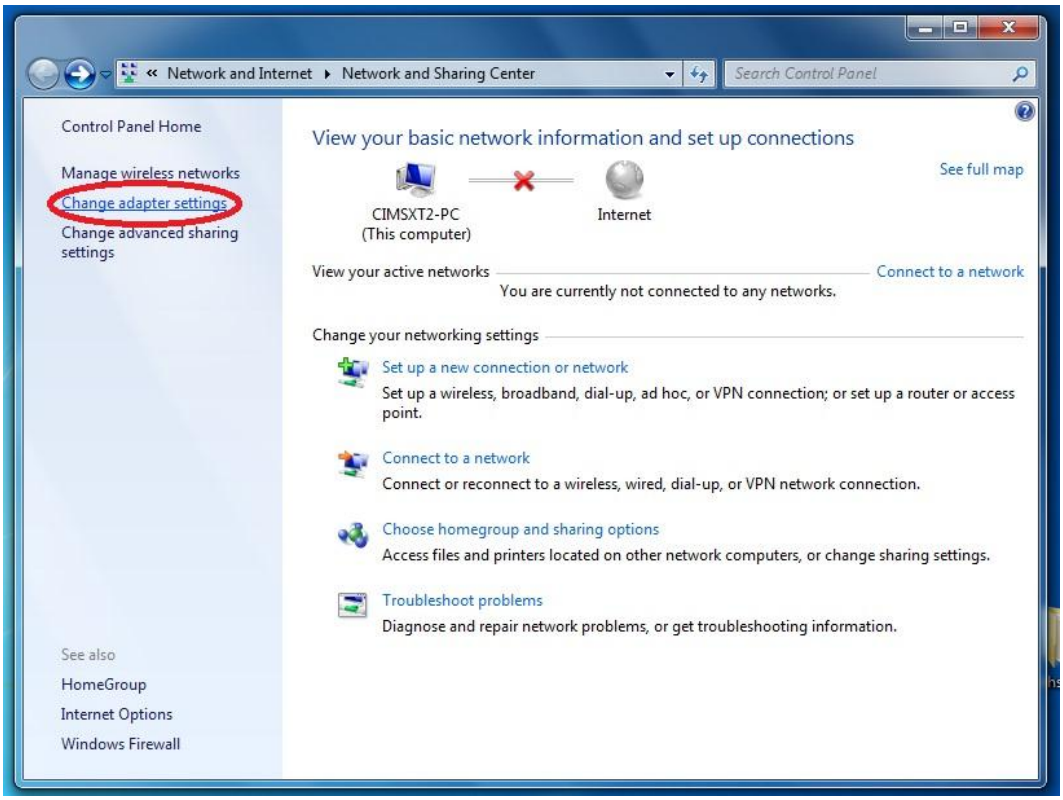
- **MAKE SURE TO UNLOCK THE SCANNER by twisting the lever on the back of the scanner**. Remove the scanner covers (only the front one if not exceeding 30 degrees vertically).
- Plug the scanner into its battery (always ensure it is well charged)
- Plug the scanner into the laptop or tablet.
- The Scanner takes several minutes to warm up. The green light indicates in is ready.

Connection Set-Up (ScanStation2):

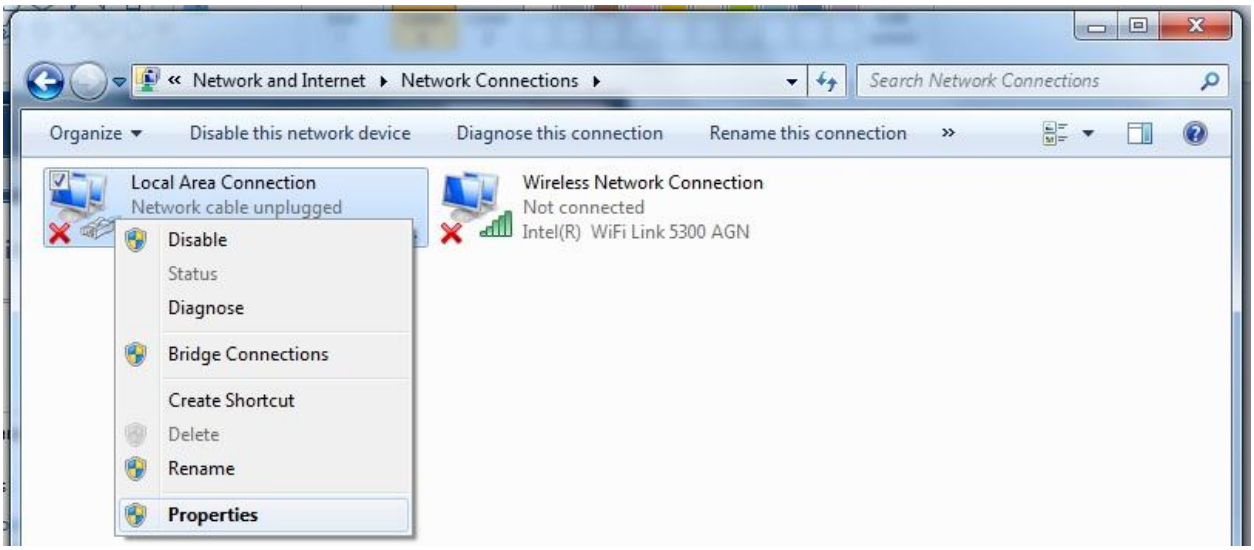
If the laptop/tablet was previously set-up to use this scanner, these steps may not need to be performed.

