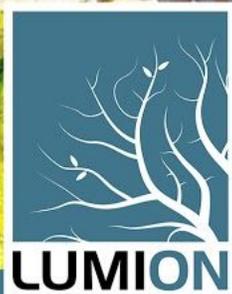


# Drone-to-3D Workflow for Architectural Visualizations



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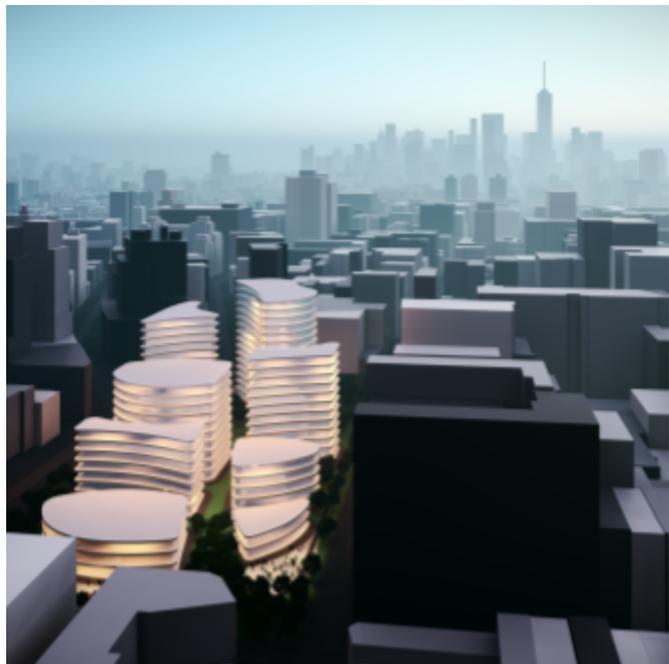
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## 1 | Background and Introduction

The field of architecture is somewhat reliant on the ability to see what a building will look like in its future surroundings. Architects and designers often need to know how a design will be incorporated into its real-life location, while clients and “non-architects” turn to photorealistic visuals (images, videos and more) for a deeper, more visceral understanding of the project and the architect’s intentions.

While working in Lumion, features such as OpenStreetMap (OSM) and satellite ground planes can provide some context for your design. They are suitable options for quickly building urban or rural environments relevant to your project’s location, but they’re also limited. For instance, OSM only provides rough building shapes, rendered white, and the satellite maps are flat, often outdated, and the resolution is too low for client visualization.

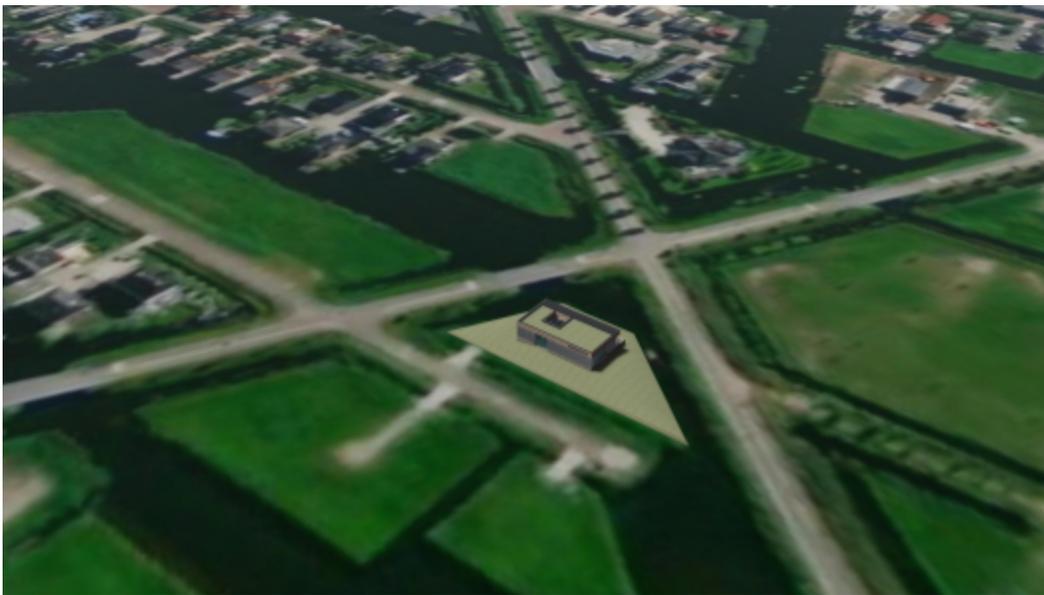
This all got me thinking — there has to be a better way to improve fast context-building without having to sacrifice photorealism. I investigated several options, starting with Google Maps and Google Earth SDKs, but these services do not allow their data to be used outside the scope



NYC skyline with OpenStreetMaps, rendered in Lumion 8.3

of Google Maps and Google Earth, such as for architectural visualization. Recently, Google introduced an [enhancement to their SDK](#), but after requests from our side, they clarified that this only concerned a new Unity-only SDK for mobile games. Since Lumion is not based on Unity and developed for Windows PC, this new SDK is not usable for context-building purposes.

Some third-party city modeling service providers use satellite data, leading to 3D models that are often outdated with low resolution for visualizations at medium range distance, 40-300m. They charge several thousand EUR per square km, probably too much for many architects.



Landscape made with a satellite image, rendered in Lumion 8.5

Another solution is to create the 3D model of the environment yourself using [photogrammetry](#), the (semi-) automatic creation of 3D models from a series of photographs taken from different directions. This technique is decennia old, though in the early days it required substantial handwork to match certain points on sequential photographs. In more recent years, thanks to the increased processing power of modern CPUs and GPUs, a new generation of software can now process large numbers of images on a standard PC in just a few minutes to hours, often without the need for any manual photo matching.

The technology is currently being used on construction sites to monitor the progress and accuracy of the finished work as detailed by the CAD design. It is also used in archaeological work and even to create assets for computer games. It is not yet widely used for architecture visualization, but on paper it looked promising.

In this e-book, I'll be taking you through the various tools and techniques when creating a simple drone-to-3D workflow that can be employed by architects (and not solely photogrammetry specialists).

Using a modern drone and the software [RealityCapture](#), it is now possible to capture an area of 300x300m and create a textured 3D model of sufficient quality for presenting a realistic background for your [Lumion](#) visualization.

Oh, and you can do all of this in one day.

Whereas traditional photo-matching and image compositing techniques provide a single rendered image, this drone-to-3D workflow makes it possible to create various images and video animations in different lighting conditions and featuring trees, people and other decoration objects.



The creation of this 3D environment model can be done in 4-8 hours of work by any architect, including the time it takes to capture the images with a drone. Adding the new design from CAD and making the high-quality renders adds another hour or so.

## 2 | Workflow Summary

### Step 1: Capture Images with a Drone.

Using a special app on your tablet for controlling a drone, e.g., [Drone Harmony](#), the first step is to capture images around the area of interest.

The Drone Harmony app lets you draw the area of interest on a map, and then it calculates the flight path of the drone, capturing images automatically with a 60% overlap from the previous shot. This overlap is needed for automatic 3D model construction.

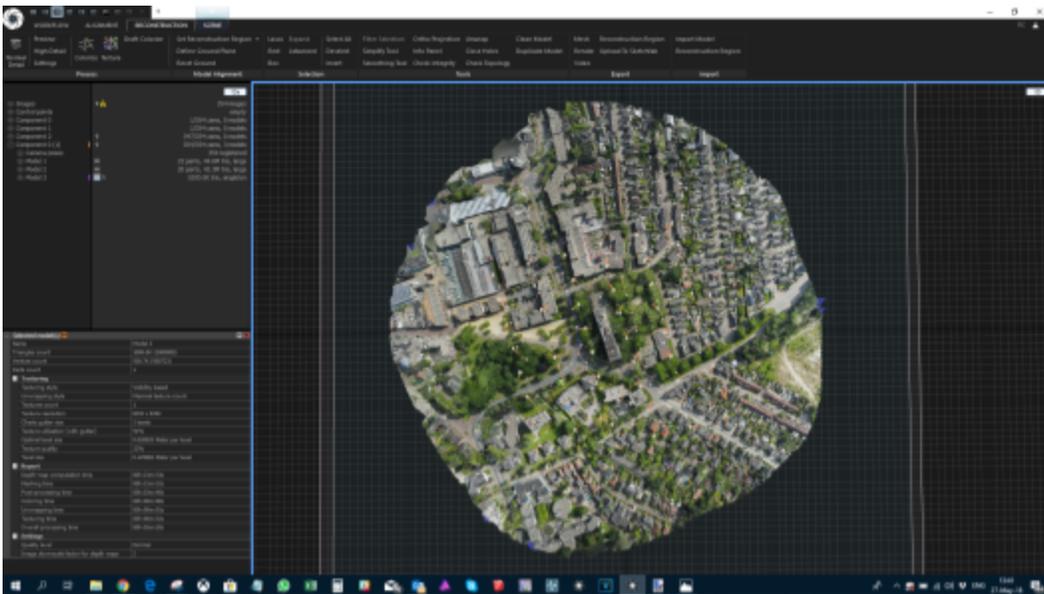


Example of a drone flight path.

Do **five runs** of the same flight path above the desired area, but make sure you assign a different camera angle for each flight. For instance, you can fly the first run with the camera pointed down and the other four runs with the camera tilted at 45 degrees. Each run takes 7 to 15 minutes, so the entire flying will take about 1 to 1.5 hours overall.

## Step 2: Enter the images into RealityCapture (RC).

[RealityCapture](#) automatically aligns all of the images and then it creates a 3D model, adds textures and inspects the model's quality. This literally takes a few minutes of manual work, and a few hours at most of background processing by the RealityCapture software.



RealityCapture software

## Step 3: Cut out the lesser detailed areas and unwanted objects.

If the quality of the model is OK, the next step is to cut out the lesser detailed areas and unwanted objects, and then simplify the 3D model to a smaller model. Depending on the model's size and complexity, this can be anything between 30K and 1M triangles.

Texture the model again and export it in an FBX format. Cutting and simplifying the model takes between 20 minutes and one hour.

## Step 4: Import the model into Lumion.

After importing the 3D drone model into [Lumion](#), you can dress it up with trees, cars, people, furniture, etc. You can also import your design from SketchUp or your CAD/BIM program (Revit, 3ds Max, AutoCAD, Rhino, etc) on a separate layer. Make renders and animations.



Lumion render that includes a house designed in SketchUp and a 3D environment made from drone imaging.

This typically takes anywhere between 15 minutes and several hours.

### **Step 5 (optional): Enlarge the visible area using OpenStreetMap.**

If needed, you can enlarge the visible area using OpenStreetMap or by creating a satellite image on a square plane in SketchUp.

In Lumion, for instance, you could add large, distant buildings using the OpenStreetMap (OSM) interface, or in SketchUp you could hand-model stretched cubes and dressing them with textures using one of the drone panorama images or hand-made, ground-level photographs.

Import these into Lumion as well. Technically, you could capture a much larger area with the drone, as it has a 7km reach with one battery, but you would need to fly higher than 120m, which is not allowed in many countries including The Netherlands.

## 3 | Detailed Workflow

### 3.1. Buy a Drone

Consumer drones with good quality cameras have been on the market for several years, with Chinese drone manufacturer [DJI](#) becoming the clear winner in terms of quality and market share. In more recent years, the size and weight of drones have come down considerably, from several kilograms to below 500 gr. The next picture shows a 2 kg, old-school drone (right) and the most recent DJI drone, the [Mavic Air](#) (left).



A 2 kg, old-school drone (right) and the most recent DJI drone, the Mavic Air (left).

