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Reality Virtually: Case Study at the Memorial to the Enslaved People of George Mason

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Learning Objectives

- Explain what reality capture is
- Differentiate between the numerous reality capture technologies
- Apply basic photographic techniques to capture real-world objects using Recap Photo
- Describe how to prepare 3d scans for fabrication and visualization

Description

Discover how to create high quality 3d models from photographs by leveraging the power of Recap Photo. It has never been simpler to digitize the world around you. Join us as we explore the various reality capture techniques available, as well as basic workflows. This course will center on my own journey with photogrammetry while working on the Memorial to the Enslaved People of George Mason at George Mason University in Fairfax Virginia.

About the Speakers

John Stinson graduated with his Master of Architecture from degree from the University of South Florida and has since become a licensed architect, Design Technology Leader and Project Designer at Perkins and Will in Atlanta. Over the years he has lead design on several exciting projects including the most recently completed building at country music star Zac Brown's Camp Southern Ground. Through the lenses of architectural imaging, physical modeling, and animation, he constantly seeks to elevate the quality and excitement of the design process. LinkedIn

Justin Cooper is a landscape architect with ten years of experience on a variety of project types. His experience includes planning for residential communities, the design and construction documentation of amenity areas for both suburban and urban mixed-use projects, and landscape plans for corporate office buildings. He has recently focused on the construction documents and construction observation for the landscape components of many Perkins and Will projects.

Contents

Introduction to Reality Capture

What is reality capture?

Reality capture is the process of creating a digital 3d model representation of a subject from the physical world. There are two common types of reality capture that are prevalent today, LiDAR and photogrammetry.

LiDAR (Light Detection and Ranging) Utilization

LiDAR is a surveying method that measures distance to a target by illuminating the target with laser light and measuring the reflected light with a sensor. It is a direct measurement. The measurements are recorded as a colorless 3d point cloud that can be accurate to within millimeters.

LiDAR is commonly used to accurately document as built or existing condition. Several years ago, Notre Dame was scanned by an art historian named Andrew Tallon. At over 850 years old, there is no documentation on who built the cathedral or how. In his forensic analysis he found unsuspected thing like columns in the nave don't align because they were built around existing structure. That scan is now being used to reconstruct it after the fire earlier this year.

The rise of autonomous vehicles is being enable by LiDAR. The laser returns thousands of point data per second to the sensor and an onboard computer uses those points to construct a 3d point cloud of the car's environment in real-time and enables the car to navigate crowded city streets.

Forest Planning and Management services also utilize LiDAR. The laser can be calibrated to use wavelengths that can measure a forest's structure and monitor changes. This data is used to help calculate the amount of carbon in our forests and how much is being released due to environmental stresses and human deforestation.

Photogrammetry(Structure From Motion – SFM) Utilization

Photogrammetry uses the same principles as the human eye, mapping distances of and between objects from a series of two-dimensional images. It is an indirect measurement. The output is full color 3d surface models or point clouds.

Photogrammetry can also be used to scan full buildings for actionable data and illustrative data. Though scans can be as accurate as LiDAR, it takes more skill and time to produce comparable results at such scale. Because of the level of detail and realism that is achievable, photogrammetry scanned environments and assets are becoming more prevalent in renderings VR simulations. Many companies like Render People and Human Alloy are producing people entourage for architectural renderings and animations. Companies like Doob-3d are setting up photogrammetry booth for consumer use. For a price you get a scanned and a life like 3d print is sent to you. Quixel is the world's largest repository for 3d scanned content. Their software and library are available through subscription and they have produced some impressive real time animations.

Why should I use reality capture technologies?

Reality capture allows analysis of existing and as-built conditions faster than traditional field measuring. New technologies are becoming more efficient, less expensive and easier to use to the effect that almost anyone can collect and process data. The 3d data attained can provide improved communication, understanding, and impressive visuals that will benefit your projects. Reality can play an important role in every phase of a project.

Conceptual Design

Some projects may benefit from scanned visual information for conceptual level planning. Aerial and handheld photogrammetry scans can provide information to aid a design team in exploring design solutions as well as an illustrative base to overlay their own ideas to help communicate with other stakeholders.

Construction Documentation

When working on renovations or a project with extensive existing infrastructure, all kinds of fun surprises can be uncovered. Reality capture can help you get out in front and find potential clashes and issues. This is useful for projects where actual construction drawings never existed or were lost to time, but also for more current projects where you may even have a BIM model. Unfortunately, built conditions are always identical to the BIM model. In addition, BIM models typically omit many elements that can cause coordination issues. More comprehensive scan can produce precise building measurements, locate MEPFP systems as well as reveal subgrade utilities and infrastructure.