- When the laptop/tablet is booted, click on the bottom right corner near the clock to open the “Network and Sharing Center”

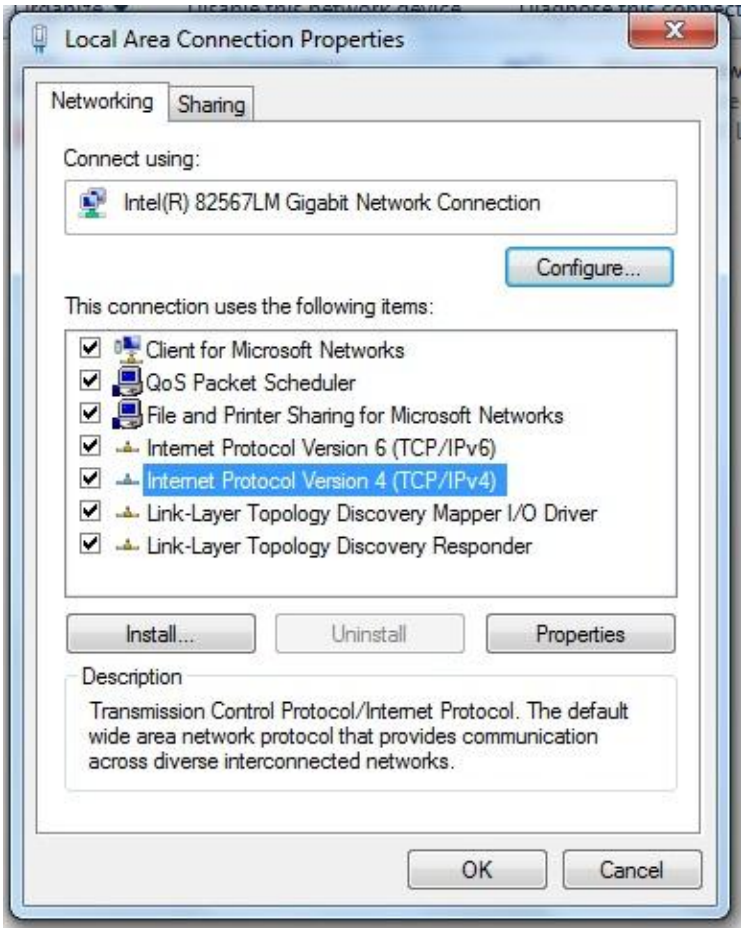
- Click “Change Adapter Settings”



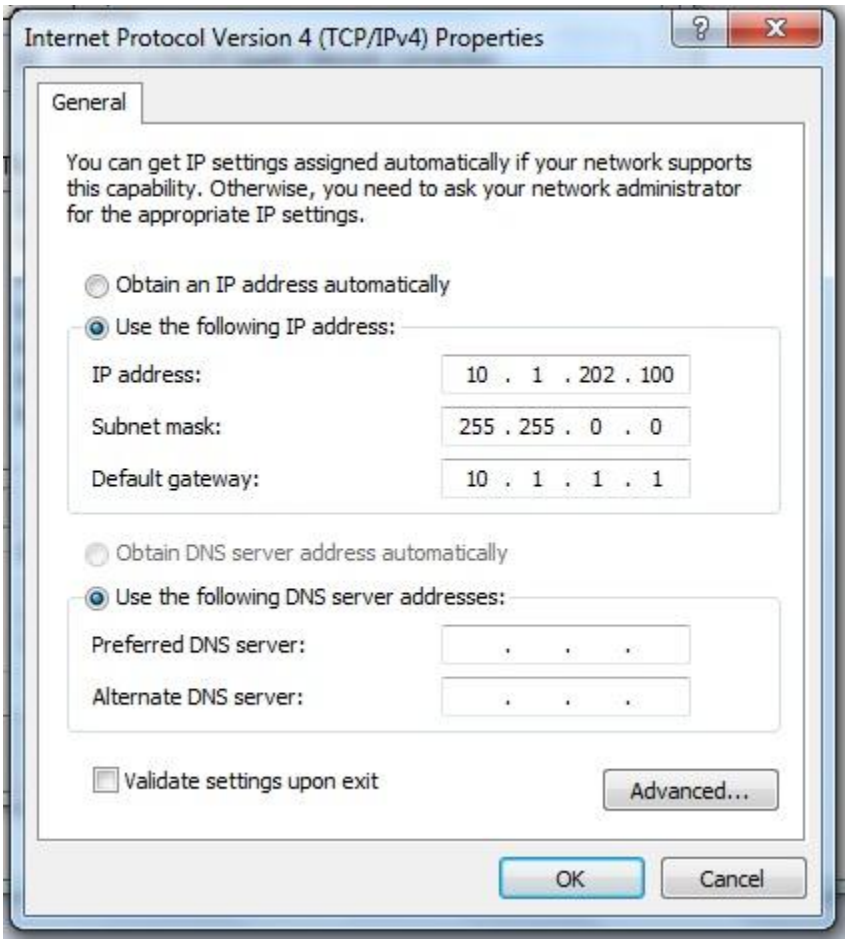
- Right click on Local Area Connection, open “Properties”



- In the centre window of the Local Area Connection Properties, open the properties for "Internet Protocol Version **4** (TCP/IPv**4**)