The Mavic Air's range is several kilometers, the flight time is 20 minutes, and the camera shoots 4K video and 4056×3040 resolution for images. The controller is designed to be connected to a mobile phone or tablet running either the manufacturer's app (in my case, the [DJI Go 4 app](#)), or a

third-party app which includes a DJI interface. Since the DJI Mavic Air was launched fairly recently, on [23 January 2018](#), some drone apps still need to be upgraded to handle the Mavic Air.

In addition to the drone itself, you need to buy some additional batteries. Effectively capturing an area will require five runs, plus you may want to take some panorama images and maybe video flyby footage. You can expect one or two runs per battery, so at least two additional batteries are needed. They cost EUR 75 each and take 50 minutes to charge.

When taking images of the area of interest, you need to use a third-party Android app, like [Drone Harmony](#), and it's better to use a 10-inch tablet than a mobile phone. You need the screen space to set the area of interest, create the flight path and adjust other settings. Any Android tablet will do. I used a 10-inch Lenovo tablet (EUR 300).

To connect the tablet to the drone controller, you need an extra device. I used the [PolarPro tablet holder](#) (EUR 45).

Lastly, to easily pack and carry the drone equipment, I bought a [carry case](#) (EUR 59). The drone, its controller with the 10-inch tablet running Drone Harmony and the carry case are shown in the next image.



10-inch tablet and tablet holder next to the DJI Mavic Air.

## 3.2. Calibrate the Drone

When you first start up the drone and run the DJI Go app, it will likely perform a firmware update. The tablet or phone running the app must be connected to the internet for this to happen, preferably through Wifi. This can take some time, involving multiple restarts of the drone and the controller.

Most drones need to regularly undergo a compass calibration. The DJI Go app will warn you and has built-in instructions for this. You need to move it in a circle, first horizontally and then vertically. If it warns you to do another calibration, first switch the tablet and your mobile phone to flight mode, as GSM and Wifi signals can influence the compass. Make sure the drone is not close to a metal object like your car or bike.

Before using the drone for photogrammetry purposes, learn how to fly it manually using the DJI Go app. When the DJI Go app is ready to fly without warnings, you can switch to the Drone Harmony app.

## 3.3. Capture the Images

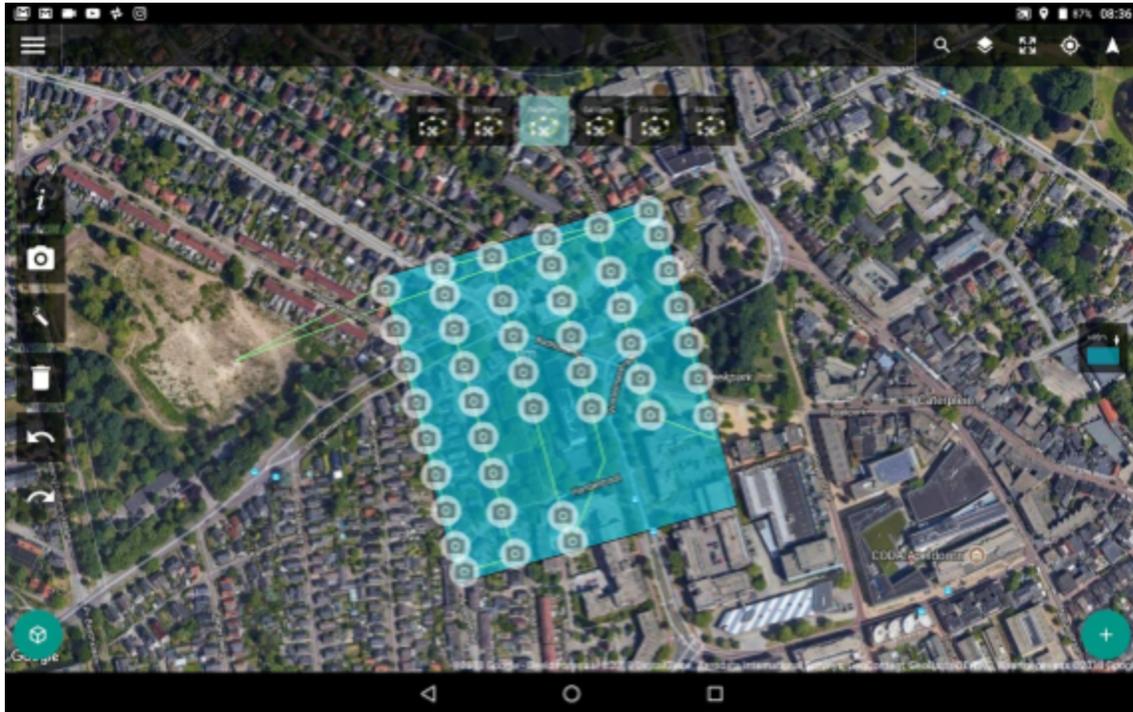
To create a 3D model automatically, modern photogrammetry software needs a set of images capturing the area of interest from different angles. The overlap between the images typically needs to be 60% or more.

On an ideal shooting day, the wind is calm and there is a cloud overcast. You don't want to have shadows casting on the captured images because, later on when rendering in Lumion, you may want to use another sun position and cast different shadows.

You also don't want to have much traffic or people, as these would make the image alignment process difficult. An early Sunday morning, for example, is ideal, especially with heavy cloud cover and little wind.

Flying the drone manually and capturing all of the required images for the 3D construction process is almost impossible. Luckily, there are a few apps on the market which automate this process. They can control the drone by uploading a flight plan, dictating the drone's flight path and taking images, even when radio contact to the ground station is completely lost. The next image shows a flight path created by the app I used, [Drone Harmony](#). It was still in beta when I

used it, but it had very few flaws. The more established app for this operation is [Pix4D](#), but it did not support the Mavic Air yet.



Example of an autonomous flight path in Drone Harmony.

For most architectural visualizations, it will be sufficient to capture an area of around 300x300m. By flying the drone at an altitude of 50m, you can expect a flight distance of around 7km and a flight time of 15 minutes.

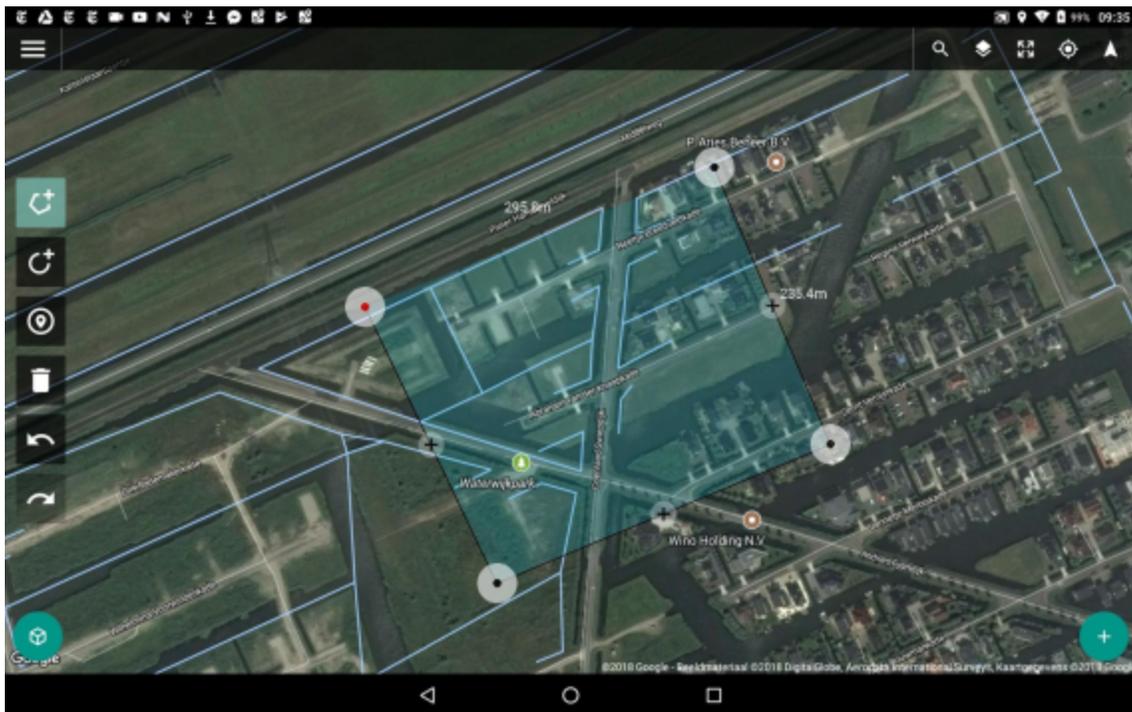
Technically, the drone can fly higher, but the resolution of the captured images will drop as a result, leading to lower quality 3D building models. If the area contains higher buildings, you obviously need to fly the drone higher than 50m. Keep a clear distance to the top of any building or tree by about 20m. In many countries, the maximum drone flight height is 120m, which would lead to a maximum area capture of 500x500m. You can combine the images of a smaller flying grid at a lower altitude with the images of the larger grid at a higher altitude in one 3D creation project. This may lead to the best overall result: a large area with more detail and quality in the area of interest.

The drone needs to capture the images in this grid five times:

1. Run One: the camera is facing down at a 90-degree pitch angle. The direction can either follow the path or be in one fixed direction, e.g. North (0 degrees).
2. Run Two: the camera is pitched at 45 degrees. The direction is North (set it at one degree instead of zero. This is because with zero degrees, the Drone Harmony lets it follow the direction of the flight path instead of turning it North).
3. Run Three: the camera is pitched at 45 degrees. The direction is East (90 degrees).
4. Run Four: the camera is pitched at 45 degrees. The direction is South (180 degrees).
5. Run Five: the camera is pitched at 45 degrees. The direction is West (270 degrees).

### 3.3.1. Drone Images from a Regular Flight Grid

The app I used to take images of the targeted area, [Drone Harmony](#), lets you prepare a flight plan at home and save it. Much like Google Maps, it lets you search for an area and show a satellite map and streets. After tapping the top icon on the left, which turned green, I started by drawing a square on the map by placing four dots with my finger:

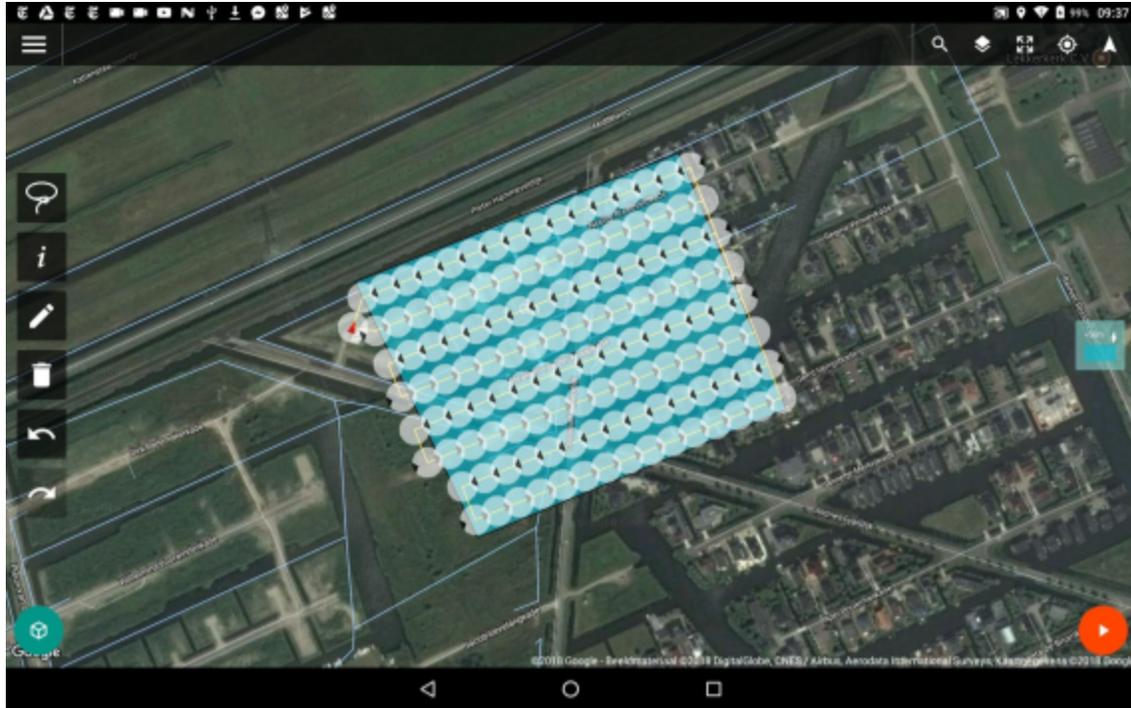


Setting the area of interest on Drone Harmony.