Construction Administration

While projects are under construction, 3d scanning can track progress and verify compliance with contract documents as well as provide the owner with a record of what is in the “closed-up” portions of their building. In a 2016 industry talk that is linked below, exploring actionable data for conceptual design, site coordination and quality control during the construction life of a project was discussed from the point of a general contractor.

Drones in Construction: Beyond Pictures—Capturing and Exploring Actionable Data

Facility Management

Design and construction aside, 3d scans of existing structure can help owners better maintain and understand their facilities. Two of the largest and most impressive data sets ever created were for this purpose:

USS Arizona - 2014

Glen Canyon Dam - 2017

What tools do I need for reality capture?

Reality capture is a three-tiered process consisting of capturing, computing, creating.

Capturing

Capturing requires the use of hardware such as laser scanners or cameras, typically mounted to terrestrial or aerial devices. In the past, where such equipment was inaccessible to most,

advances in technology have simplified the learning curve and lowered costs, reducing the barriers that rendered 3d scanning inaccessible to most. In addition, hardware is available for purchase or lease, allowing customers to sample the benefits of integrating reality capture into their process without a significant commitment.

Computing

Captured data must be processed to make it useful in a project workflow. The scanned data is imported into specialized scan software that automatically builds and stitches the information into a coordinate system as a mesh or point cloud.

Autodesk Recap (Reality Capture) is a software that allows you to import point cloud data to other Autodesk software to allow you to work off of accurate as-built conditions.

Recap Photo is an Autodesk 360 service that processes 3d images into 3d models It has formerly been called Memento, Remake, Recap, and currently Recap Photo. It is subscription-based service that utilizes cloud computing to process large, complex files. Like other cloud services, ReCap Photo requires cloud credits per use. Processes using 20-300 pictures costs 12 tokens.

Creating

Once you have computed the scanned data, point clouds or meshes can be imported into other software to be used as accurate, existing geometry.

Getting Started

Project Goals

The first step to getting stated with reality capture is to identify your project's goals. As discussed above, reality capture can be an asset at any phase of a project, but depending on project needs, different approaches and technologies can be explored. In my experience, simple photogrammetry has been our primary need and is what I will discuss in the following. This application can be done with a relatively low time and equipment commitment. More extensive LiDAR and sonar scans require less casual training and a greater financial investment.

Workflow for Successful Photographs for Photogrammetry

Garbage in, garbage out. Quality photographs are the cornerstone of a successful photogrammetry project. Ultimately you want to create high resolution, sharp images with proper overlap of your subject. A bad image is worse than no image; poor images can taint an entire scan. Using the equipment and techniques below will give you a good chance at achieving positive results.

Equipment

Cameras

The first and most obvious item you need is a camera. Fortunately, almost everybody carries camera in their pocket every day. Apple, Samsung and the other major manufacturers integrate adequate camera in their cell phones and are improving with every generation released.

Compact digital cameras are the next step up from cell phone cameras. As a dedicated camera, they tend to offer more settings and therefore more control as well as higher resolution. This is probably the least expensive option for a dedicated camera solution.

DSLR (Digital Single Lens Reflex) cameras are one of the best options when choosing a camera for photogrammetry. They are historical a tried and true tool to achieve high quality images. One of the main benefits is the ability to attach different lenses to fit your needs. This offers a versatility and ability to grow into more mature lenses that compact digital cameras typical don't allow. Prices vary depending on the level of camera. Entry level cameras can start around $400 and advanced professional cameras can top out around $7,000. Without diving into the minutia of detailed technical data, I find that every couple hundred dollars of price increase, you get a few more capabilities, increasingly better performance, and the possibility of better results. Everyone has to decide for themselves based on needs and budget. Personally, I found the best value camera for me lies on the lower end of that spectrum around $1000.

Lenses

Lens selection is arguably more important than DSLR selection. The performance and character vary much more between lenses than most DSLRs. For photogrammetry it is best to use a prime (does not zoom) lens. These lenses have less distortion and the trade for not being able to zoom is more sharpness. If you do use a zoom lens, pick you focal length and tape the lens so that it can't zoom. Depending if you are using a crop sensor or a full frame camera, you will choose a different focal length for you camera. The lower your focal length the more "fish-eye" images look; the higher the focal length the "flatter" images look. The best idea is to pick a lens that most closely replicates the human eye. This magic number varies depending on who you ask but I found that targeting 40mm to 50mm gives adequate results. For most crop sensor cameras (1.5 factor), this targets a 28mm, 30mm or 35mm lens. For full frame, you would be looking at a 45mm or 50mm.
More reading ion the eye as a camera

Lighting

Photography is basically the recoding of light, which makes scene lighting extremely important. Lighting determines not only the brightness of a scene but subsequently the texture, color and legibility of your subject.