- Make sure the selection for “Use the following IP address” is selected and enter the following information:
    - IP Address: 10.1.202.100
    - Subnet Mask: 255.255.0.0
    - Default Gateway: 10.1.1.1



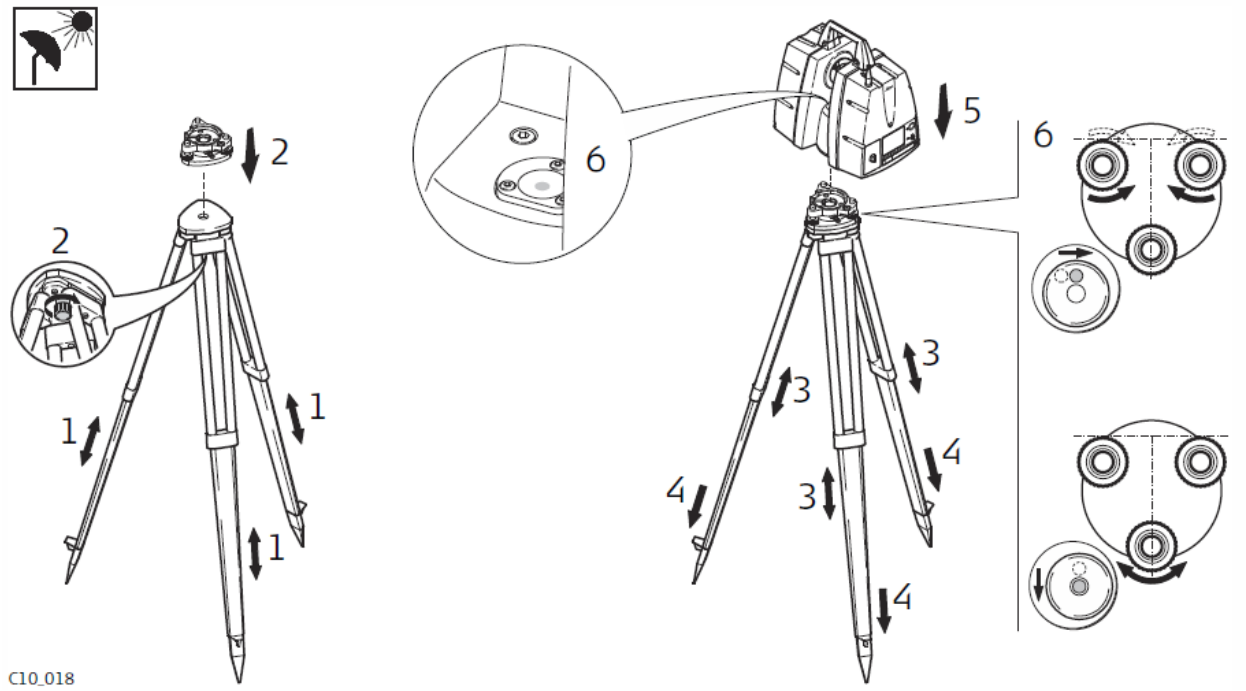
- Make sure the selection for “Use the following DNS server addresses” is selected and leave the fields blank.

There are in-depth trouble-shooting scenarios in the ScanStation2 User’s Manual, located in: Projects\CDMICA\04_Replicate\Laser Scanning Manuals\ The most common issues when setting up the scanner revolves around these networking settings.

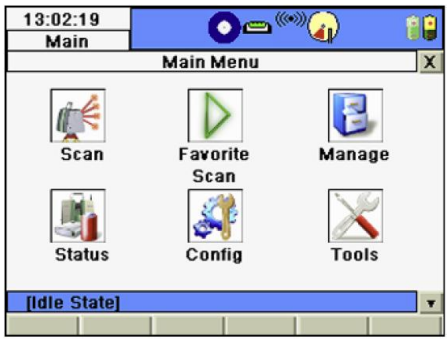
Scanner Setup – C10

Please read the complete instructions located in [Projects\CDMICA\04_Replicate\Laser Scanning Manuals\] These instructions are provided to serve as a reminder for use in the field.

The tripod setup and levelling is identical to the other scanner, the only exception is that the C10 does not need to be unlocked.



- Make sure to remove the top handle of the scanner, once it is attached to the tripod.
- Turn on the scanner by pressing the silver button near the screen.
- Wait for it to boot (avviamento), this may take several minutes. It is ready when the "Main Menu" appears on the screen.



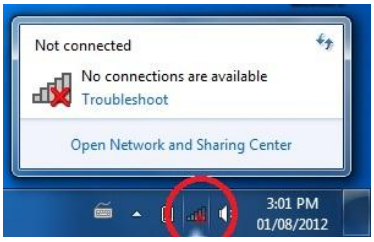
- Do not connect the laptop/tablet to the scanner until this screen appears.

- To access the battery meter, use the stylus to click “Status” on the home screen, then click Battery. Battery A is the one adjacent to the screen, Battery B is the one on the far side.

