# RealityCapture Workflow

## Background

RealityCapture (later called RC) is a photogrammetry software that creates 3D models from photographs or laser scans. It creates a 3D point cloud by aligning the images together. It can be used for extracting spatial data from point clouds or it can also be used for reconstructing detailed, textured models for visualization. The models created in RC are then exported for post-processing analysis in other 3D software like CloudCompare.

RC was a licensed software however, now for students and users having an income less then $1M USD revenue in the past 12 months, it is free to use with all features.

## Objectives/Learning Outcomes

1. Understand the principles of RC.
2. Learn what kind of images can be imported in RC.
3. Learn how to align the images together.
4. Learn how to scale and orient the model to real world dimensions.
5. Learn how to manually add ground control points (GCPs).
6. Learn how to reconstruct the model to create dense 3D point cloud.
7. Learn different filtering tools in RC.
8. Learn how to texture, simplify and reproject the model.
9. Learn about different export file formats.

For the purposes of this exercise, you are required only to create a sparse 3D point cloud by the aligning the images together that were shot in the Aalto tunnel and then reconstruct the model to make a dense 3D point cloud. You don't need to export the final output because a separate dataset will be provided for post-processing in CloudCompare. The goal of this exercise is to understand how photogrammetric processing in RealityCapture works.

## Dataset

RC imports different types of photos such as JPEG images. For this exercise, we will use an image set captured beforehand in the Aalto research tunnel. Please download the image set from Aalto OpenLearning:

- 'T8_S30-40_images.zip' containing 24 images of tunnel 8 section 30-40

**Instructions**

First download and install RealityCapture software:

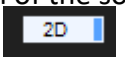
1. Download the latest release of RealityCapture from RealityCapture - 3D Models from Photos and/or Laser Scans (capturingreality.com) In the website, click on download now on the upper right corner of the screen. After download is complete, install the software.
2. Create an Epic games account using your email.
3. The installation steps are also given in the website link.
4. Previously the software could only be used in PPI mode if not purchased which imposed limitations on exporting the models. However, it is free to use now with all features available. More information is on the website.

**Note:** You can only complete all the steps if your computer has an NVIDIA GPU with CUDA cores. If it doesn't, feel free to download the entire RC project file from Aalto OpenLearning ('T8_S30-40_RC_project.zip'), extract it and open the RC project file to inspect the final models created from the tunnel image dataset. Please note that when opening the project file, the software will ask you to locate the image files from the image dataset you downloaded.

Below you can find a detailed description of the instructions for creating 3D models in RealityCapture. A video instruction can also be found in Aalto OpenLearning ('RC Video 1.mp4' and 'RC Video 2.mp4 from the 'Full video tutorial' link.

**Detailed steps in RC:**

Run software and import data

4. Run RC
5. Set the **layout to 1+1+1** in the top section of the software. Then set the middle layout to 2D and the right layout to 2Ds. 

6. First step is to **import images** in RC. Go to workflow tab and then click on the folder icon. Find the folder containing the 'T8 S30-40' images and import that folder. Wait for the images to load.

Detect markers

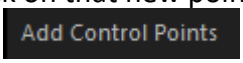
7. After the images have been loaded, use **detect markers** feature (alignment -> detect markers). A new options menu will open in the left 1Ds view. Select the correct marker type as circular, single ring, 20-bit and don't change other settings. Click on detect after that. The software should detect 38 markers automatically, while other markers will be manually added later.

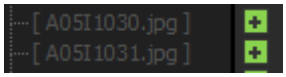
Align the images

8. Set the **image overlap** to **Low** (alignment -> Registration -> Settings).
9. **Align** the images (alignment -> align images). After alignment, a sparse point cloud will be made.

Edit the control points

10. **Control point editing**. If there is a red sign by the 'control points', it indicates a low quality of some markers on specific images. Then it's necessary to remove the images by clicking on that respective control point which has the error and expanding the list of images that contain this marker. Now, let's delete the images which have a lot of pixel error. Start with the images that have the highest error. As these images are deleted the error will slowly come down and become less than 2 pixels for every image. 

