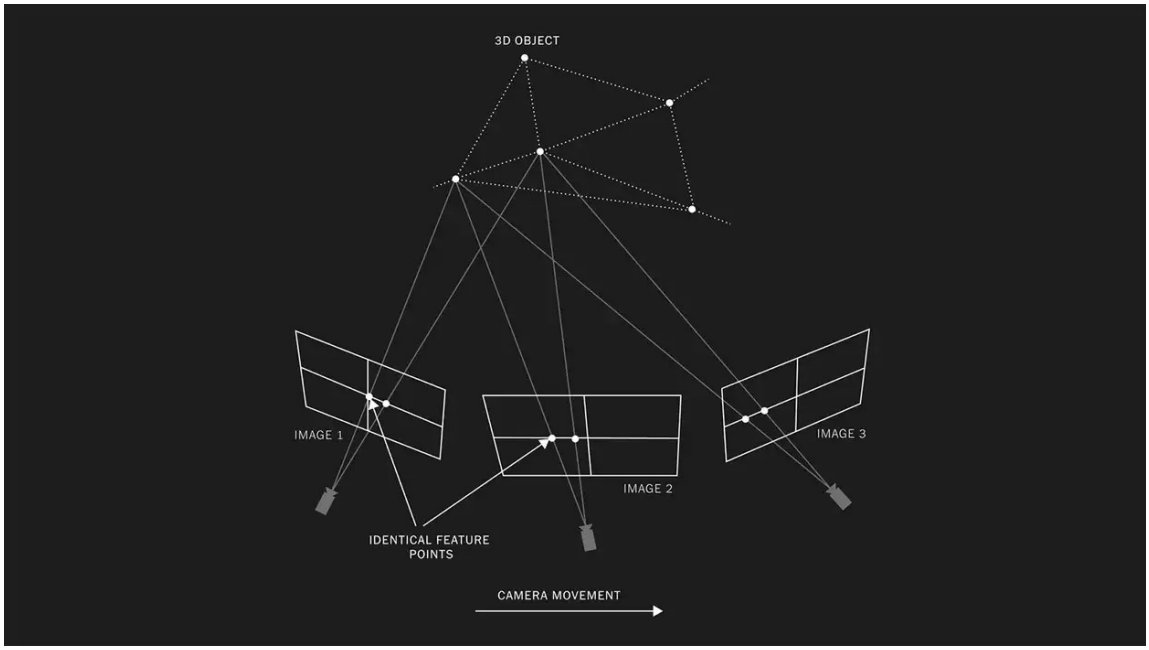
Spatial Journalism

Capturing Images for Photogrammetry



When creating a 3D model using photogrammetry, photographs should be taken from different points in the scene. This difference in apparent position is called parallax, which allows the photogrammetry software to calculate depth, making it possible to render a 3D model.

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The latest generation of iPhones and Android phones come with powerful cameras and a range of features that make it possible for more journalists to create publication-quality 3D visuals for use in their reporting. We've tested dozens of methods, cameras and apps for capturing photogrammetry scenes, and have found that the approaches listed below create the most detailed and performant 3D models.

What this guide covers: Tips and best practices for using an iPhone or Android phone to capture images that can then be used to create a high-quality 3D model of an environment.

What you'll need:

- An iPhone X or newer, or an Android phone from 2018 or later
- For iPhone users, we recommend camera apps such as ProCamera, Halide or ProCam
- Photogrammetry software such as RealityCapture or Meshroom (open-source)

Planning and Pre-Production

- **Seek even, well-balanced lighting.** When shooting outside, very bright or dark light can present challenges. Hard shadows or a changing light source (such as a setting sun) can make photo alignment difficult, as these types of conditions require the camera to use multiple light settings. When shooting outdoors, try to capture your scene when light is more diffused, such as on a cloudy day or in the early morning. When shooting indoors, lower the shades to help reduce strong shadows and make the room more evenly lit. Diffused indoor lighting, such as overhead lights or lamps with shades, can be helpful as long as they don't cast strong shadows.

- **Minimize reflective and transparent surfaces.** Due to their transparency, reflective or glass objects are difficult to align in a 3D scene. Also watch out for wet surfaces, as these can create challenging reflections as well.

- **Make sure your scene is still.** Once you start capturing, any changes to the space, such as movement from a bumped chair or a new footprint on a dusty floor, will cause a blur. Consider tidying the space before the capture process begins to avoid any mid-process changes within the scene.