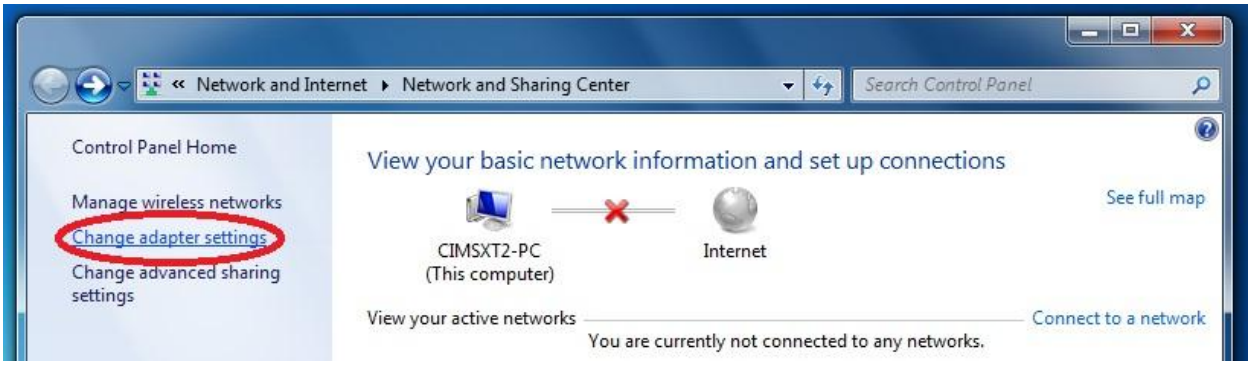
Connection Set-Up (C10):

If the laptop/tablet was previously set-up to use this scanner, these steps may not need to be performed.

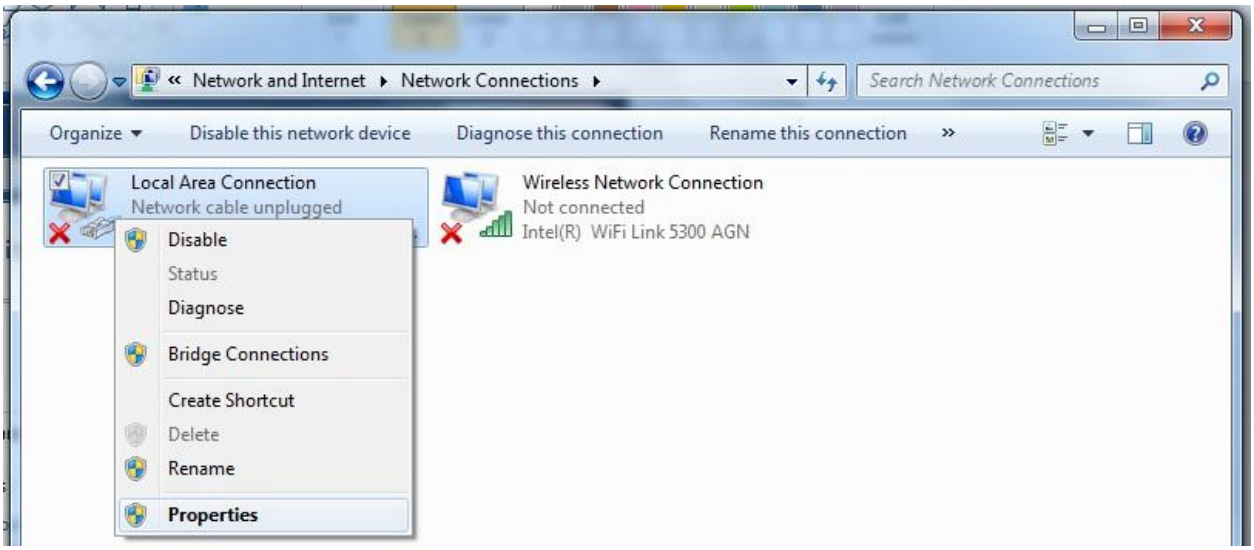
- When the laptop/tablet is booted, click on the bottom right corner near the clock to open the “Network and Sharing Center”



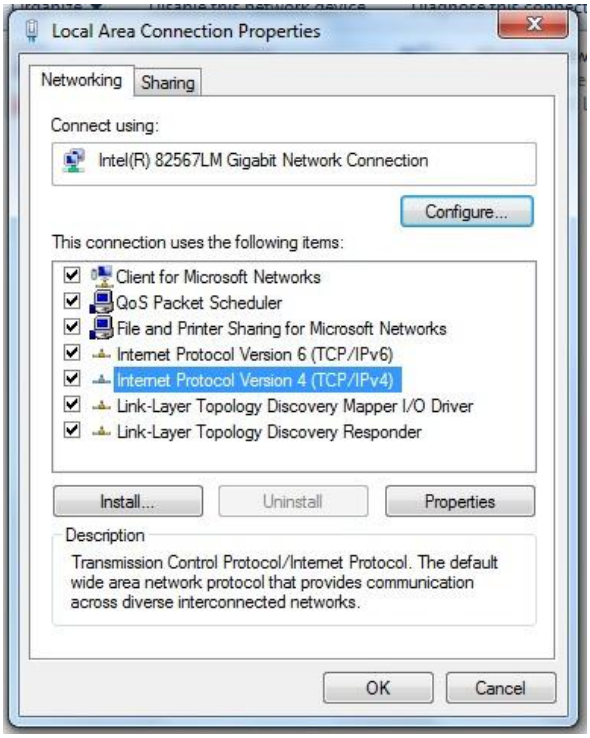
- Click “Change Adapter Settings”