The + inside the little circle on the bottom-right corner brings up a series of screens where you can indicate the lift-off position, flight height, overlap area, camera direction (heading), and camera pitch. The app then generates the path and capture points to achieve effective image

overlapping. You can do all this at home and save the resulting file. A new icon appears with this flight plan on the right-hand side of the screen, as shown in the next image.

On the actual location, click on the desired flight plan (there can be more than one in a single file), and the little arrow in the bottom-right corner lets you connect to the drone.



Flight plan saved and uploaded into Drone Harmony.

In the above image, the app wasn't yet in contact with the drone. A USB cable needs to connect the tablet to the drone controller. The next step is to start the drone and the drone controller. A small window will pop up asking which of your installed apps should be used to control the drone. Select Drone Harmony, "just once" and not "always". The app then connects to the drone and Drone Harmony will show some extra status indication icons on the top of the screen.

Once connected to the drone controller, the app leads you through a series of screens where you:

1. Set the flight speed. I set this to the max at 8m/s.
2. Capture mode. Use: in full flight.
3. What needs to happen after finishing the flight plan. Choose: hover in place.
4. Launch the drone.

The last step loads the flight plan, starts the drone, and lets it carry out the flight plan automatically. All you need to do now is watch the drone follow the path and capture the images, either on the map or by viewing the camera.



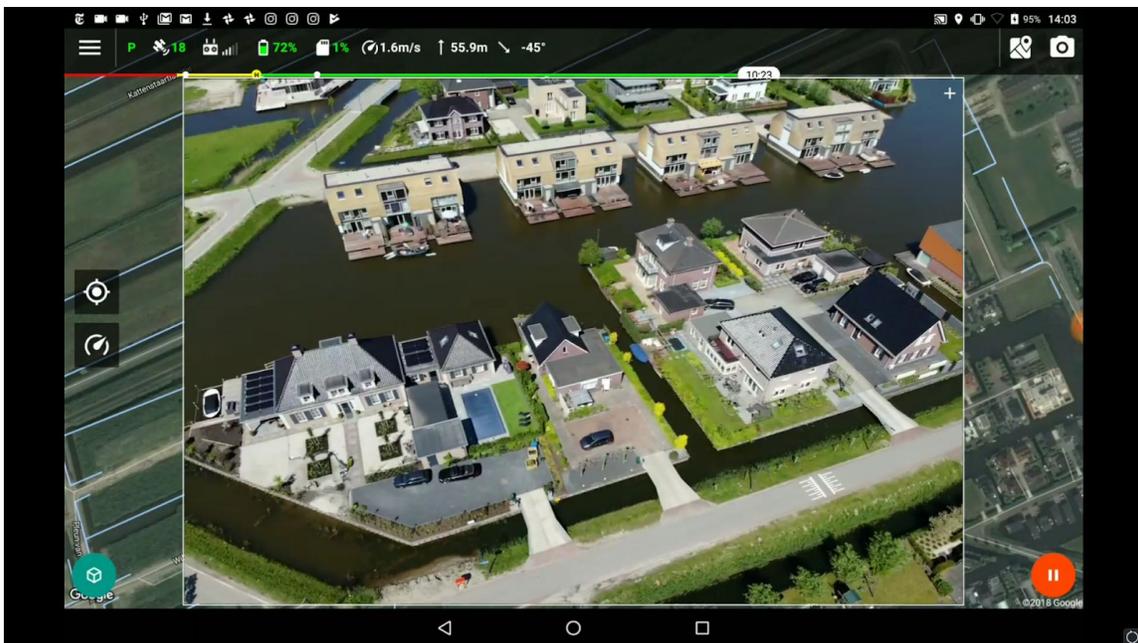
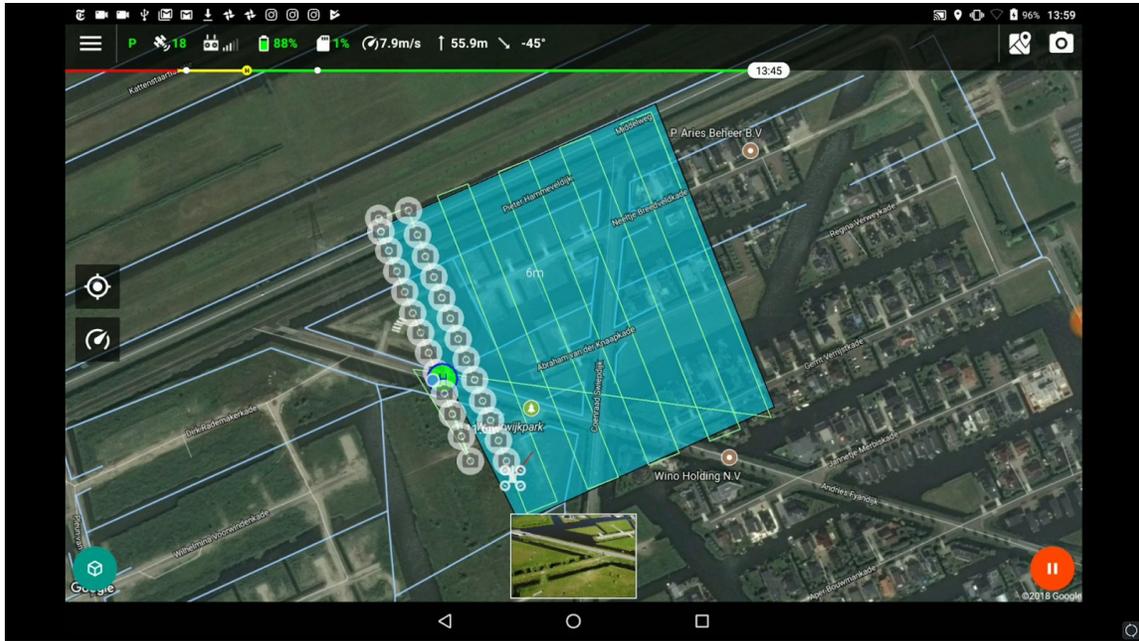
Drone launch screen in Drone Harmony. Note the “Success” indicators; the drone will only fly if all four are green.

Regarding the flight speed, you need to consider several factors. To get the best quality models, you need the best quality images, which means the best ISO value (100) and no smearing. You get smearing when the flight speed is so fast that one frame captures a distance higher than the distance covered by one pixel. Here’s a simple calculation regarding smearing:

1. If the drone flies with a speed of 8m/s and a shutter speed of 1/320 (a typical value), it covers a distance of 25mm during one frame. When the camera is pointing straight down, this distance matches 100% with the ground area distance, and your effective accuracy is 25mm. Not very accurate! You need to fly slower to achieve a higher accuracy, or set the shutter speed shorter, but that affects the ISO since the lens aperture is fixed for many drones. For example, the lens aperture of the Mavic Air is f/2.8. In general, don’t go for a higher ISO value than 400.
2. If you fly at a height of 25m with the camera pointed straight down, the Field of View is roughly 90 degrees and the resolution is 4000x3000. This means that one pixel covers roughly 9mm distance. That’s much more accurate than the effective accuracy of 25mm (from Point 1). Flying at a height of 50m gives you an effective accuracy of 18mm, closer

to the 25mm of Point 1. Ideally, however, the “smearing” accuracy would be much less than the pixel accuracy.

In conclusion, you probably need to use a shutter speed much shorter than 1/320, or a flying speed that’s much less than 8m/s, to achieve the max image quality.



The following link shows the process of creating a flight plan with Drone Harmony:

<https://youtu.be/PebocPvgbNI>

After finishing the flight plan, the drone will return to the position you set as the lift-off place. Now, depending on how much battery life the drone has left, you can upload another flight plan with the camera in a different 90-degree angle or let the drone land so you can change the battery.

In my case, I was usually able to execute two flight plans on one battery. I could have created all five flight plans beforehand and save them, but I created each flight plan on-the-go, starting from the area of interest and changing the camera angle each time. All it takes is a few “clicks” to make last-minute changes to the area of interest, fly height, etc.

If the drone does not start in the last step, the compass probably needs to be recalibrated. The current (beta) version of Drone Harmony does not interpret error messages coming back from the drone very well, so you need to start the DJI Go app for this. Since each app needs to be in control of the USB interface to the drone controller, the best way to switch between apps is to switch off the controller and then switch it on again. When switching it on, the tablet senses the activation of the USB interface and gives you a list of apps which can handle the device connected to it. It lets you choose an app and then asks if you want to use this app “just once”, or “always”. Choose “use once”, as you need to switch back to the Drone Harmony app later on. For calibrating the drone, see section 2.2.

### **3.3.2. Drone Panorama Images**

When you have completed the five flights, each time with a different camera angle, you should have all you need to construct a 3D model. But since the drone flies pretty high, usually between 45 and 80 meters, you might be missing some important details; making sure you capture these details could increase the quality of the model.

Depending on the available space, you could create images by hand at ground level or make panorama images by using the DJI GO app to manually fly the drone to lower points above or close to the area of interest. The drone can create a 360-degree panorama by taking a series of 24 images with different camera angles taken at the same spot. It processes these images internally to create one 360 image. This 360 image is not usable by the photogrammetry software, but the series of 24 images is very useful as they provide more detail to the buildings in view.

Here a screen video capture of the DJI Go app for making a panorama image:

<https://youtu.be/EI2ys9mUgo8>

At the 1:10 mark, the steps are shown to take a panorama image.

The panorama is also shown in the next image. With a special 360-degree viewer app, it is possible to move around in this image and zoom in and out. With a VR headset like the [Oculus Go](#), it is possible to experience the view from the drone at the position it took the panorama images (this has nothing to do with the drone-to-3D process).



360-degree panorama image taken from a drone.

When taking panoramas for the 3D model construction in the RealityCapture software, make sure to take multiple panoramas at different heights of the same spot. This enables automatic alignment with the images generated from the higher-altitude flight plans.

If some houses are not properly captured by the drone under the 45-degree pitch angle, you may need to take images at ground level, making sure each image overlaps at least 60% with the previous one.