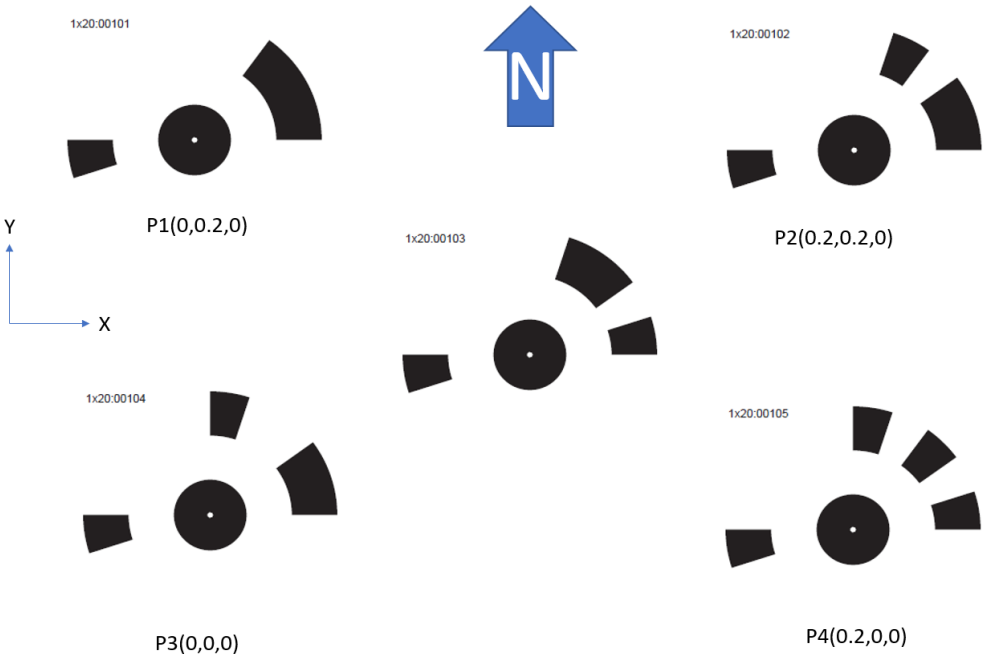
Remember to delete the control points which contain only one image as these ones are not shown in the point cloud.
11. To see the front of the rock face, right click the mouse, hold and rotate.
12. It's time to add the control points (CPs) on the markers which couldn't be detected by RC, or which had only one image (Alignment -> 1Ds view -> control points -> create). A new point will be created. Click on that new point in 1Ds view and then add control points from alignment tab. 

13. Now with the add control points tool enabled, hover over the sparse point cloud and find the marker which wasn't detected by the software. For convenience, set the view to 2D on the right layout and compare it with the 3Ds view. Now when hovering over the 3Ds view, you will see the crosshairs move in the 2D view. In this way, find the marker pattern and place the point there.
14. Once the point is placed, new suggestions will open in that respective control point. Add the control point to at least 3 images (if it allows) and remove the other images in that control point. 

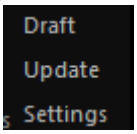
15. Click on add control points again to stop using it. Once the new images are added in the newly made control point, it's necessary to check whether the projection error is less than 2 pixels. You will see this yellow or red icon in front of the image. If not, then its still a good idea to manually check whether the control point is in the center of the black pattern. To do this click on the image in the control point that was created and go to 2D view in the right layout. Click on the point and hold it to enter crosshair mode. While in this mode, try to place the point as accurately as possible in the middle of the black marker. Once placed, keep the left mouse button pressed and press the down arrow key on the keyboard to move to next image in that control point. (Remember to only leave the left mouse key after all images' points are in the center of the black marker).
16. Do these above-mentioned steps to add all missing GCPs.

Orientate the model to true north and horizontally, and scale the model

17. It's time to align the model to true north. Find the alignment board in the 3Ds view and click on the points there. The settings menu will appear on the left. Change type from tie point to ground control. There are 4 markers on the alignment board. Set the coordinates on the patterns as shown in the following sketch such that the Y-axis is facing to the north arrow.