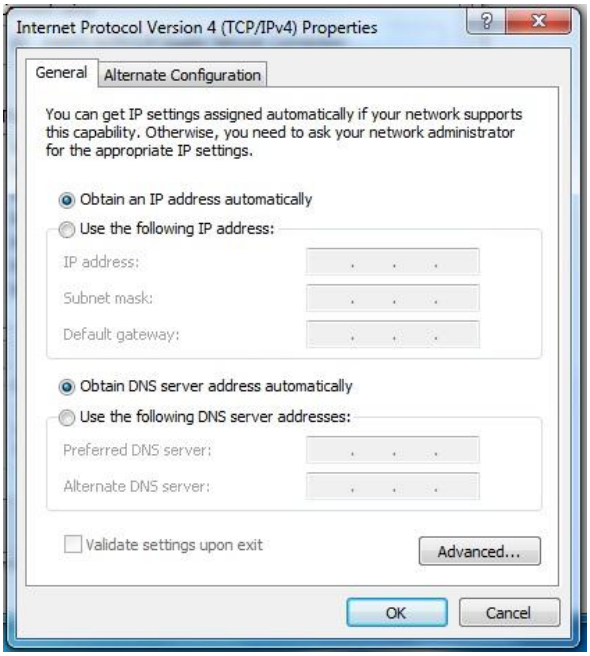
- Right click on Local Area Connection, open “Properties”



- In the centre window of the Local Area Connection Properties, open the properties for "Internet Protocol Version **4** (TCP/IPv**4**)



- Make sure the selection for "Obtain an IP Address Automatically" is selected.



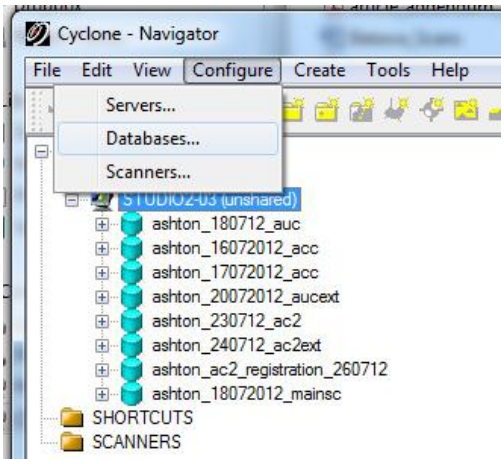
- Make sure the selection for "Obtain DNS server address automatically" is selected.
- If these settings don't work, you can open "NetSet" manager from the start menu, and click on the tab for the C10 scanner and apply those settings. This may solve the problem.

Scanning

The scanning procedure is almost identical for both scanners. The software interface that operates both of them is Cyclone.

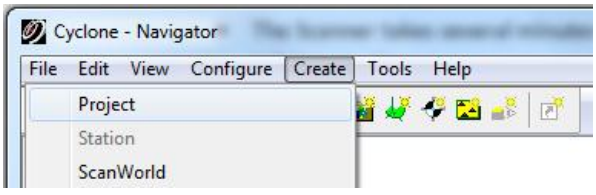
Database Set-Up:

- Open *Cyclone Navigator*
- Click on Servers, and expand the unshared folder for the computer on which you are working .ie. CIMSXT2-PC (unshared)
- Click Configure → Databases



- If you are starting a new project, click Add.
- IT IS VERY IMPORTANT TO USE THE FOLLOWING NAMING PROCEDURE
    - The database name contains the overall project name, the date the scan took place, and a description of the subject of the scan.
    - ie. project_ddmmyy_description
        - All lower case, separated by underscores.

- Use the same filename as the database name. Click okay to add the new database. Close the Configure Databases window.
- When back in the Navigator home screen, you now need to now create a Project within the Database. This is done by clicking Create → Project

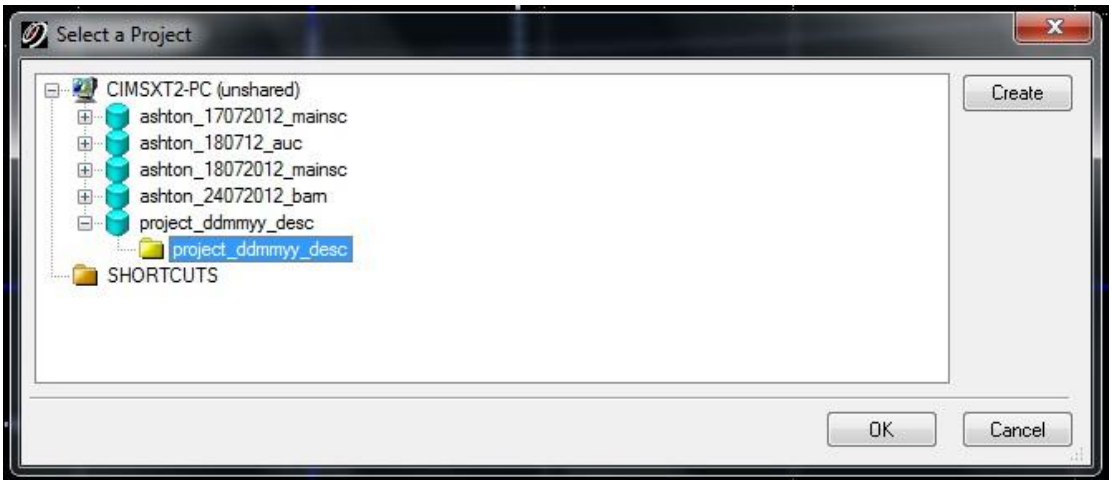


- Use the same Project name as the Database name, to avoid confusion.