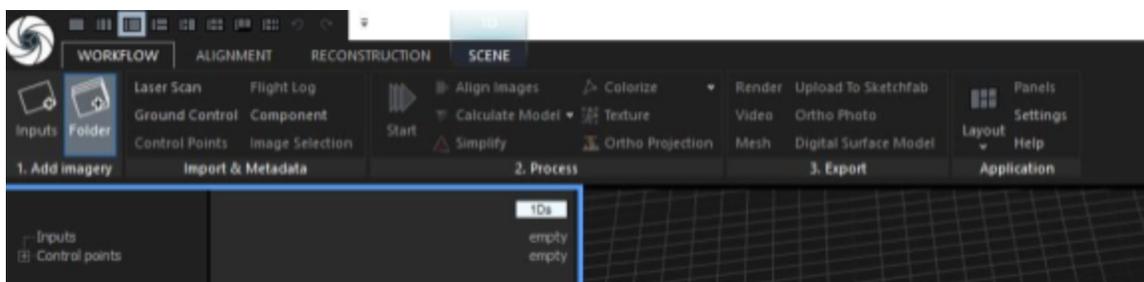
### 3.4. Process Images into a 3D Model

The 3D model can be created automatically from the drone images. I tested several software programs and online services for this: [AutoDesk ReCap Photo](#), [Bentley ContextCapture](#), [RealityCapture](#), [DroneDeploy](#), [Pix4D](#). The best software was RealityCapture from a Slovak company called CapturingReality. It was also the cheapest solution at EUR 99 for 3 months. But the process works roughly the same for other photogrammetry software tools.

#### 3.4.1. Align Images

RealityCapture has one button, “Start”, which can perform all the necessary steps after loading the image set. But as you may need to perform some fine tuning, I will describe the steps in more detail. [A video screen capture recording is also available](#).

The first step is to align the images. This is a CPU-intensive process that can take anywhere from 20 minutes to several hours, depending on the number of images and the software’s ability to easily find similar points between the images. It is a fully-automated process, so all you need to do is click “Align” and wait for the point cloud model to be generated. The next image shows the menu when starting RealityCapture.



The RealityCapture interface.

RealityCapture has a number of ribbons with several options and functions for the automatic 3D model creation process. First, you need to select the drone images (they’re usually all present in a single folder) by using the “Folder” button shown above. The images are then loaded and quickly analyzed.

The next step is to start the alignment process. There are two ways of doing this: Using the “Start” button in the “WORKFLOW” ribbon, or using the “Align Images” button in the “ALIGNMENT” ribbon. Both options are shown below.



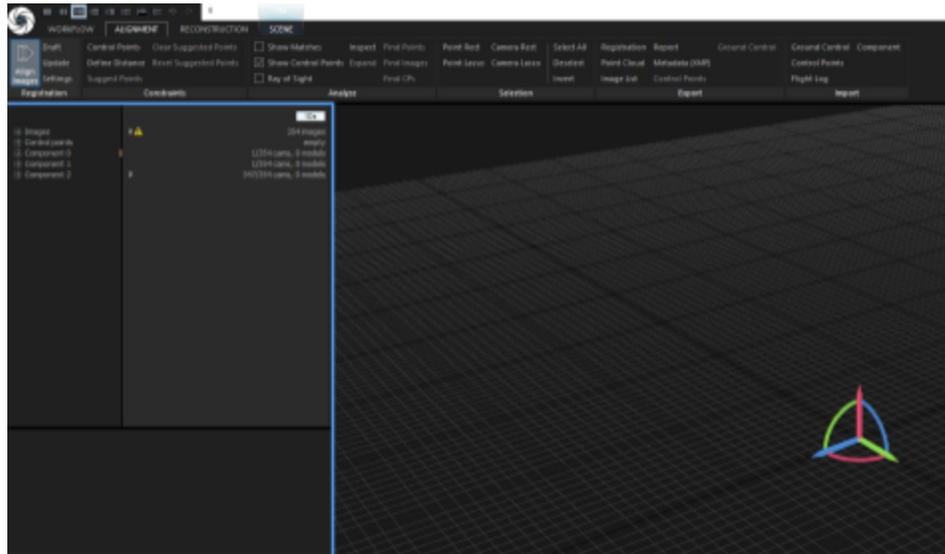
Option A: Use the “Start” button in the “Workflow” ribbon to start the image alignment process.



Option B: Use the “Align Images” button in the “Alignment” ribbon to start the image alignment process.

The difference between these two options is that the “Start” button, as the pop-up message states, will execute the next steps of the 3D model creation process. It starts a script with a number of subsequent actions. The “Align Images” button, on the other hand, only starts the alignment process. This can be beneficial because it lets you inspect and possibly optimize the result before proceeding to the next step. I usually choose this option.

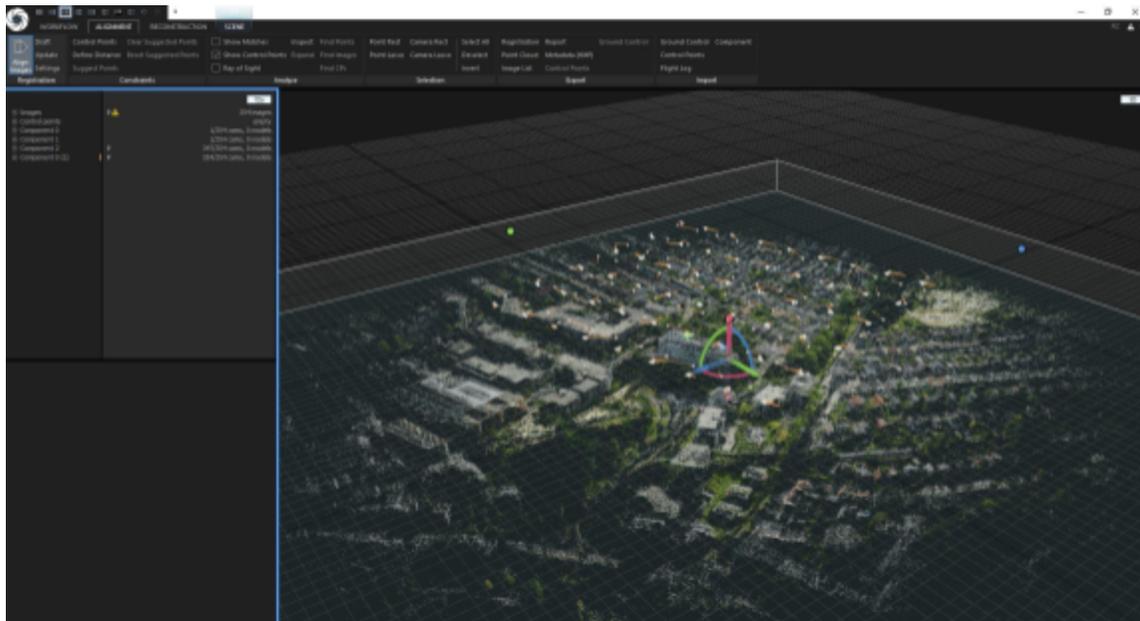
If you followed the earlier guidelines for automatically creating the images with a 60% overlap, Reality Capture will probably generate a single model. In the software, this is called a “Component”. The next image shows the result for the Apeldoorn project.



Three Components were created for the Apeldoorn project.

No model is visible yet, but RealityCapture did create three Components. The first two Components are based on one image, and the third is based on 347 of the 354 drone images. This means that RealityCapture couldn't match 7 of the total of 354 drone images.

To align all the images, you can try the alignment process again.



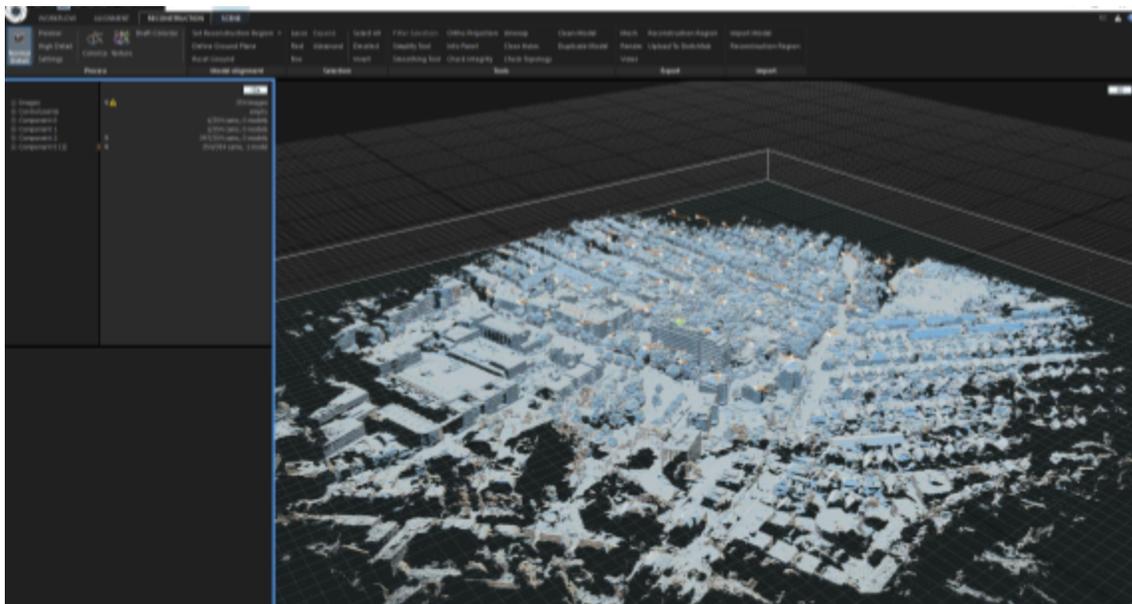
This time, RealityCapture managed to align all 354 images in a colored point cloud. Save the project.

If you also added a series of images taken by hand at ground level, it is possible that RealityCapture did not find similar points in all images and created multiple components. You can process these components into separate 3D models, but that's not the best way to go about it. We want to create just one model, automatically, from all images. If multiple components are created, you have one of the following options:

1. Forget about the component(s) made with only a few images. Just proceed with the largest component.
2. Add match points by hand between images from the separate components. This is a labor-intensive process and it doesn't always work properly in my experience.
3. Create more images to cover missing areas between the different components. If the area of interest is far away from your home or office, then this option can be time-consuming. Also, the light conditions may be different the second time, making it difficult for RealityCapture to match the new images with the old ones.

### 3.4.2. Create the 3D Model

The next step is to create the 3D model. Select "RECONSTRUCTION", which brings up functions related to 3D model creation and texturing, as well as the leftmost button, "Normal Detail". The next image shows the result after 20 minutes of processing.



3D model after 20 minutes of processing.

As you can see on the left, the Component consists of 22 parts and a total of 44.6M tris (triangles, or polygons). The reason why RealityCapture made so many separate parts has to do with the memory limitations of the PC, but this is not something to worry about.

Next, we will simplify the model to reduce its complexity (reduce the triangle count) to a point where the model only has one part. Even if you wanted to export the initial high-triangle model, the parts are all assembled into one file during the export process.

### 3.4.3. Simplify the 3D model

Technically, Lumion can handle 3D models with up to 60M triangles, but at these high triangle counts, the import process takes a long time, the performance drops considerably, and saving your Lumion projects takes a while as well.

But more importantly: simplifying the model actually leads to a higher visual quality!

The reason is that 3D models automatically created from images or laser scans usually have surfaces that look wobbly. This has to do with the limited accuracy of the alignment process, as well as the resolution and quality of the input images. For that reason, it's important to fly as low as possible over the targeted area during the capture process. Watch out for high buildings and trees, and you don't want to annoy the local residents. Flying a small drone like the Mavic Air at an altitude of 50m won't upset anyone and it should result in models that are accurate enough for architectural visualizations.