18. Remember to change from tie points to ground control on all the 4 markers on the alignment board.
19. Now for the distance scaling part -> manually create the distance between created points on the scale bars - > control points -> create distance -> constraints. In the constraints, give number to the distance and then give it the defined distance (distance between markers on the scale bars). After that update the model (-> alignment -> update)



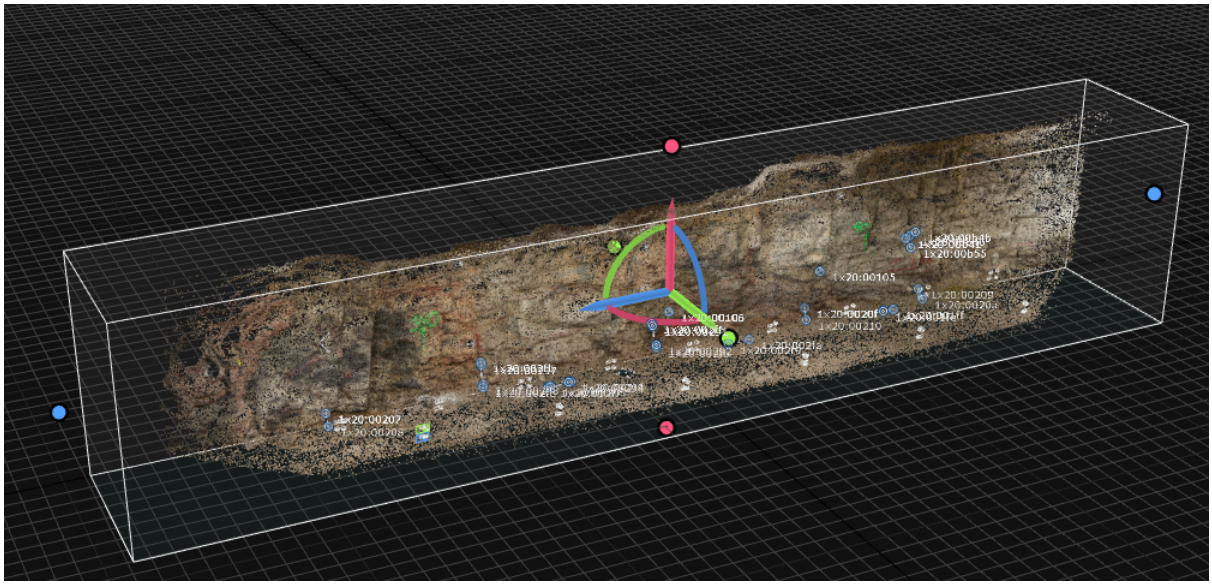

20. Do the same step for all the scale bars. (Note that those markers which were detected by the software, another way to scale them would be to create a text file and then include the coordinates there with the defined distance and then import the text file in RC (workflow -> distance definitions). Following line shows the way to create the command in a text file for distances: [name of distance] then space [A point] then space [B point] then space [defined distance]

    e.g. dist28 1x20:0020f 1x20:00210 0.25

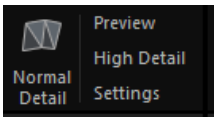
21. After distance definitions of all markers are done, it's time to disable half of the distances for error control purposes. Click on some distances in the constraints menu and disable them, change their name to control distance with a number as well.
22. Change the position accuracy (X, Y and Z) of all the 4 markers on the alignment board to 0.0001 -> this will lower the total deviation error after 2$^{nd}$ alignment.
23. Now align the images again. After the 2$^{nd}$ alignment, you will now see a scaled and aligned model. Enable the distances that were disabled before and note down their error in excel sheet. In the excel sheet, write down the number for control distance, the defined distance, calculated distance and then calculate the absolute and average control error from that.

24. Now there will be scaled and aligned model on the screen. It's time for reconstruction of the point cloud. First, go to tools tab in the scene 3D contextual menu and set the reconstruction region. Set the region as reasonable as possible so that it encloses the sparse point cloud and doesn't include irrelevant scenes. (**Remember not to use the ground plane tool now as it will change the orientation of the model, affecting the north alignment!)**

**Note:** If you are struggling with the alignment or control point definition, feel free to download the 'T8_S30-40_alignment.zip' file that contains the already aligned component (.rcalign) which you can import into RC. The folder also contains an importable list of control points (_CP.csv) and ground control points (_GCP.csv).



Meshing - **Note: This step can only be completed if your computer has an NVIDIA GPU with CUDA cores!!!**

