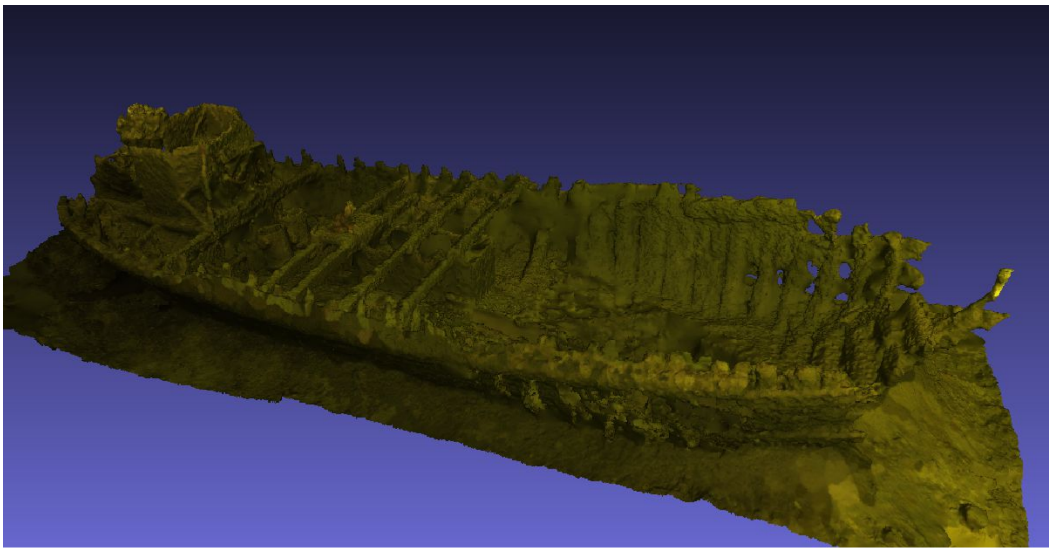
Photogrammetry under water

A tutorial for the first steps
in underwater-photogrammetry

Version: 5.0



Foreword

This manual is dedicated to everyone who wants to start into photogrammetry. There is not much information to be found about photogrammetry under water, it is a relatively new development.
I became enthusiastic about the possibilities after a presentation given by Othmar Schimmel during a meeting of the Dutch LWAOW (National Workgroup Archaeology Under Water).
With ups-and-downs, through experimenting (first with the garden furniture, after that in the lakes near my home and then with our ship, the Bernicia, in the North Sea), I found out what does *not* work. During this process I gained some insight about the background and the functionality of the software.

This does not mean that I have found THE method to come to a perfect result, absolutely not, alas. This tutorial is written to prevent newcomers to make the same mistakes as I did.

It is my intention to update this document on a regular basis, also through input from the users. In that way it becomes a document *from* all of us *for* all of us.

Your comments and additions are not only appreciated, but also expected!

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1 3D-rint of an inshore wreck

2 3D-print of the steam engine of an unknown wreck in the North sea

Contents

What is….

Photogrammetry is the specialism that uses pictures of an object to obtain a three-dimensional representation of that object. The end result is a 3D-model of the object.

Application and aims

In order to manage our cultural heritage under water it is, in the first place, important to have a good insight of the exact shape and status of every object on the seafloor. Because of limited visibility and the 3-dimensional structure an overall view is often impossible. This makes it difficult to obtain a detailed overview of a complicated and extensive site. An accurate 3d-model can be of great assistance to study such sites, and also to assess their condition.
Besides that, it will become possible to monitor the deterioration of a wreck. By making a new 3D-model at a later date, the models can be compared easily. In this way it is possible to establish exactly if, and if yes, how the condition of the wreck has deteriorated.
These 3D-models also give a very good opportunity to show the wrecks to the general public.

In contrast with the measuring and drawing of an object, which always involves a generalisation, photogrammetry (and the pictures themselves) gives the exact situation in which the object was found. It is always possible to go back to that information at a later date for further study.

