Photogrammetry Using Smartphones
User Manual

Version 1.0

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Overview

In order to 3d print customized prosthetics for amputees, correct geometric 3d models must be constructed for them. This manual will instruct the reader on how to carry out the process of photogrammetry correctly and efficiently. Photogrammetry uses a photos taken with a basic smartphone camera to generate a 3d model, this

Hardware Needed

Common hardware: three scale bars.
Minimal configuration
Camera: Current flagship phone camera with flash light on it.
Computer:
Windows XP or later(32 or 64 bit), Mac OS X Snow Leopard or later, Debian/Ubuntu(64 bit)
Intel Core 2 Duo processor or equivalent
2GB of RAM
Recommended configuration:
Camera: single-lens reflex camera with build-in flash light or external flash light.
Computer:
Windows XP or later(32 or 64 bit), Mac OS X Snow Leopard or later, Debian/Ubuntu(64 bit)
Intel Core i7 processor
12GB or more of RAM

Software Needed

Agisoft PhotoScan

Meshmixer

General Workflow Guide

1. Set up target and scene
    a. Well lit area with neutral lighting
        i. No bright spots or light sources should be directly captured by the camera
        ii. Shadows should be minimized as much as possible. The easiest way to accomplish this is to utilize the camera's inbuilt flash function. If the camera does not have a flash, holding a light source next to the camera pointed at the target works as well. It is important to make sure that ambient lighting is not so bright as to overwhelm the camera's flash
    b. Contrast between target and background is beneficial. A dark background should be applied whenever possible, holding a dark background such as a blanket behind the target when taking photos is a viable option
    c. Scale markers should be set up now. Scale markers need to be in the scene for at least some photos, they do not need to be visible for all photos, and can be removed once they would occlude the target. If the markers move at all before they are removed, remove them immediately. The markers must be stationary for all photos that they appear in. If scale markers are not to be used, the limb must be scaled, see point 2d below

2. Set up patient
    a. Patient should be stable and comfortable
        i. This is important as the patient should not move during the process
    b. Residual limb should be facing down and naturally hanging
    c. Residual limb can be uncovered, if covered, the material cannot be shiny, smooth, or monochrome
    d. If the residual limb is to be covered with a scaling sheath, it must be put on the limb and then measured. The scaling sheath should be a tight fitting cloth that has a high contrast pattern on it, a chessboard pattern works best. Distances between specific points need to be taken and given along with photoset

3. Camera Calibration (if possible)
    a. Agisoft has an inbuilt chessboard pattern for camera calibration
        i. Found in Tools > Lens > Show Chessboard
        ii. Take photos of this chessboard from many different angles
            1. Around 30 photos should be taken
            2. These should be from many different angles
        iii. Process these photos in agisoft using camera calibration
            1. Found in Tools > Camera Calibration
            2. Once processed, export camera settings for future use

4. Taking photos
    a. Photos must be in focus and clear
    b. Photos should be taken ~30cm from the target
    c. Take 30-35 photos per circular orbit around the target
        i. Two orbits at a minimum
        ii. Each photo should be equally distant from the previous and succssive photo
        iii. Each photo should overlap about 80% with the previous
    d. As detailed in the lighting section, the camera flash should be turned on

5. 3d Model Generation
    a. Upload all photos taken to Agisoft
    b. If using camera calibration, do this now
        i. Go to Tools > Camera Calibration and click on Load in the Intial tab
        ii. Load in calibration data for whatever device took the photos
    c. Remove excess data
        i. Delete all data points that are not part of the target in question, this can be down using the selector tool to select points and then delete them, or by using the move region tool to set the region to only contain the target
    d. Next steps are all contained under Workflow
        i. Align Photos > Medium Quality
        ii. Build Dense Cloud > High or Ultra High
        iii. Build Mesh > High or Ultra High
        iv. Build Texture > High or Ultra High
    e. Mesh refinement
        i. Go to Tools>Mesh>Close Holes

6. Scaling
    a. If scale markers were used, go to Tools > Markers > Detect Markers
        i. Select what type of marker was used, and then set a tolerance of 20, only increasing if not all markers were detected
        ii. Select the Markers area of the reference pane to view tagged markers
    b. If scale markers were not used, right click on the model to generate a marker
        i. These need to correspond to measurement points taken on the target
        ii. In the Marker area of the reference pane, select two markers and right click then select “Create Scale Bar.” Enter in measurements, and do this for all scale sections that were measured
7. Export
    a. The model is now finished, select File>Export>Export Model and select whatever file type is convenient

Photos taking

To get a successful 3D geometric model, all photos must be taken in a deliberate and careful manner. The photo taking step is the most critical step in the entire process.