Shooting

Photos taken with consistent camera settings will help the photogrammetry software successfully triangulate each image into a clear and detailed 3D scene. It's important to dial in your ISO, aperture, shutter speed and white balance at the beginning of the shooting process, using the focal point of the scene to choose the most appropriate settings, and then keep these settings consistent throughout your shoot.

PHONE SOFTWARE

On the iPhone, there are several apps that are relatively easy to use, and which will give you a level of control similar to a professional DSLR or mirrorless camera.

For iPhone users, ProCamera is our preferred app because it is possible to shoot in a lossless TIFF or

JPG format, and because you can lock the camera's aperture and speed. Halide and ProCam are also good options.

For Android users, we recommend using the native camera app because it has advanced features that let you control all of the necessary camera settings.

CAMERA SETTINGS

To create consistent shots, you'll want to shoot in manual mode. This will allow you to set the camera's ISO, aperture, shutter speed and white balance so they're the same in every shot. If you're using more than one phone to capture your scene, be sure they both use the exact same camera settings throughout the shoot.

Here are the basic camera settings to use:

ISO: Grain in the image can cause problems with alignment and texturing, so it is helpful to keep the ISO as low as possible. An ISO setting of 100 is ideal, but if you need to use a higher ISO, avoid going past 800 .

Aperture: It's important to have a large depth of field and to keep everything in focus. In most cases, an aperture between f/9-13 will work best.

Shutter speed: To avoid blurry images, the shutter speed should be set to 1/200 or higher . If the speed needs to be lower due to a dark scene, the camera should be mounted on a tripod. Set the speed to properly expose the main subject of the room, and do not adjust it again afterwards.

White balance: Set the color temperature for your scene as a static setting and keep it consistent. Do not use auto white-balance. If your scene includes multiple rooms with different color temperatures, or a room with different light sources (like a bright window and interior track lighting), shoot with a color chart passport in all rooms.

File type: In this guide, we use the JPG file format. If you're interested in color correction during post-processing, a process beyond the scope of this guide, RAW or TIFF files can be used to avoid compression artifacts and to preserve true colors.

Focus: In general, using autofocus is fine. You should verify that the autofocus is working for each shot, but know that with a smaller aperture, most things in the

know that with a smaller aperture, most things in the frame should naturally be in focus.

Flash: Turn off the flash.

ADDITIONAL CONSIDERATIONS

Zoom: The iPhone 12 Pro has three lenses: a wide-angle, an ultra-wide and a telephoto lens. Generally, it is best to stick with a single lens, preferably the wide-angle lens (labeled 1x), rather than to change zoom settings in the middle of a capture. However, if for some reason you can't walk up close to the scene and are therefore shooting at a distance, you may need to zoom in for some shots. Whenever possible, moving closer to the scene is preferable to zooming in.

LiDAR: The iPhone 12 Pro and iPad Pro both come with a built-in LiDAR scanner, which can measure distance and depth by sending hundreds of laser measurements to create a 3D point-cloud of an object or a space. While the built-in LiDAR makes it possible to capture and export 3D point-clouds quite quickly, after testing it against the camera-based shooting method described in this guide, we found that the onboard LiDAR was not precise enough to be useful for publication-quality photogrammetry.

Capturing

When capturing a scene, it's important to ensure enough photo coverage from all angles so that the photogrammetry software can successfully triangulate an accurate 3D mesh with clean and detailed textures. To make sure that all the necessary photos are taken, it can be helpful to use what's called a "capture pattern" (more on these below).

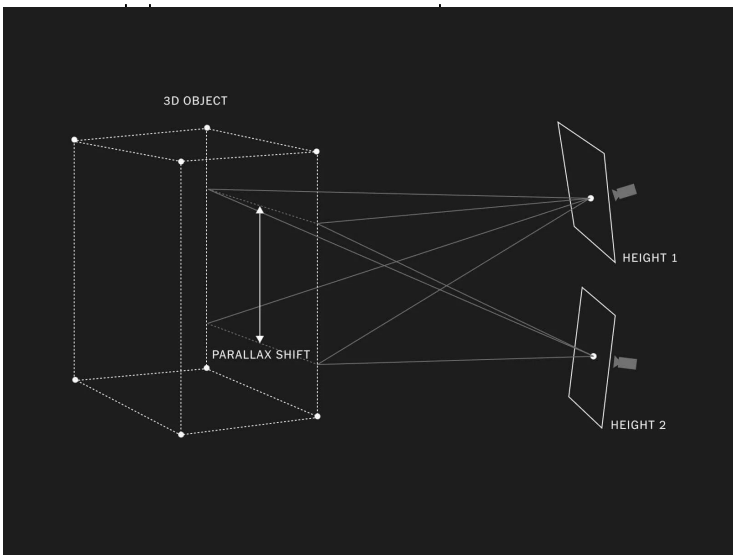
Additionally, we've found that as you move through the capturing process, the contents of each new shot should overlap with the previous shot's contents by 70% in order for the photogrammetry software to successfully identify and render a scene's details. To maximize parallax, or the three-dimensionality of the scene, you should attempt to achieve this amount of overlap in between shots for both vertical and horizontal orientations, as well as for depth (i.e. X,Y and Z space).