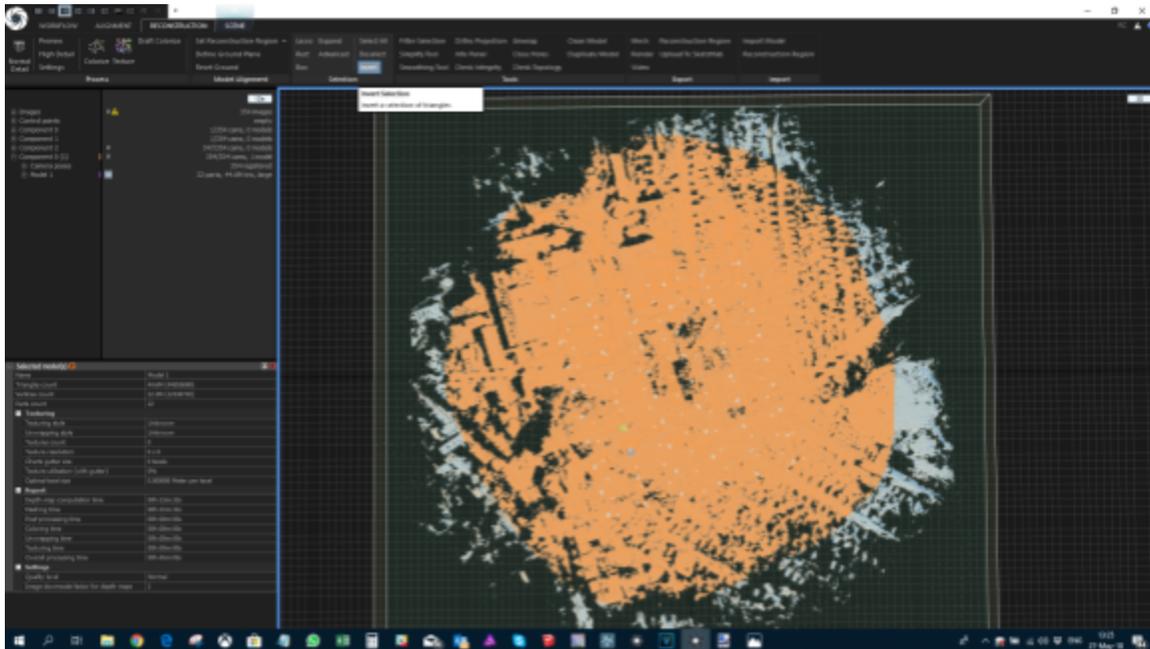
The wobbliness of the resulting 3D model can be reduced by simplifying the model. To what level (i.e. how many triangles are in the final model?) requires some experimentation. It could be anywhere between 30k and 1M triangles. For the Apeldoorn model, it turned out to be 1M.

The simplification process works as follows:

1. Cut out the outer areas, which are outside of the drone's flight grid and contributing to the messy 3D geometry.
2. Reduce the triangle count using the Simplify function.
3. Perform the following functions, all available from the "RECONSTRUCTION" ribbon: Close Holes, Check Integrity, Check Topology, Clean Model.

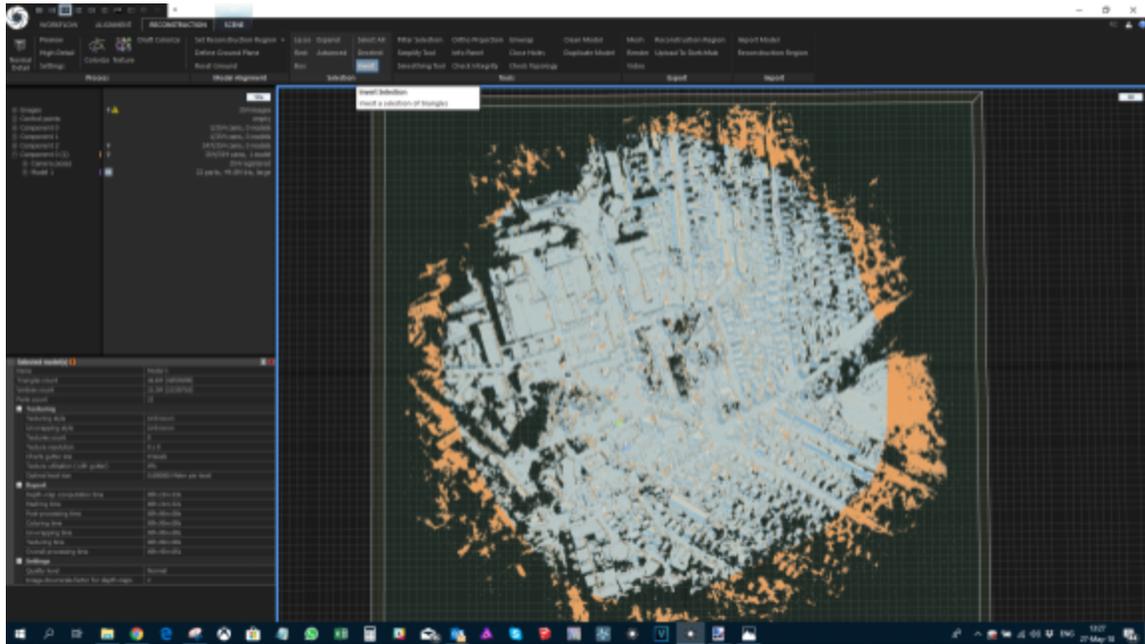
Some of these steps are shown in the next images.

First, select the area of interest with the Lasso tool. This tool lets you draw a line around the area of interest by click-dragging the mouse. Releasing the mouse selects the triangles inside the area you've drawn.



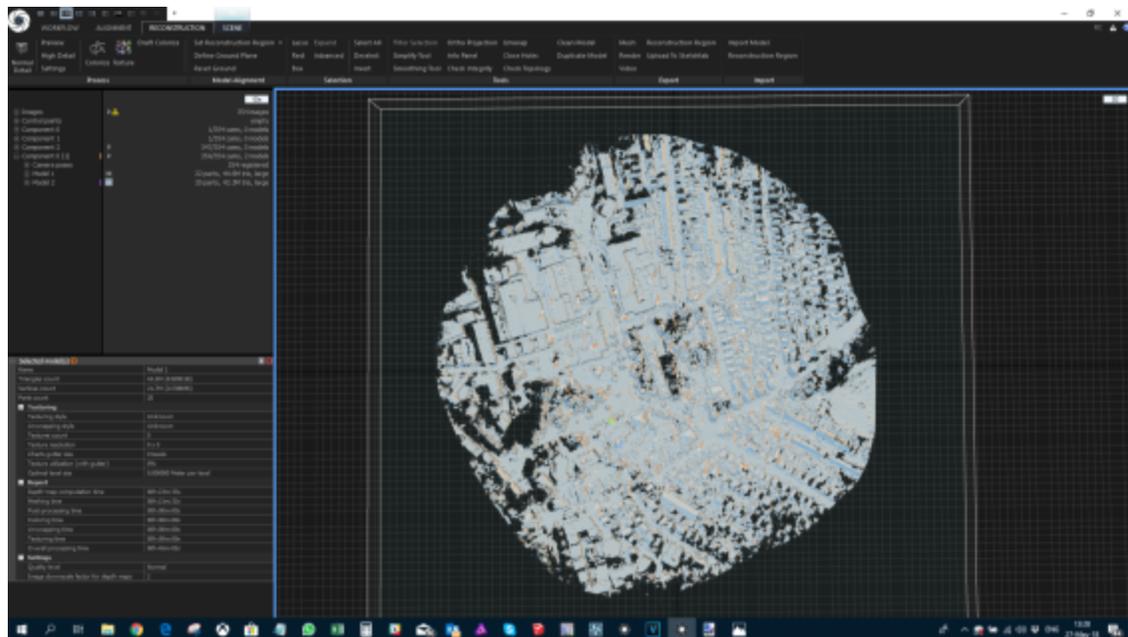
Simplify your 3D model by cutting out unnecessary areas.

Because the Filter operation creates a new 3D model with the selected triangles left out, you first need to invert the selection using the Invert button in the ribbon:



Use the Invert button to select the points outside of your area of interest.

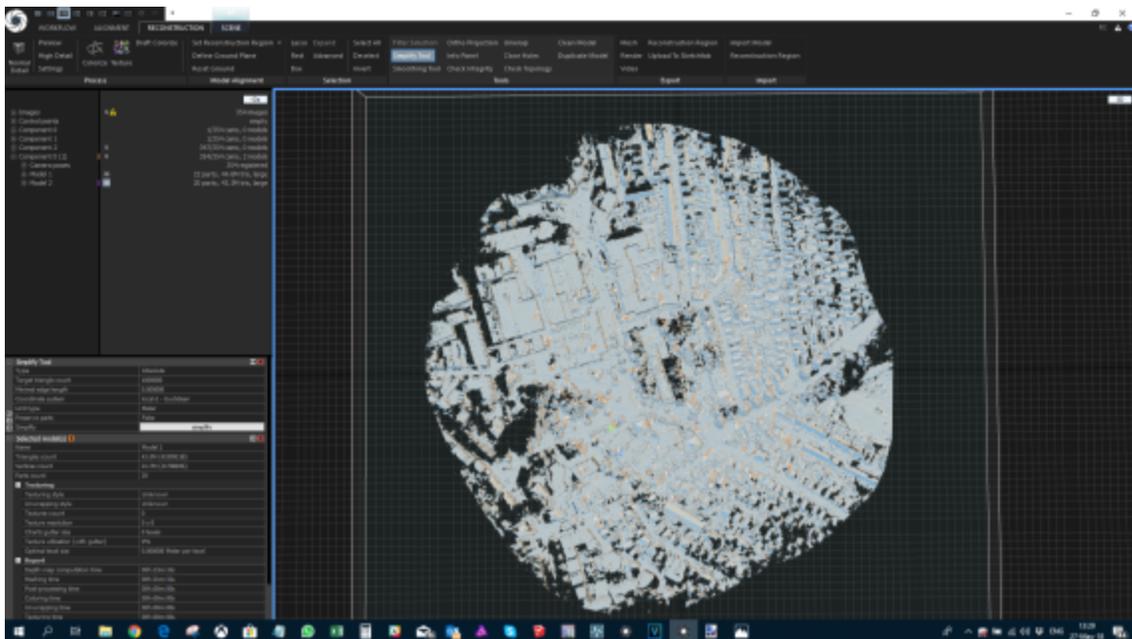
Then, perform the Filter Selection operation and you get this:



Trim the extra parts of your model with the Filter Selection operation.

With each operation that affects the triangle count, RealityCapture creates a new model, as shown in the left-hand sidebar. If a step produced unwanted results, you can always go back to an earlier version and continue from there. Each unused model can be deleted from the model sequence later.