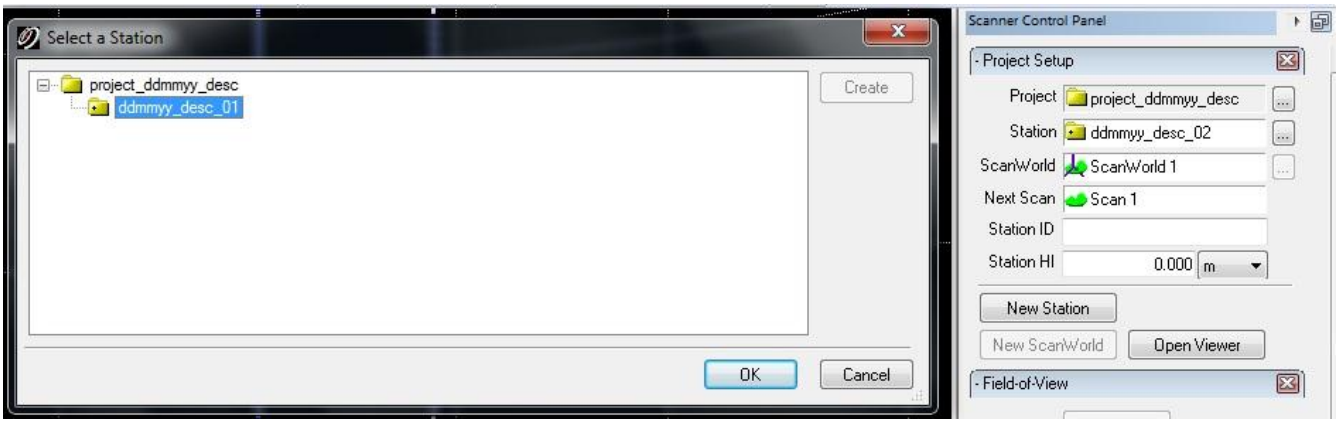
- Make sure that you keep all of the scans for this particular site/building in the same project folder. This makes registration and data management much simpler.
- To set-up your first station, select the project you just created, click Create → Station
- IT IS VERY IMPORTANT TO USE THE FOLLOWING NAMING PROCEDURE
    - To name each station, start with the date, then the description, then the station number. Each new station will be numbered sequentially.
    - ie. ddmmyy_description_01

Scan Set-Up

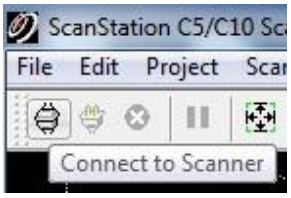
- In *Cyclone Navigator* expand the section that says Scanners.
- Choose the scanner you will be using, either the ScanStation2 or the C10.
    - The ScanStation2 may be listed as CIMS on some of the laptops/tablets.
- Double-click to open *Cyclone Scan Control*
- Cyclone will prompt you to choose a Project. Point to the project you just created and click okay.



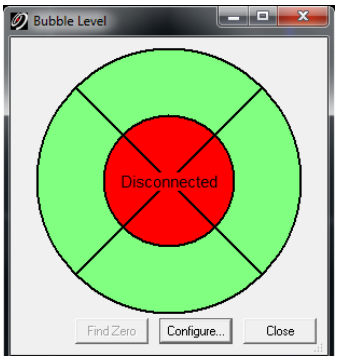
- Cyclone will automatically advance to a new station (ddmmyy_desc_02), you need to tell it to go back and use the one you just created.
    - On the right hand site of the Cyclone interface, there is the Scanner Control Panel. At the very top, the section is titled Project Set-Up. Click on the three dots adjacent to the station name, this will open a window similar to *Navigator*. Select the project, then select the station (ie. ddmmyy_desc_01). Hit okay.



- Now connect the scanner by clicking the icon of a plug, immediately below the file menu.



  - If you are using the ScanStation2, make sure it is unlocked, otherwise this process will fail and you'll have to reset.
  - It may take up to about a minute for it to connect, do not attempt to start a scan or any other process during this time.
  - You will be able to tell when it is connected when the progress bar on the bottom right resets to zero, and on the bottom left the status bar says "Connected"
  - If there are issues connecting:
    - Check that the cables are connect and properly seated.
    - Verify your network settings are correct for the scanner being used.
    - Reset scanner and laptop, and try to connect again.
- Once the scanner is connect, double check that it is perfectly level. There is a more precise level built into the scanner that you can use for this. It is accessed by clicking Scanner→Bubble Level
  - Do this slowly, the level takes a fraction of a second to read properly. The acceptable level of tilt is anything below 0.01°
  - There might be a message the pops up saying that the dual axis compensator has been activated, this is a mechanism that keeps the scanner level during a scan.



Imaging

Before starting a scan, an image of the field of view needs to be performed. This image allows the operator to locate targets visually, as well as define the area to be scanned. It also uses the images to assign colour values to the points in the point cloud.

- On the Scanner Control Panel (to the right hand side of the window), there is a section called “Field-of-View”
    - Under presets, select “Target All”
        - You can perform a partial image to save time, but deciding upon the appropriate field-of-view can be difficult without any previous references.
    - Select the appropriate image exposure, by click Image → Adjust Exposure
        - For the C10, select automatic exposure.
        - For the ScanStation2, select the appropriate preset (indoor/outdoor)
            - If the image is too bright, or too dark, you may need to adjust it manually. This can be done by stopping the imaging process (hitting the stop button on the bottom right) and sliding the dial under exposure settings.
    - Click *Image* on the bottom right, this process may take quite some time depending on the exposure settings and the scanner. Try to stay out of the images, if you are imaged, your colours will be assigned to the points for the scan.