CAPTURE PATTERNS

A capture pattern is the physical path that you follow as you move through a scene taking photos to capture it in its entirety. Although each capture pattern should be tailored to fit a scene's unique environment and characteristics, we've developed a series of reference patterns that work well for the photogrammetry of rooms, streets and landscapes (see below for diagrams).

In thinking through how you'll capture your scene, it's helpful to approach the shoot in four stages:

1. **Wide establishing patterns:** These shots help the software map out the necessary features within the scene.
2. **Parallax patterns:** These ensure your scene can generate 3D geometry by capturing the same feature across different angles and heights.
3. **Detailed shots:** Close-up shots of textures and specific points of interest will ensure high-quality detail in your scene.
4. **Context shots:** These ensure that the entry points of

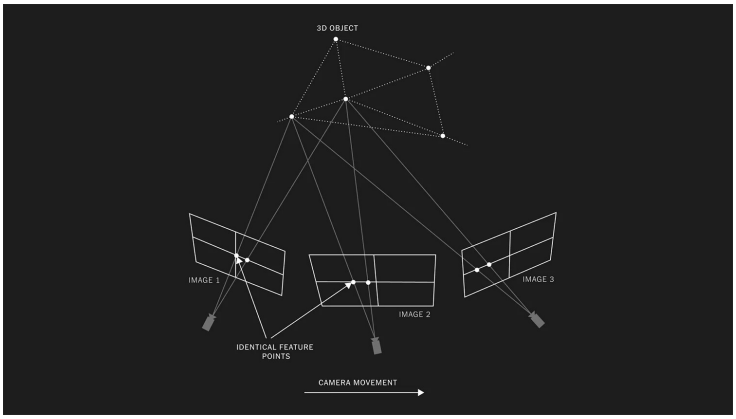


Photographs taken from different heights are used to create a vertical parallax shift or displacement that is necessary for photogrammetry software to triangulate a 3D model.

As you shoot along your capture pattern, it is important to capture height across the vertical axis by shooting from two or three different points, depending on the complexity of the scene. This will help create parallax on the vertical or y-axis. To do this, follow these steps:

1. Take a photo from a low position, looking upwards
2. Take a photo from straight on
3. Take a photo from up high, looking downwards

Remember that the contents of each shot should overlap with at least 70% of the previous shot's contents. This means that the larger your scene, the more photos you will be taking.



Photographs taken from different points are used to create a horizontal parallax shift or displacement that is necessary for photogrammetry software to triangulate a 3D model.

PLANNING CAPTURE PATTERN ROUTES

To get good coverage of your scene, it's a good idea to map out each capture pattern in advance. When working with a team, this also makes it easier to coordinate who will capture what section of the scene.

At The Times, when sending photographers out into the field, we use screenshots from Google Maps or Google Street View to draw out and assign capture patterns in advance. Of course, plans can change if conditions change in the field, but it's always helpful to have a rough plan before a shoot begins.

Before finalizing your routes, make sure to map out a capture pattern that enables you to get full coverage of the ground or ceiling (something that is often overlooked).

We used an iPhone to capture photographs every two steps with approximately 70% overlap between each image.

Capture Pattern Example: Freeman Alley in NYC

To better illustrate how we use capture patterns, we'll walk you through the six paths we took to create our Freeman Alley example. Keep in mind that some capture patterns will be completed two or three times: once to photograph the path from a low position, looking upwards; a second time following the same path but photographing from up high, looking downwards; and finally a third time, photographing the same path from straight on.

Given that we were shooting a relatively flat alley wall, we opted to take just two photographs at each position within each capture path (rather than three, which is recommended for geometries more complex than a wall).