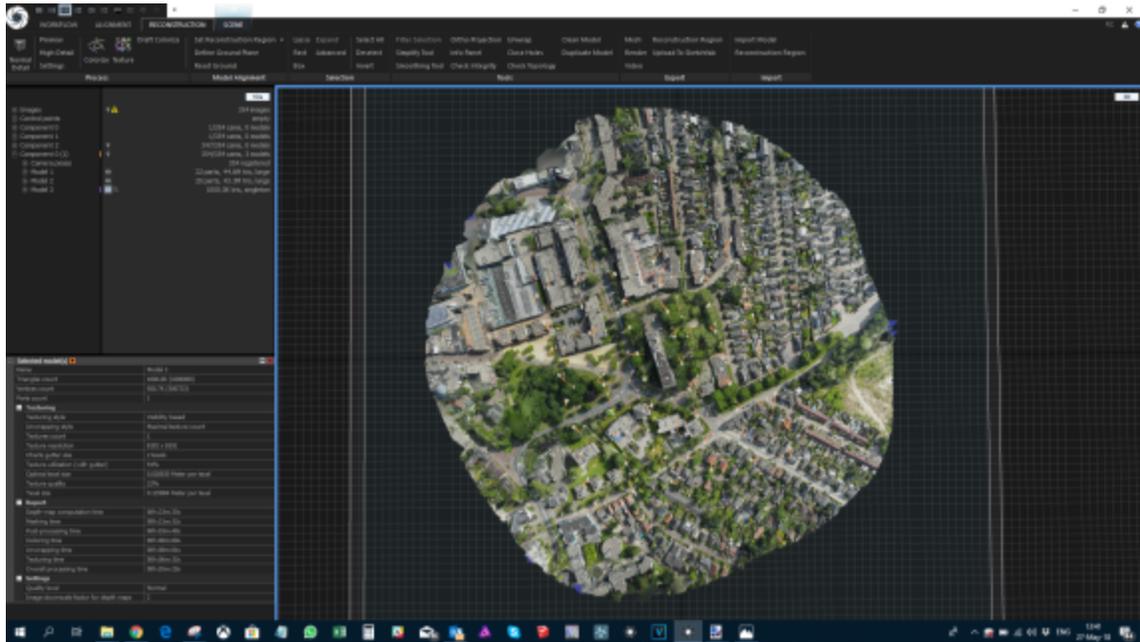
After the filtering process, the model was reduced to 43.3M triangles. This still needs to be reduced to 1M, which can be done using the Simplify function. Clicking on “Simplify” in the ribbon brings up a settings box on the lower-left side of the screen. You can set this to relative (e.g. 20% of the original triangle count) or absolute, like in our case. Type in 1,000,000 in the Target Triangle Count setting (next image).



Simplify your model by setting an absolute triangle count.

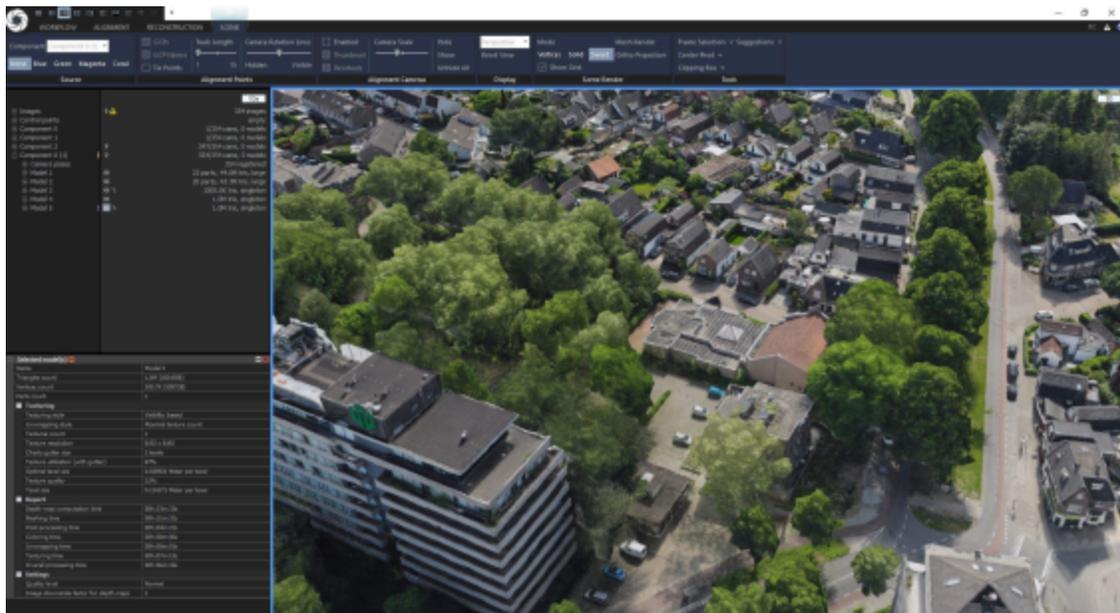
Click on “Simplify”. The result looks very similar at this distance. On the left side you can see that the new model is made of 1M triangles.

Now click on the Texture button. This process will take some time, 20-40 minutes. The result is shown in the next image.



The 3D model after texturing.

Now click on the following buttons: Close Holes, Check Integrity, Check Topology, Clean Model. Zoom in by using the scroll wheel to closely inspect the model. Pan left and right with the left-mouse button, and rotate with the right mouse button.



Close-up of the 3D model.

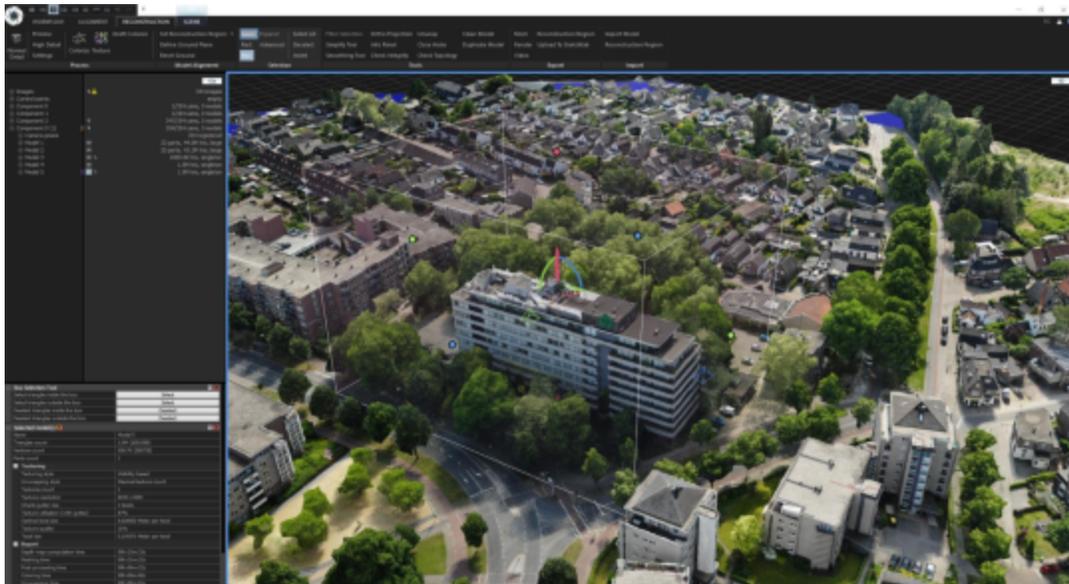
Here is a [video of me inspecting the resulting model](#).

In principle, the model is now ready for exporting; however, you still need to cut out a part of this environment so that you can replace it with your 3D CAD design(s) in Lumion.

### 3.4.4. Cut Out Unwanted Objects

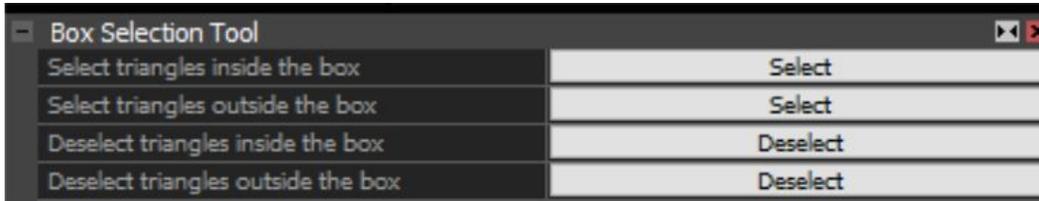
To cut out objects or areas that you do not want to appear in the visualization, RealityCapture offers 3 tools:

1. **Lasso.** This tool lets you draw an arbitrary path in a 3D model and select the triangles inside this path. This not only works with a top view, but also a side view. Small trees, for example, can become ugly green blobs floating in the air. You can cut these out and replace them with Lumion trees. The holes in the ground can be fixed by RealityCapture (if they are small enough) using the Close Holes function. Re-texturing is then required.
2. **Rectangle.** Works similar to lasso.
3. **Box.** This tool is handy when you need to cut out trees while leaving the ground plane intact. The box starts with a size bigger than the whole 3D model. Using the small colored dots on the sides, you can shrink this box in all directions to make it encapsulate the undesired elements. You can also rotate the box on the colored circular lines or shift it along the axis lines.



Use the Box tool to select a desired area of your 3D model.

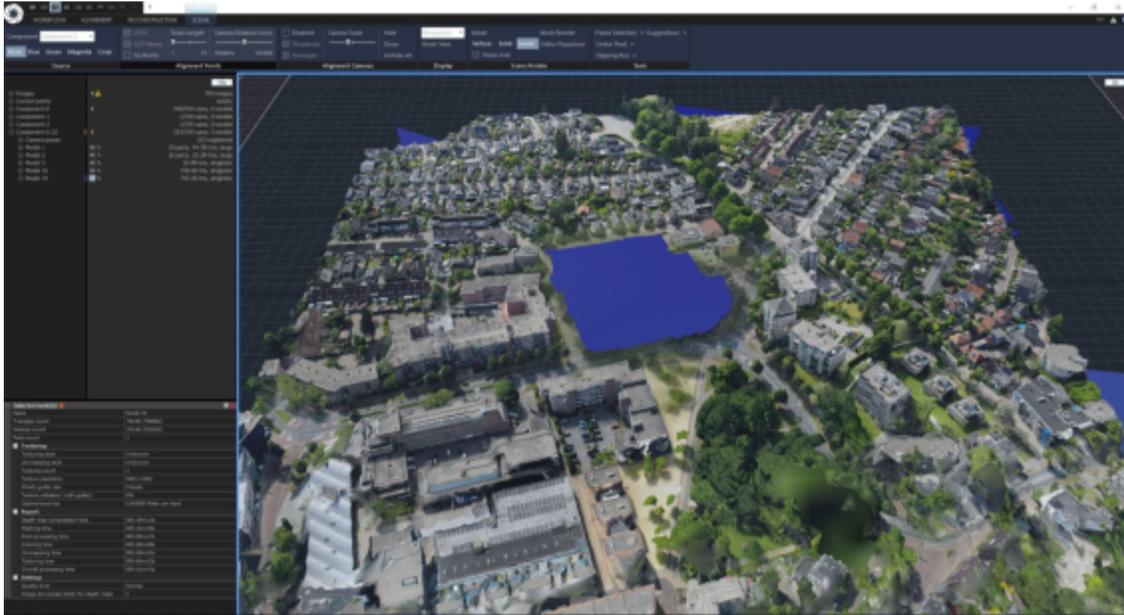
Clicking on the Box button brings up a settings section in the left-hand side:



You normally want to select the first option, “Select triangles inside the box”, and then perform the Filter Selection function to create a new 3D model with the selected triangles left out.

When going through the cutting out process, it’s best to use your high-detail model before simplification. One drawback is that operations are slower on that model and saving it also takes some time. You can also cut out from the lower-detail model, but if you prefer a higher detail model for better quality in the end, you’ll need to do the cutting out process all over again.

After cutting out the main area, you probably want to perform another few select and filter actions. Holding down the Ctrl key while making multiple, sequential selections adds each new selection to the existing selected set, saving you some time during filtering. Pressing the Shift key while selecting inside of an already selected area will unselect that part. The next image shows the result.