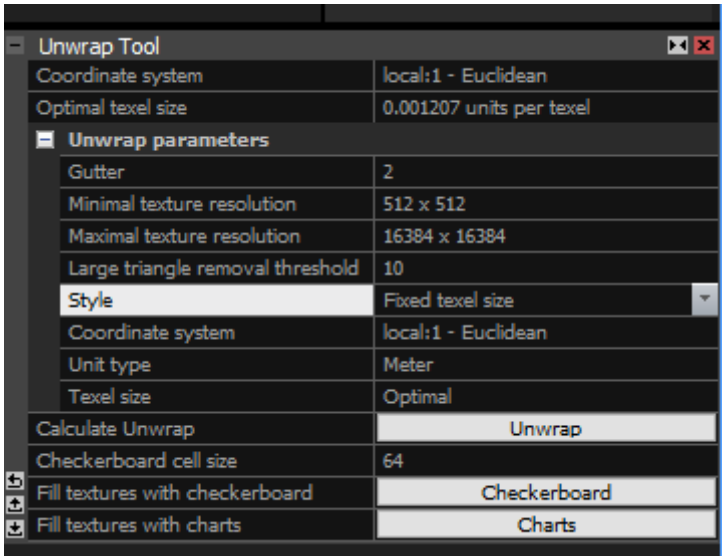



25. Now go to mesh model tab and click on the settings.
26. In the reconstruction settings, set image downscale to 1 for normal model.
27. Now click on normal detail and wait for the reconstruction to finish.
28. After reconstruction, you will see a dense 3D point cloud with solid box around the rock face. It's important to filter these unwanted triangles from the model. For this, use selection tools like lasso, box, or advanced. Initially, use advanced (Scene 3D -> tools -> select marginal triangles -> filter selection). This will remove the solid box around the model.
29. Similarly use lasso and box tool to refine the edges of the model by filtering out large unwanted triangles.
30. Optionally, use smoothing tool in the same tab to smoothen the outer edges of the final, filtered model.

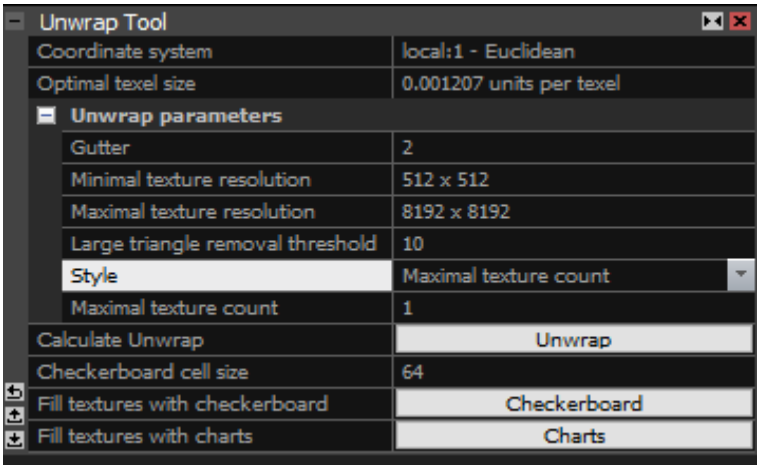
31. Remember to delete the previously added models as every time you use filtering, it creates a new model. Keep one model that is fully filtered and smoothened.
32. Check and clean for topology defects (mesh model -> check topology -> clean model). This will also create a new model. Delete previous models.
33. Check the integrity of the final model in the same tab.

Texture the model - **Note: This step can only be completed if your computer has an NVIDIA GPU with CUDA cores!!!**

34. Before texturing, it's important to unwrap the model (mesh model -> unwrap). Use the following unwrap parameters for the model:




35. Click unwrap in the calculate unwrap.
36. After unwrapping is done, finally texture the model (mesh model -> texture).
37. When texturing is done, it's often necessary to simplify the source model since it may have millions of trigons in the model. Click on simplify tool (Scene 3D -> tools -> simplify tool). Set the triangle count to a lower number like 1 million or 500,000. (Note: less triangle means less detail in the model).
38. The simplified model doesn't have any textures, so texture reprojection tool is needed for it. First click on the simplified model in the 1Ds view and then go to mesh model and click unwrap. Use the following unwrap parameters for the simplified model and then unwrap:




39. Use texture reprojection (Scene 3D -> tools -> texture reprojection). A new menu will appear in the 1Ds view. Select the source model as the one with the highest number of trigons and result model as one with the lowest number of trigons. Select supersampling to 64 samples per texel. Finally reproject.
40. After reprojection is done, you have high-res detail on the simplified model.

**Things to remember:**

- Remember not to interfere with the ground plane after the 2nd alignment is done.
- Sometimes it's possible that RC will create two sparse point clouds instead of one, uniform model. In such cases, import the images again and detect the markers **after 1st alignment.**
- Delete the older models after filtering and keep only the finalized, filtered and clean model as the source model.
- Remember to save the project as you go along.