Acquiring Targets

In order for the scanner to recognize the targets that were placed, we need to tell it where to look. This is primarily a slow manual process, but it is very important to follow the steps carefully, these targets are essential for registering scans.

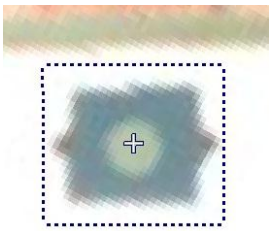
The controls for navigating in Cyclone are as follows:

- Left click is pan.
- Pressing the centre button (scroll wheel) is zoom, the centre of the zoom is from the centre of the screen, not from where you click.
- Right click is orbit (not active in image mode, only active when viewing a completed scan.)
- Control+Left Click is “Look Around”

First zoom into the first target you are going to acquire.

- Centre it in your screen, and then click the “Fence” tool from the top toolbar.

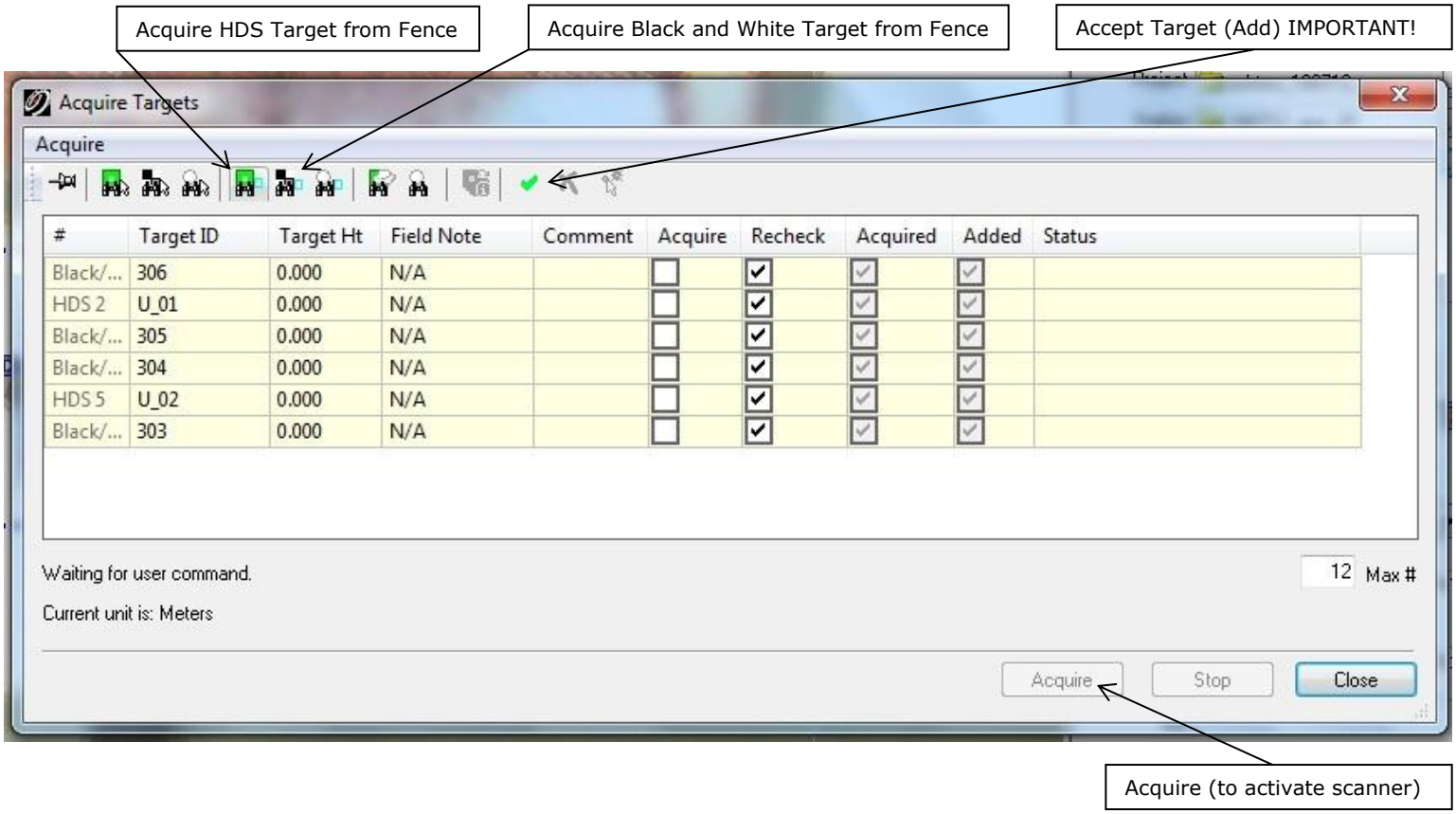
- Set the box generously around the target, and make sure that the crosshairs are centred on the middle of the target.



- Click Scanner Control → Acquire Targets
- In the Acquire Targets window, click either “Acquire HDS Target from Fence” or “Acquire Black and White Target from Fence”
    - The HDS targets are “High Definition Surveying” targets, the blue targets with the white circular centre (whether a sticker or a proper target with a base.)
    - The Black and White targets are the checkerboard targets.
    - BE SURE TO SELECT THE CORRECT ONE, if not there is a high probability of mis-targeting and inaccurate registrations.
- This will add a new line to the table in the window, under target ID type the name of the target from the field notes.
    - IT IS VERY IMPORTANT THAT TARGETS ARE GIVEN THE SAME NAME BETWEEN SCANS, use the field book, otherwise you won’t be able to register the scans.
- While the line is still highlighted, click the “Acquire” target at the bottom of the window.
    - The scanner will perform to scans, first a coarse scan, then a detailed scan. If successful, the “acquired” box will be checkmarked on the table.
    - After this is complete, highlight the line for that target and click the green checkmark. This will add the target to the scan.