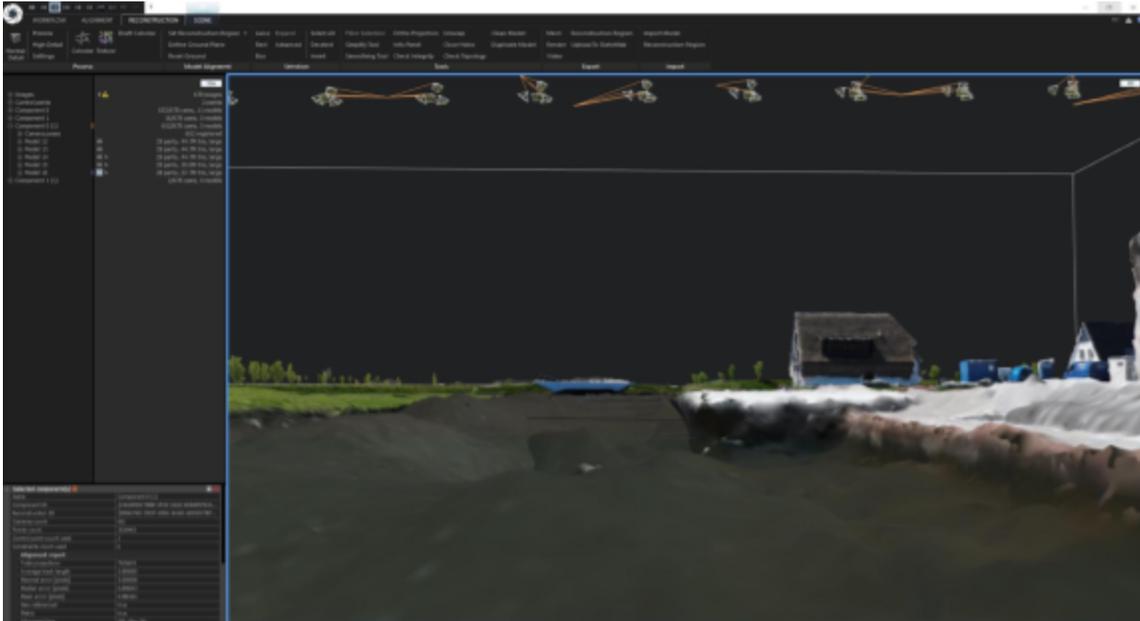


After cutting out this area, we can now upload the model into Lumion and insert the CAD design.

A [screen video recording of the whole process](#) is available, and it shows how we cut out the main building and surrounding trees of the Apeldoorn project.

### 3.4.5. Optimize Water Areas

Water surfaces, especially on a windy and sunny day, are hard to process for any photogrammetry software. The reflection and waves will look different in every image, so the software won't be able to find similarities between the images. The result is often a very uneven surface. Since the water surface will be replaced with attractive, animated water in Lumion later on, we need to get rid of water surfaces from the captured 3D model. The next image shows an example.



Remove the water elements from the captured 3D model. They will be replaced with attractive Lumion water later on.

For my first attempt at improving the model, I cut out all these water areas with the RealityCapture Lasso tool and then performed multiple Filtering operations. But because some of these water areas were sticking out above the water level, this resulted in land areas floating above the (Lumion) water surface. Instead of cutting it out, the wobbly water surface needed to be pushed down somehow, below the water level.

RealityCapture currently does not have any tools for that ([I wrote a feature request on their forum](#)). Nevertheless, by exporting the 3D model in an OBJ format and then importing it in [MeshLab](#), a free mesh editing tool, I was able to push the water level down. The before and after are shown in the next two images. The first image shows the scene in Lumion with an added water plane set at the correct water height.



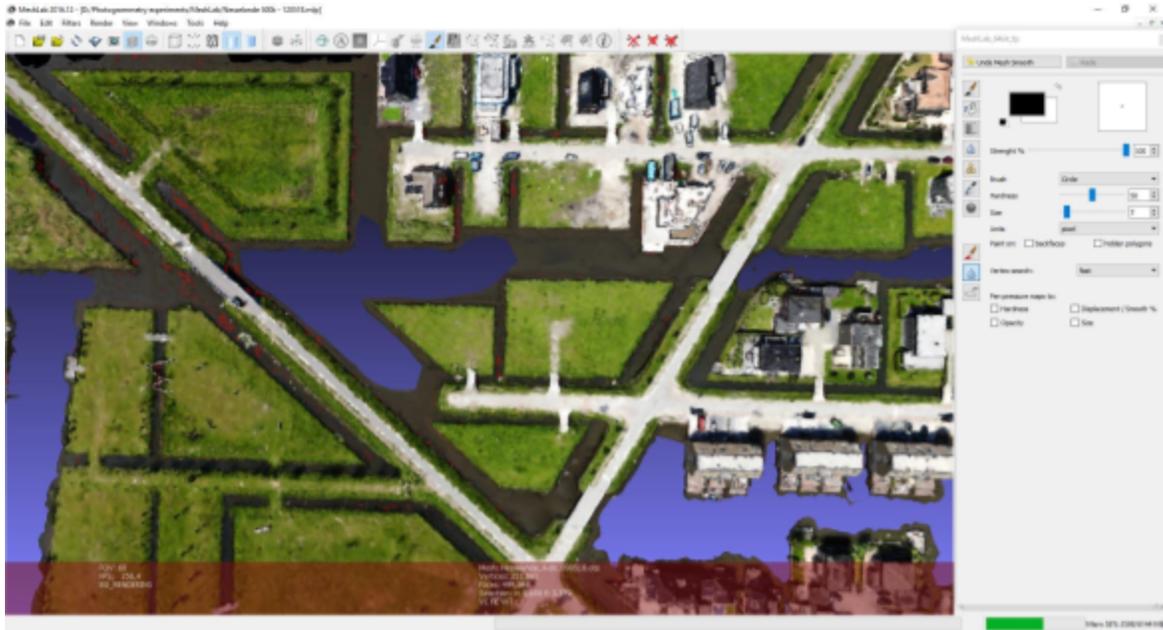
Because water isn't processed well in some photogrammetry software, you can get bumps above the water level, such as in this Lumion render.

The next image shows the scene after pushing down the wobbly triangles with MeshLab and also cutting out some unwanted objects in the far distance. I also added some Lumion trees.



By pushing down the water level with MeshLab, we were able to produce a clean-looking water surface in Lumion.

Screenshot of MeshLab:



MeshLab, a free mesh editing tool, allowed us to push the water levels down for a “water optimized” result in Lumion.

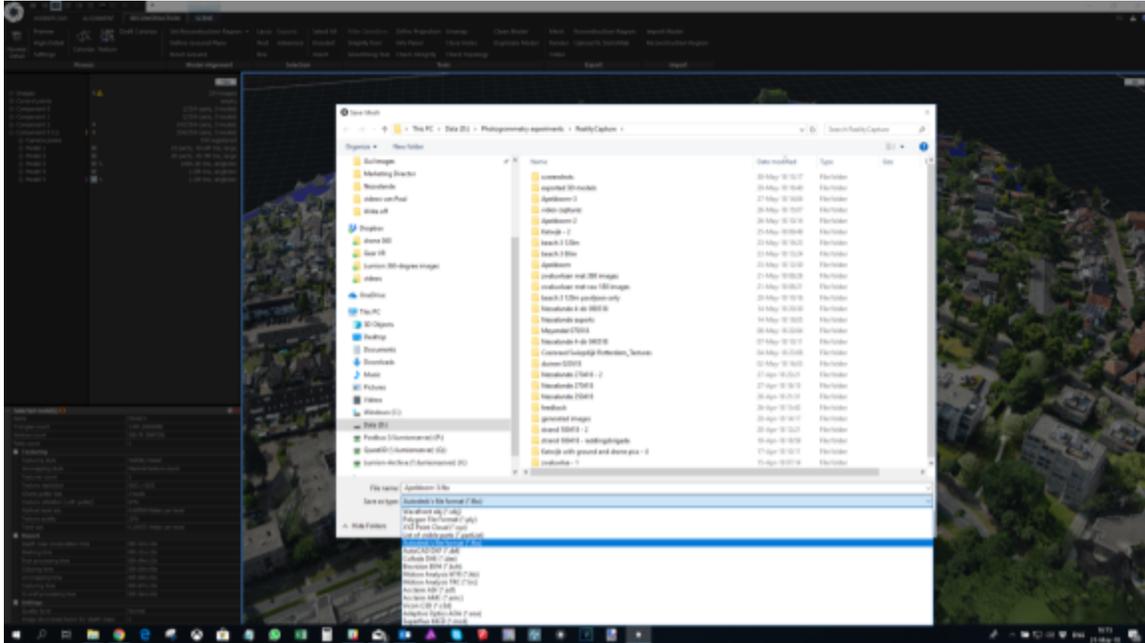
To drop the water levels in MeshLab, select the paintbrush icon (shown in blue in the screenshot above), and then the water drop icon in the settings box on the right. Set the strength to 100%, and adjust the size for the water areas you want to modify, but make sure you don’t accidentally push down land areas.

You can further optimize the terrain, either with MeshLab or another tool. [Rhino](#), for instance, has some mesh editing functionality. [SketchUp](#) also has some low-cost terrain plugins, e.g. [Artisan](#), but SketchUp does not handle 3D mesh models of several 100k triangles very well. It is possible to create and export a lower-triangle version of the terrain to Sketchup in an OBJ format.

### 3.4.6. Import the Model into Lumion

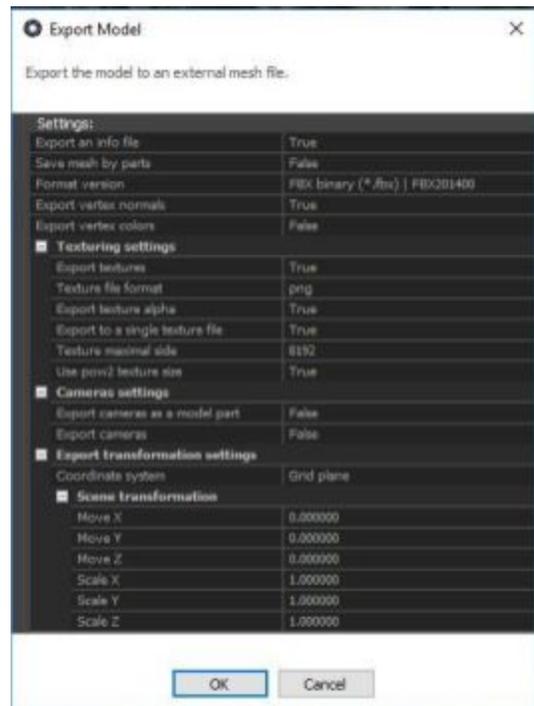
RealityCapture includes a number of 3D file formats for exporting meshes. The one that works best in Lumion is FBX. The export is done through the “Mesh” function in the “RECONSTRUCTION” ribbon.

This function brings up a dialog box (shown in the next image) where you can select the FBX option from the dropdown menu:



Export the 3D model as an FBX file for the best result when importing it into Lumion.

Selecting it and specifying the file name brings up the settings box (shown right). Check that you have the same settings.



Clicking OK starts the export process, which can take a few minutes. An 8K x 8K PNG texture is also created. This FBX model can be imported into Lumion like any other model. Depending on the triangle count of your exported FBX model, this import process can take several minutes, or even half an hour, during which you won't see much activity on the screen. Please be patient and do not touch the PC.

When the model appears in Lumion, you may need to adjust its height to make it hover over the green ground plane. The reason for this is that you may

need to add extra areas for the water and a satellite image, which will also need to float above the ground. The orientation is usually geographically correct, so if you set the sun at South, the shadows will be correct for 12:00 noon. The next image shows an example.