FREEMAN ALLEY CAPTURE PATTERNS

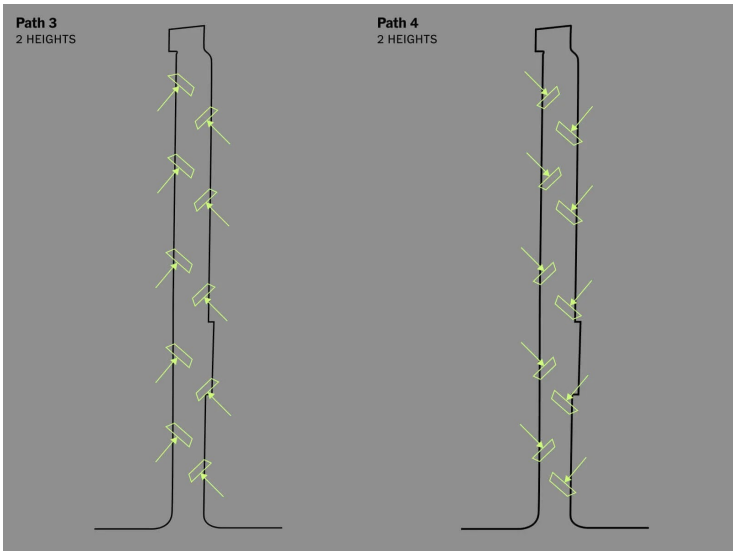
Path 1: For the first capture pattern, we took broad, wide establishing shots of the full alley. This ensured that we had good coverage to align features across the scene. Using the ultra-wide 0.5x lens on the iPhone 12 Pro lens, we walked straight down the alley, making sure to capture both sides of the alley within the frame and taking photos every step. As you capture, it can be helpful to think to yourself, "One-step-shoot, one-step-shoot," and again, remember to repeat the path at different heights.

Path 2: The second capture pattern was similar to the first, but we walked and took photographs in the opposite direction so that we could capture the reverse angle.

This screenshot from Google Maps shows the recommended paths and heights to take photos in each route (into and out of the alley). Note the significant overlap.

Path 3: For this capture pattern, we focused on getting good texture and parallax. To achieve this, we walked down the alley, photographing one side at a time at a 45-degree angle and taking a photo every two feet.

Path 4: This capture pattern was similar to the third pattern, but at a 45-degree angle in the opposite direction.

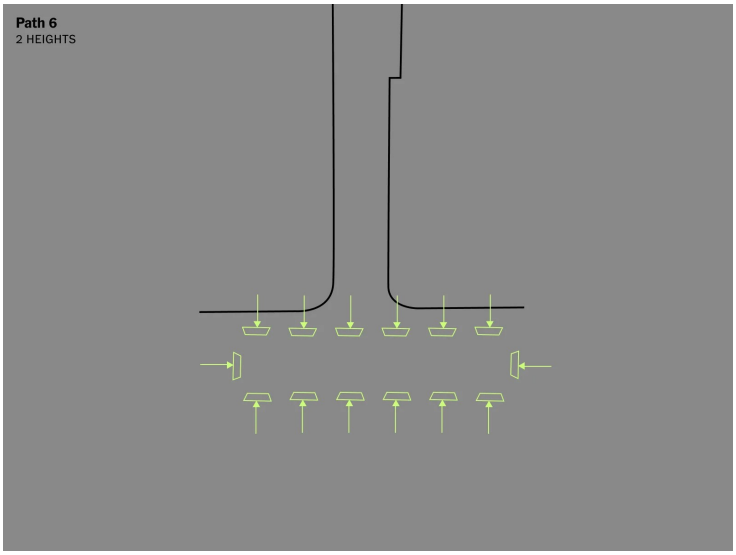


A top view diagram of Freeman Alley demonstrating the capture pattern for Path 3 and Path 4.

Path 5: The focus of this pattern was on detail shots, particularly complex three-dimensional areas that we knew would become focus points in the model, such as graffiti on the wall or the very end of the alley.

When capturing objects and details in the scene, it's helpful to take photographs from every angle, including top-down.

Path 6: This path focused on contextualizing shots to ensure we had good coverage of the alley entrance, shooting inwards in an elliptical pattern.



A top view diagram of Freeman Alley demonstrating capture pattern of Path 6.

Note that for this example, we captured 1,414 photos in total.

A TIP FOR SHOOTING HIGH UP

The ProCamera app has a useful feature that works as an alternate shutter release, which is handy during shoots when you're holding a camera up high, or using a phone mounted on a monopod for extra height. In this situation, reaching the phone to tap the screen can be cumbersome, so a useful trick is to use the volume button on a pair of headphones to toggle the shutter.