- DO NOT CLOSE THE WINDOW UNTIL YOU HAVE ADDED THE TARGET, otherwise you will lose that target and have to rescan. There is no way to re-add a target.

- Repeat until all targets have been acquired.



Resolution

This setting determines the amount of points that the scanner will register. In essence, it is the density of the point cloud.

To decide the quality, find the smallest detail that will need to be captured. The point cloud density should be half this size. For example, if scanning a window frame with 1cm wide detailing, then the point density must be set for 5mmx5mm.

The following equation can be applied, where Q is quality, m is point density, and λ is the smallest detail spacing. Should aim for Q to equal 0.5.

$$Q = 1 - \left(\frac{m}{\lambda}\right)$$

The following scan resolutions have been used on previous projects:

Exterior Scan	Interior Scan	Fixed Details
5cm x 5cm	1cm x 1cm	1mm x 1mm

- In order to determine the resolution, we need to know the distance of the furthest point for which we require complete information. (ie. the furthest point in the room from the scanner.)
    - Use the fence tool to select the point in the image window.
    - On the right hand Scanner Control Panel, in the section called Resolution, click the button that says “Probe”
    - This will act like a disto and measure the distance to that point.
- This sets the “Range” of the scan, anything closer will be of higher resolution, anything further will be of lower resolution.
- Under the same section (Resolution) select either a preset from the drop-down menu, or enter the Sample Spacing in the boxes. Make sure to be aware of the units being used.

Scanning

Once all the targets have been acquired and added, it is time to set up the scan. The scan itself is the process that takes the most time, but it is automatic and does not require the operator’s attention.

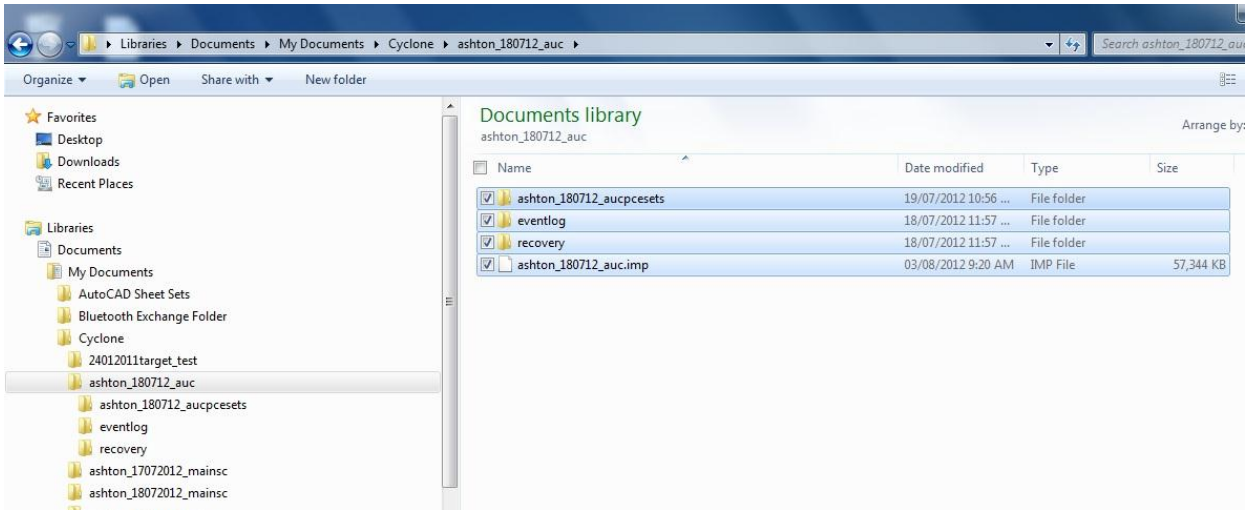
- If you are doing a 360° scan, make sure the Field-of-View is set to the preset “Target All”
- Otherwise, you can draw a fence in the image window, this will automatically set the Field-of-View to that fence (use the same Fence tool that was used for the targets.)
- Click the “Scan” button on the bottom right corner.
- The Estimated Time Remaining will update in a few seconds, giving you an approximation of how long the scan will take. Depending on the scanner, resolution, and distance this could be anywhere from several minutes to several hours.
    - As a rough guideline, a 360° interior scan at 1cmx1cm @10m will take about 30 minutes with the C10 and about 2 hours with the ScanStation2.

- You can view the scan in progress by clicking the "Open Viewer" button near the top of the Scanner Control Panel.

Once this scan is complete, within the same ScanWorld, use the fence to select the areas of the Fixed Details as determined above, and set the resolution to 1mmx1mm. Scan these as well.

Transferring

In order to transfer the scans from the laptop to a computer at CIMS, copy the entire directory of the database. This can be done either by copying to a USB, or by connecting to the CIMS network and placing it on the server. Registrations must be done on the local drive, they cannot be done with the files on the server.



For registering scans please see the Registering_with_targets or Registering_without_targets protocols.