For photogrammetry, you want your lighting to be as diffused, even and consistent as possible. The scanning software stitches the images together like puzzle pieces. Inconsistent images, due to changing shadows or lighting levels effectively changes the shape of each puzzle piece such that they don't fit together. I find the best way to achieve this is using natural sunlight on a cloudy day. However, you may be limited by schedule and not have the luxury of waiting for ideal conditions. If your subject is small, you can set up an artificially lit scene indoors. Using soft boxes, umbrellas or LED panels you can achieve acceptable lighting. Never use a flash because each image will have a different light source and will not piece together. Reflector and diffusers can help direct natural and artificial light.

General accessories

SD Card

There are tons of accessories, some useful, others not so much. One item that is frequently overlooked is a quality SD card for your camera. Low quality SD cards right slower, which effects the speed at which you can take photos. Even more importantly, inferior cards have a higher chance of corruption and losing all your pictures. Invest in a high capacity(64GB), high speed (Class 10) SD cards and protect your data.

CPL Filter

Glossy objects have surface reflections and highlights that change as the camera moves around the subject. These aberrations make it difficult for the software to stitch the model together. CPL filters help reduce glare and reflection.

Tripod/Monopod

One of the best ways to steady your camera and eliminate camera shake, which causes blurry photos, is to use a tripod or monopod. Camera shake becomes more of an issue when you subject is under illuminated. With adequate lighting, this may not be necessary, but may also be convenient to rest your camera on.

Unmanned Aerial Vehicles(UAV) aka Drones

Most large scans could use an UAV to help capture difficult perspectives. While an extremely valuable tool, they come with a lot of responsibility. In the US you must register any drone over .55lbs/250g. In addition, if flying for commercial purposes, you must pass a Remote pilot test and adhere to any other local laws and ordinances which are changing frequently at a state and municipality level.

Many UAVs have small built in cameras. Larger UAVs are capable of carrying DSLR cameras and larger. Entry level drones that are capable of scanning start below $1000 and go up from there. There are a number of apps they can help scanning large sites:

Hivemapper
DroneDeploy
Pix4d

Prepare for photography

Once you know what you will be scanning you need to make a plan of how you are going to complete your scan and come up with any alternatives if things don't quite work the way you think. Below is a list of things to consider when planning your scan.

Location

The environment where you take photos will also be a part of the scan. If possible, choose locations where the subject will stand out and have high contrast with the background. The environment needs to be as static as possible. When taking photos on sit, beware of passing cars, people walking by and other dynamic objects that can mess with the continuity of the data in the photos. For small objects, a textured or patterned base can give distinct points for the software to aligning and stich the photos.

Lighting
If possible, plan to use diffused, natural light. Large, immovable objects such as buildings give you fewer options. Smaller objects can be scanned in a studio setting. Try to minimize shadows and glare.

Surface Properties
You will have challenges scanning anything that is reflective or transparent. As you move around the object reflection change making it difficult for the software to stitch the picture together. If possible, you can use specialty sprays to give objects a dull, flat surface. Note this will permanently alter your object. For less severe cases, matte spray or a CPL filter can help knock some of the shine off objects.

Similarly, blank, monolithic surfaces can also give the software issues given that it basically uses texture to stitch photos together. Give these surfaces definable character using pencils, makers, stickers or the alike. Beware that some alteration is permanent and that these identifying makes will be baked into the scanned texture for your subject.

Scale
The scale of your object will drastically affect how you take pictures. Small, light objects can easily be moved or moved around for easy access for scanning. Some objects may be to the scale that you need a latter, lift or drone to attain line of sight to all the necessary faces of the object. Large subjects, such as building, will require a different technique all together as discussed below.

Whatever the scale of you subject, be sure to place elements of determinable scale in the scan such as a measuring sticks or scales. Also, take numerous dimensions of the scene objects. This will help you in scaling the digital scan after it is stitched together.

Position
You want to make sure that all the sides of your subject are visible and that you have camera access to them. Elevating, lowering or rotating your subject can increase photo quality and quantity. Beware of significant overhangs and recessed nooks on your subject. These areas tend to be underlit and can create gaps in information in your photos.