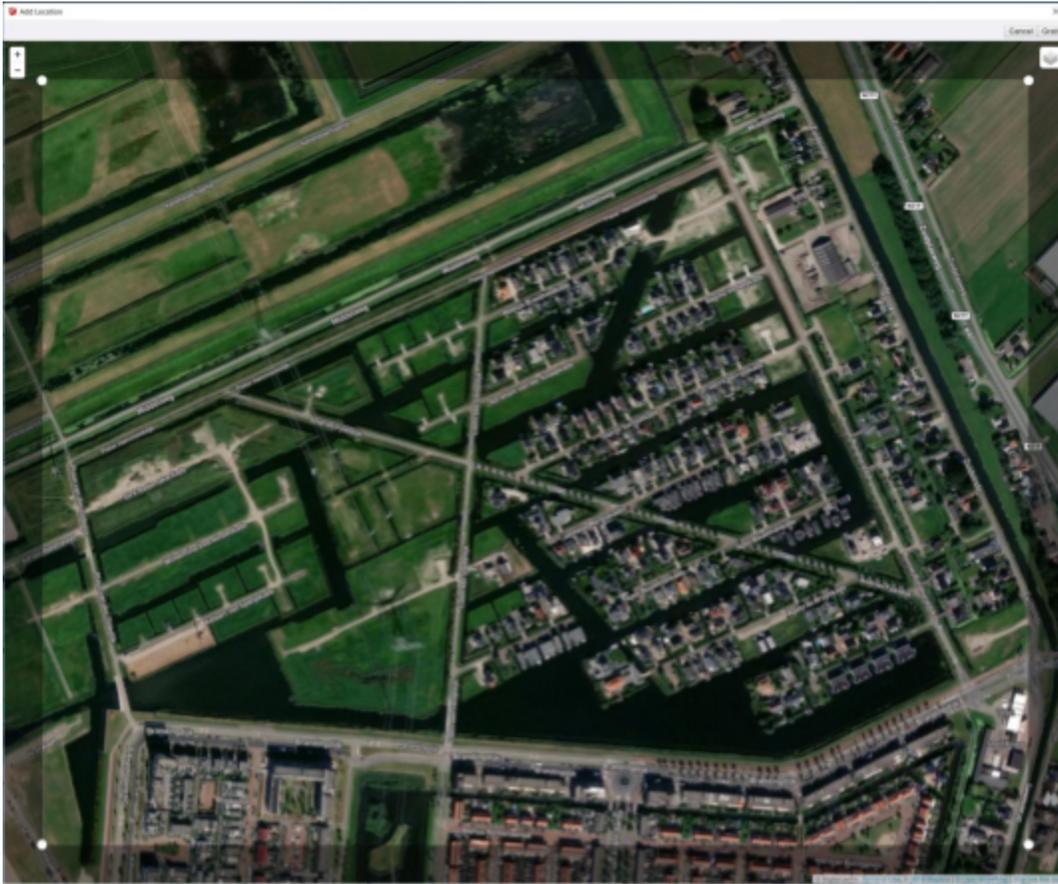
After importing the model into Lumion, make sure to raise its height so that it hovers above the green ground plane. This will allow space for water elements, a satellite image and more.

### 3.4.7. Enlarge the Area

Since the drone area is usually limited to 300x300m, it can be useful to add more environment to cover a larger distance for background visualization. It all depends on the renders you want to produce. Ask yourself, “Do the renders need to show a distance so wide that you would ‘miss’ the distant background?”

There are several ways for adding a larger area at lower detail:

**Option 1: Using a satellite image on a flat ground plane.** This is a standard feature in SketchUp, for example. In SketchUp, simply geo-locate your model by clicking on the bottom-left button. Click “Add Location” to bring up a Google Maps-like area browsing window with a search function. Set the region and click “Grab”.



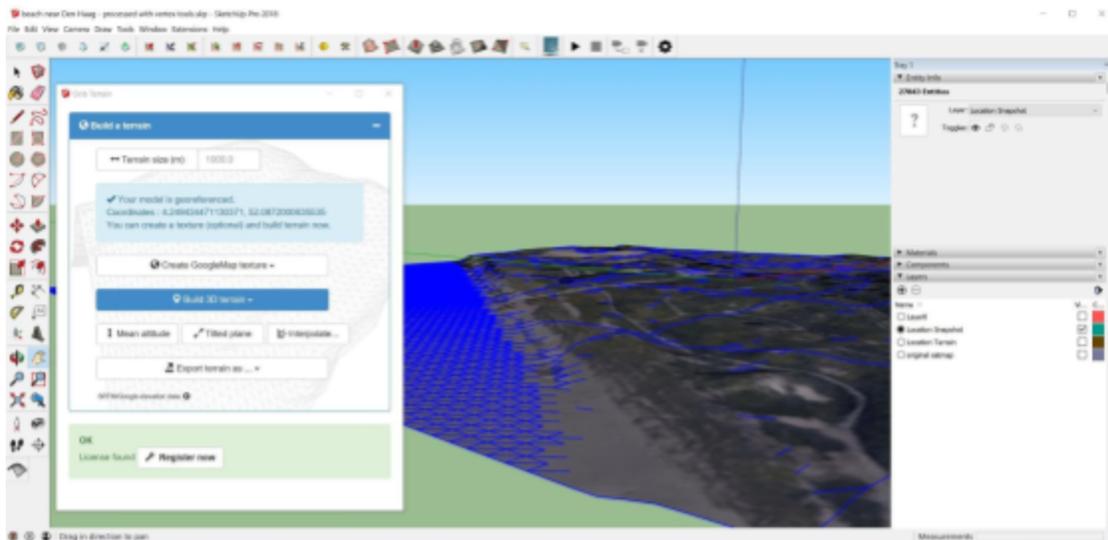
SketchUp's geolocation feature lets you quickly capture a satellite image for importing into Lumion.

After clicking “Grab”, you will create a flat ground plane with a low-resolution satellite image. For distant viewing, this may be just enough. Import it into Lumion, set it on a new layer, and set the height and position so it matches with the RealityCapture 3D model. The next image shows an example of the result.



Extend the area of your 3D environment with a low-detail satellite image.

**Option 2:** Use the [Oob Terrain](#) plugin. If a flat plane is not sufficient and you want more relief, you can use the Oob Terrain plugin for Sketchup. It uses the same geo-located area set as the previous option, but it will create a 3D terrain file with a better quality satellite texture.



The Oob Terrain plugin in SketchUp creates a satellite image with more relief and better quality.

This terrain may need to be smoothed and subdivided, e.g. using the Artisan plugin. Export the result to Lumion, set it on a new layer, and shift it so that it matches the RealityCapture 3D model (you may need to shift it down as well so it doesn't show through the RealityCapture model).

**Option 3: Use the OpenStreetMap feature in Lumion.** OpenStreetMap can import distant buildings as basic white shapes. In some areas, the building shape is better defined with accurate height and width parameters.

**Option 4: Add simple stretched cubes on the satellite image where you have buildings.** Create facade textures, e.g. from the drone images that were used for creating panoramas, or by taking pictures of these buildings manually. Stick these on the cubes. From a distance, the shape, place and general look-and-feel are now correct, leading to a more realistic impression. The next image shows an example (the buildings in the far distance).



Adding simple cubes with facade textures can help create a realistic impression for your audience.

### 3.5. Create Rendered Images and Video

In Lumion, you can add the new design, a water plane, the satellite image plane, the extra simple shape buildings, trees and other decoration objects. The next image shows an example.



Lumion's dynamic scene editor makes it easy to quickly combine all of your modeled elements together, along with the satellite images, decorations, environmental lighting and more.

Now you can make renders. Since the RealityCapture 3D model is not as crisp and detailed as the designed house, it's good practice to make the background slightly blurry using Lumion's Depth of Field effect, an artistic rendering effect, or another post-processing filter. Some examples are shown in the next sections.

### 3.5.1. Nesselande Project

Private house design on a small island in a new residential area near Rotterdam, The Netherlands.

Architect: [Studio Aaan](#).

From the architect: *“The house is located on a private island in a new urban development close to the city of Rotterdam. The house is oriented towards the new park located on the next island southwards. In order to be able to enjoy the views, the living areas are projected above the surrounding dike levels and the sleeping areas are located below. The lower floor is half sunk into the island and is organized around two patios. As a structuring design principle, the roof consists of expressive wooden beams in a dense pattern. The beams create a canopy on the south facade as well as a characteristic interior ceiling.”*



Lumion render of Studio Aaan's model (center) with a drone-captured intersection in Nesselande, east of Rotterdam.



Living room interior of the Nesselande house.

Some animations:

1. [Flyby animation 1](#)
2. [Flyby animation 2](#)

Feedback from the architect, Hilbrand Wanders, of Studio Aaan: *“For any architecture project, but especially a private, freestanding housing project, the interaction of the building with its surroundings is crucial. We want to study the project as an architectural object on its location, but also want to consider how the surroundings are experienced from the interiors. Only once a house is finished and the owners move in, one can precisely see how certain trees are creating shadows in the house, what objects in the surroundings are blocking views from a certain position, or how window openings are positioned relative to window openings of the surrounding buildings. These aspects are highly influential on the living qualities and are difficult and too time-consuming to model by hand completely early in the design process. It is very interesting for a designer to consider the correct 3D environment from the first moment on, to test the first design-ideas within a correct 3D surroundings, but also to communicate these to a client in a very clear and tempting format. In the case of this project, the fact that the views on the site were blocked by surrounding dikes, were the reason to place the living rooms on the first floor. All other design steps (bedrooms around patios in souterrain, the stepped garden wrapped around the house) were consequential to this notion.”*

### 3.5.2. Westpoint Apeldoorn Project

Refurbishment of an existing office building into 98 apartments, each with a balcony, in Apeldoorn, The Netherlands.

Architect: [Paul Spaltman](#)



Westpoint Apeldoorn project in Apeldoorn, The Netherlands, by architect Paul Spaltman.

Feedback from the architect, Paul Spaltman:

*“Even though the 3D scan isn’t completely perfect, I can say that it offered an enormous additional quality and offered many new options. The fact that my design was embedded so clearly in the environment is an added value, not only during the design, but also during presentations and discussions with the customers, governments, and local citizens or whoever is involved. My client called that he is really positive about my design, and he will now discuss it with the city council (landscape, urban design, review etc.). The plan to replace the existing building is a sensitive topic with the people living in the area, so everybody is super critical. The 3D scan of the environment will play an important role in this approval process.”*



Front view of the Westpoint Apeldoorn Project

[Animation of the Westpoint Apeldoorn Project](#)

### 3.5.3. Beach and Dune Area

Test project. Existing Lumion beach bungalow added to a 500x500m captured beach area near The Hague, The Netherlands.



Test renders of the beach and dune area near The Hague, The Netherlands

[Animation of the Dune and Beach Project](#)

[Download Lumion Project](#)

## 4 | Cost Overview

The following table sums up the software and hardware components I used. Other components may be needed, with additional costs, as well.

<b>Item</b>	<b>Product used</b>	<b>Price, EUR</b>
Drone	DJI Mavic Air	800
4 additional drone batteries	DJI Mavic Air	300
Carry case for drone	DJI	75
Tablet to control drone	Lenovo 10"	300
Tablet holder for drone controller	DJI	45
Drone control software	Drone Harmony (beta)	0
3D creation software	RealityCapture	99
<b>TOTAL</b>		<b>1619</b>

## 5 | Conclusions

My experiences have shown that creating 3D environment models from drone images is very straightforward and feasible for any architecture design visualization.

The investment in time and money is relatively low, and any architect can do it without extensive training and/or the need for a 3rd-party service provider. The resulting models have value both in the design process (Lumion LiveSync) and for communicating with clients and other interest parties, like the city council and local citizens (Lumion rendered images and animations).