Camera settings

• Using RAW data losslessly converted to the TIFF files is preferred, since JPG compression may induce unwanted noise to the images.
• Take images at maximal possible resolution.
• ISO should be set to the lowest value, otherwise high ISO values will induce additional noise to images.
• Aperture value should be high enough to result in sufficient focal depth: it is important to capture sharp,not blurred photos.
• Shutter speed should not be too slow, otherwise blur can occur due to slight movements.

Basic Rules

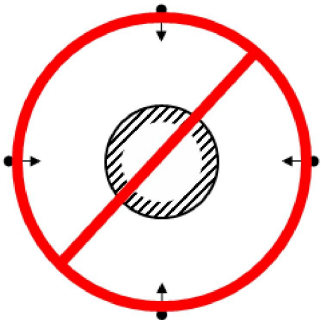
Light condition is critical, the Indoor light is recommended.
Avoid reflective objects.
Avoid shiny and transparent objects.
For complicated object, more overlapping between two pictures is needed.
For less complicated object, less overlapping is also fine.

Particular Rules for residual leg

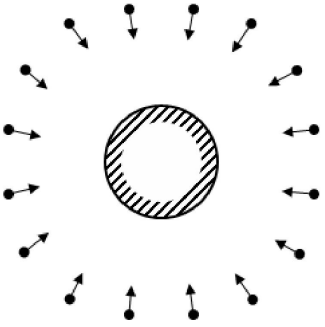
Leg should be freely vertically suspended in the midair.
Avoid laying on the bed or pointing to the sky.
Shorten the time period of taking photos for residual leg as much as possible in order to decrease leg movement.
Around 30 photos should be taken

Photos taking scenarios

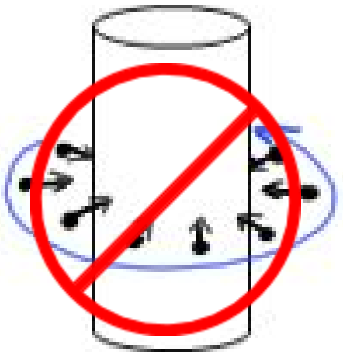
For isolated object like residual leg, the following figures represent typical capturing scenarios:



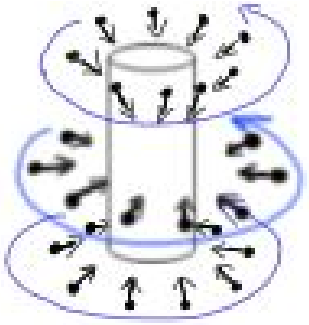
Isolated Object (Incorrect)



Isolated Object (Correct)



3D Isolated Object (Incorrect)



3D Isolated Object (Correct)

Troubleshooting

Q: The photos are not aligning or the model looks wrong

A: There are a variety of reasons for this, but the following are a list of common causes. Agisoft lets you know which of the photos in the set failed to be aligned. These photos lack a green checkmark. Compare these photos with the photos that are aligned. Check the lighting and background, are they the same as the aligned photos? Is there an 80% overlap with the previous picture that was able to align? Is the photo blurry, or did the patient move?

Q: There are gaps in the model

A: Setting the model quality to high can occasionally cause some errors, try to lower the setting for Align Pictures and Build Dense Cloud to High or Medium. Other possible reasons could be that there is not a camera angle that covers that section of the target. In the 3d model after it has aligned the pictures, you can see where Agisoft thinks each picture was taken relative to the object as blue rectangles. If the blue rectangles do not cover every angle then there is likely a gap somewhere. You can close these gaps manually with the Fill Gaps command but the infill that Agisoft creates will follow an estimated geometry. Retaking the photos is suggested, as this estimated geometry is not likely to be correct.

Q:It is taking a long time to process anything

A: Reducing the quality will speed up the process. Limiting the amount of photos will also speed up the process. Use the Selection tool (photo) to select details that are not needed in the model and deleting them before building a dense cloud will greatly speed up the processing time.