Technique

The goal is to get every point on the subject in at least 3 images, each from a different angle. Images taken from the same spot or close to it do not benefit the data set. It is tempting to fire of a bunch of pictures in rapid succession, but that just adds unnecessary processing time. It is important to deliberately move between each photo, allowing them to have about a 2/3 overlap. Note the more complex a subject's shape, the more photos you will need to take.

Walk-Around Technique
Position your objects so that you can move all the way around it. The subject should be at height that you shoot from below and above. Depending on the size of your subject, you may

need a step stool or ladder to get to the necessary vantages. Once you have everything positioned, check your settings, focus your shot and take it. Move radially in 12-15-degree angles for each following shot. Take time to position yourself, steady the camera and focus on the subject between every shot. Depending on the subject, you may need to make this ring at multiple angles below and above the subject. Make sure to get all the "hiding" areas but don't overshoot. More is only more if the pictures are good quality and not repetitive. Bad picture will lower scan quality.

Turntable Technique

With the turntable technique, the camera stays stagnant and the subject rotates on something like a lazy Susan. For best results, the camera should be set up on a tripod, lighting should be set up for one angle, and an evenly lit backdrop should be placed several feet behind the subject. Spin the subject, pausing every 10-15 degrees to take a photo.

Large Objects

Some objects are too large to scan by moving around them. Instead of circling them, move along their surface shooting in a grid pattern, still assuring proper overlap.

Camera Settings

It is best to use the manual setting on your camera. Auto settings will expose each image differently, which will cause issues with the stitching in the software. Understanding the exposure triangle will allow you to toggle setting manually and properly exposed you images. Ideally, you want the shutter speed fast enough to eliminate any blurriness from camera shake(1/200ish). A medium focal length(F8ish) usually provides the sharpest images and eliminates most depth of field. Preferably, the ISO should be kept as low as possible (100), But you shouldn't see issues(graininess) until it gets much higher. A histogram is a graphical representation of the exposure of the pixels in your image that many cameras can display. Learning to read a histogram can help you avoid images that are too dark or to bright. You should shoot in RAW if possible, to give you the most versatility should you choose to post process your images.

Preparing Photograph for Recap

Though not necessary, I have found good results when I process the captured images, lower the overall contrast, whites and highlights, and increasing the shadows and blacks. Contrary to typical photography, the goal is to make the images as even as possible with no hierarchy or focus. It is important to edit all the images such that they still match each other. Using Adobe Lightroom, you can edit one image and batch process the rest of them to match. Be carefully because it is easy to over edit.

Converting Captured Photos to 3d Scan Geometry with ReCap Photo

Interface Overview

The Recap photo has a simple and easy to use interface. When you start the software, you are brought to the dashboard. This is where you manage your various projects as well as start new ones.

Uploading Photos

To upload the picture you have taken, under “Create 3D” you must choose to start a new Aerial or Object project. Once you choose, you will be asked to browse to your photo’s directory and upload. For both categories, there is a minimum of 20 photos to create a project. You will be asked to give your project a name and view how many tokens the processing will require. It costs 12 credits for projects between 20 and 300 images. Once you hit start, your images will begin to upload to the cloud to be processed and a status thumbnail can be viewed at the bottom of the dashboard under My Cloud Drive. The length of this upload depends on your internet speed. All your projects in the cloud can be accessed in this area of the dashboard.

Processing and Downloading Models

Once your photos have uploaded, they will begin processing. The length processing time varies from project to project, but generally the more photos and the more complex the subject, the longer it will take. I haven’t experienced wait time between half an hour and 2 hours.

Opening Models

Once your model finished processing, it will notify you it is ready for download. When you are ready, download you model to a reasonable place on your computer or network. This is the model you will edit. As long as you keep the processed photo project in the cloud, you can download the original model. Once the model is saved in the specified directory, you can open it in the editor and get to work

Editing 3d Scanned Geometry

Model Settings

Before you start editing the mesh geometry, it is wise to set up the proper units and scale the model settings. Scans are stitched together with no real concept of scale. Using the objects in the scene of known length as reference, you can scale the entire scene.

Common Operations

Hopefully your mesh won’t need much editing or fixing, but whatever your needs are, there are tools to help you. At a minimum, you will probably want to separate your model from the base from which it sat. Select/delete selection are also good for this. Using surface tools, you can add, remove, or change the detail of the mesh. Simple holes in the mesh can be closed by using the fill holes tool.

List of Edit Operands

Slice and Fill/No Fill	Smooth	Smooth boundary
Surface tools	Delete selection	Bridge gap
Sculpt	Fill holes	Extrude

Re-topologize

These commands are meant to redefine the mesh face characteristics more than the models form. You can retriangulate, refine or decimate the mesh. Your mesh will come in with an extremely high triangle count which is taxing for software to compute. Decimating the mesh to an optimized level is advised, however I prefer to do it in 3d Max.