How to use a remote trigger with wired or Bluetooth headphones:

1. Turn on the volume on the phone
2. Inside the ProCamera app go to Settings > General Options > Toggle on Volume Buttons

Capturing Components

To capture an environment with many individual components, such as a street filled with parked cars or a gallery filled with sculptures, it is often necessary to divide the scene into several smaller capture sections, where each object is treated as a separate component. This approach can be helpful when your scene is a larger environment with a lot going on, or when there are specific points of interest (POIs) that you want to ensure are captured in high detail. Focusing on individual components can also improve the alignment ratio (i.e. the number of images that align correctly) within your scene, because it is easier and faster for the software to find corresponding features within a smaller group of images.

Overall, the component-capturing process involves focusing on specific objects or features within a scene, which are then grouped together for processing in RealityCapture, the photogrammetry software we'll be using later.

When shooting individual components, it still works best to start with wide-angle establishing shots, and then capture medium-angle shots for the geometry or 3D shape of the scene. Finally, you'll want to capture close-up shots for detail and texture. To help with file management later on, it can be helpful to take a photo of your hand as a marker between each component-based capture path. (For more information on how to capture individual components

information on how to capture individual components, RealityCapture has a helpful tutorial.)

Skybox Panoramas

"Skyboxes" are 360-degree images that can fill in the negative spaces within a 3D scene, such as the sky or the background that surrounds the photogrammetry model (for example, see the Abaco scene in "Reconstructing Journalistic Scenes in 3D"). To ensure consistency in the 3D model, skyboxes should be captured on the same day and in the same location as the photogrammetry photos. Capture a few of them, as they will be helpful in ensuring that the published 3D experience contains enough visual context for the story. This is important if users will be seeing a sky or a larger environment surrounding the model, but if, for example, you're shooting an interior scene, this won't be necessary.

While it's beyond the scope of this guide, there are several methods you can use to capture skyboxes, such as using 360 cameras and reprojecting them on a sphere in Maya or Blender, or aligning photos using Photoshop or PTGUI.

Shooting Video

We don't recommend shooting in video to create 3D models using photogrammetry because the fidelity is lower. However, it can be worth experimenting with if you're looking for a quicker approach. Videos are essentially a sequence of images, and therefore can provide a good set of overlapping images for the photogrammetry software. However, there are other factors that make them less helpful — such as image noise, motion blur, pixel binning, aliasing and rolling shots, all of which tend to increase misalignment and add artifacts that the photogrammetry software may have trouble processing.

Media Management

Below we'll cover a few simple tips to improve your workflow.

FILE TRANSFER

Follow these steps to import the captured photos from

your iPhone to PC:

1. If you have iCloud Photos turned on, you need to download the original, full-resolution versions of your photos to your iPhone before you import them to your PC. Select “Settings > [your name] > iCloud > Photos,” then turn off iCloud Photos.

2. Download the latest version of iTunes on your PC. Note that importing photos to your PC requires iTunes 12.5.1 or later.

3. Connect your iPhone to a PC with a USB cable.

4. Unlock your iPhone. Your PC can’t find the device if it is locked.

5. If you see a prompt asking you to “Trust This Computer,” tap Trust or Allow to continue.

6. On the PC, select “Start > Photos” to open the Photos app.

7. Select “Import > From a connected device.”

8. Select your photos to begin the transfer.

   Another approach is to select all the files in iOS Photo, and then select the option to “Save To Dropbox” or another cloud storage system.

   Android has a built-in file system which makes it easier to export files. It’s also possible to use an SD card, if supported by your phone, or Android File Transfer.

FILE MANAGEMENT

It is important to keep your project files organized, particularly with projects that may go through many iterations. Here is how we structure our file names to keep them organized:

Root Folder:
YYYYMMDD_STORYSLUG_LOCATIONSLUG_VERSION

00_SOURCE (Anything captured in the field, photos, drone video)

01_PROCESSED (Materials ready to be used in RealityCapture)

02_REALITYCAPTURE (RealityCapture files)

03_GEOMETRY (All geometry and textures exported

from RealityCapture)

04_MISC (Screenshots, errors, renders)

05_PRODUCTION (Anything in post-production)

06_DELIVERY (Any assets ready to hand-off to developers)

Next: Processing

Once you've captured your scene and have transferred all the photos from mobile phone to PC, you're ready to move on to our next photogrammetry guide, Processing and Aligning 3D Scenes.

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