Analyze

Analyze tools can be used to detect and fix model issues. This is important for model health as well as a necessity for fabrication. Once you hit "Detect issues", Recap photo will find all particles and holes and offer a solution to fix them.

Export

Export can be used to export images or video of the model as well as the model itself. Images and video can be in multiple display modes and at various resolutions (Up to 8k images, 4k videos) Videos can export simple turntable keyframes or you can customize your own camera path.

The model has a quick export as well as an advanced export rollout. The quick rollout optimizes the model for use in designated software. The advanced rollout allows you to specify several fields individually.

Preparing Scanned Geometry for Visualization

3ds Max

Once edited to your satisfaction in Recap, you can bring models into the modeling software of your choice for rendering. I prefer to bring models into 3ds max. Once in 3ds Max, first check to make sure the scale of the model is correct, and you are using the proper units. Then use the ProOptimizer modifier to interactively optimize the mesh by reducing the vertices and number of faces. Doing this lowers the scene's memory requirements, increases the viewport's display speed and reduces render times. Most meshes can be dramatically reduced without any perceivable quality differences in renderings. It is important to make sure you check the keep material box in order to maintain your mapped textures

After utilizing the pro-optimizer modifier, I create a material for the mesh using the maps exported from Recap photo. By default, the mesh will have a standard material applied. You can choose to keep this material or created a material specific to the render engine you plan on using. Recap Photo is capable of exporting diffused, normal and displacement maps which can be used in the 3ds Max material editor.

Once your model is optimized and has proper materials applied to it, it is ready to be saved to your asset library and used into a scene.

Preparing Scanned Geometry for Fabrication

Meshmixer

Not to be confused with Meshroom, Meshmixer is a free mesh editing software with numerous tools for creating and prepping files for fabrication. I find it has similar editing tools as Recap Photo, but with more control and complexity that allows you to further refine your model.

Interface Overview

Once you import your model, you can perform basic transformations to make sure your model is scaled properly. However, where Meshmixer really excels is in its ability to analyze for optimization. The inspector allows you to auto repair common mesh issues. However, Meshmixer can also run a series of commands to make sure your mesh can successfully print and be able to be handled. See the links below for the different types of analysis you can run

Thickness
Strength
Stability
Orientation
Overhangs
Export
File Types

When model have substantial overhangs or bridges, temporary supports must be printed to hold up the model. Most slicers generate lattice supports, but with Meshmixer, you can generate custom tee supports. Besides looking cool. Tree supports are easier to remove and less likely to damage the underside of you model. Also, tree supports are more customizable and can be optimized to use less material and provide shorter print times. Meshmixer is a great and free tool to prep 3d model for print. There are tons of videos and guides available online to help you along the way.

Lessons Learned

The automated cloud computing of Recap photo allows users to upload picture sets, let the software do the hard-computing work, and then download the model. While this is great when your model pops out the way you expect, when it comes out half baked, diagnosing the problem can be difficult and frustrating. Recap Photo is a magic black box that you can't really change. The best you can do is understand what input requires and delivery it just that, accurate data in the form of quality pictures.

Though a powerful tool, the software can't do it all, and what it can do might not always be perfect. By managing expectations and understanding the technology's limitations, you can create workflows to get your desired results. For instance, photogrammetry is not reliable when used to scan subject with certain surface characteristics, but with this understanding you can implement various methods to overcome these hurdles.

There is a standard deviation in accuracy that you will have to be comfortable with. Similar to construction tolerances, there are scan tolerances. By taking multiple measurements of the scanned object you can realign some of that deviation by sculpting the scanned mesh.

Time seems to always be a luxury we don't have, but if you can dedicate some to ensure proper techniques you can significantly increase your chances of success. In addition, proper planning ahead of the scan will expedite your workflow come scan time.

Cloud credits are not free. You should develop a credit budget for your projects and make sure all team members are aware. Excessive processing of photo sets ends up costing more money and more time. Focusing on getting quality pictures can eliminate multiple iterations of scan processing.

Conclusion

Photogrammetry is opening up new possibilities and enriching the old ones. You can now model just about anything by taking a series of pictures. These are models are digital assets that can be used for countless applications, from as-built models, terrain mapping, character creation, to customized consumer products and immersive virtual environments; With the ever-growing photogrammetry community, new methods and ideas are developing every day. There has never been a more exciting time to be a creator; what will you make?