Practice

Principle

Many overlapping pictures are made of the whole object. Every picture is made from another standpoint. The software compares all pictures and searches for points that are visible on overlapping pictures. From this data the position in space of every camera standpoint is calculated. Now it is possible to calculate the position of every point on the picture in an xyz-coordinate-system. This result is called the Pointcloud.
The next step is to draw triangles in between neighbouring points to give the model a surface. This is called the Mesh.
The triangles are coloured according to the colour-information from the original pictures, this is the Texture.
Applying the texture and the final illumination of the object is a lengthy procedure and is called Rendering.

Requirements and limitations

Every photo has at least 60% overlap, horizontally as well as vertically. The lighting must be even, so-called hotspots cause problems during processing. Flashlight does not work well, because the bright spots on one picture do not appear on the next picture. Above water, moving clouds in the background hinder the process, also people walking around prevent the software to find equal points.
Every part of the object that is not present on at least two photos will show up as a hole in the model.
Smooth, transparent, reflecting and/or monotonous surfaces give great problems due to a lack of recognisable points.

Difficulties underwater

On a wreck we have to deal with different circumstances than above water. To mention some:

- Bad visibility because of floating particles
- Bad lighting and dark holes
- Animals like jellyfish and fish swimming around the wreck
- Other divers swimming in front of the camera
- Complex situation of the wreck itself
- Empty sandplains between wreckparts
- Fishing nets draped over the wreck
- Limited Bottom time

All these factors will have to be considered to come to a good approach and subsequently to a good result.

Equipment

General

The quality of the resulting 3d-model is ***entirely*** and ***solely*** dependent of the quality of the pictures with which the software has to work. ***No*** compromise is allowed, the pictures must have enough quality to be successfully processed.
The requirements for every picture are, in sequence of importance:

1. In focus
2. Good exposure
3. Sufficient resolution

The demands for sharpness and exposure are mutual dependent, alas. For a good exposure a long shutter speed is required, a sharp picture wants the opposite. Working from a tripod is out of the question, using a flash gives a big chance of problems with processing. Because of the changing position of the flashlight every time different points are extra illuminated, preventing the software from recognising them as identical points. Floating particles are also more prominent in the photo. Perhaps video lights are a

solution, but I would not know which setup will give a good, even illumination of the whole field of view. The same applies to filming, with a high framerate (fps), there is a chance that not enough light reaches the sensor. A low frame-rate can lead to blurred images. The advice is here not to go under 50 fps.
Screwing the sensor-sensitivity up will not lead to better results, upping the ISO-value gives more “noise”, leading to problems in the software. Users of photo cameras will also have to keep an eye on the depth of field, which has to be sufficient bring all objects in focus. There are limits to using low f-stops.

A resolution of minimal 5MP is advised. With a higher resolution the software will probably find more points that appear on several pictures together. In practice I get good results with 4.1MP GoPro-pictures.

Photo cameras
Current photo cameras are capable to produce real good pictures, also under difficult lighting conditions. But it is not realistic to shoot 1000 to 4000 photos by hand.
Almost all cameras have timelapse-functionality, where every few seconds a photo is taken. This does work, but (depending on the settings and features of the camera) there is a big chance that much blurred photos are being recorded. Tests with a GoPro 5 Black gave poor results, only one in three pictures was acceptable. A high-end camera with a big sensor and a light-sensitive lens will allow a fast shutter speed at a high ISO-setting, what could produce good results.

Video cameras
Amongst sport divers the GoPro actioncam is very popular. Due to it’s extensive range of possibilities these cameras are very usable for photogrammetry.
The GoPro can be used as photo camera and as film camera. Using the GoPro as a film camera, the film is cut up in separate pictures during pre-processing. The advantage is that there is much material to select from, a disadvantage is the rather low resolution.

Choice of lens
The processing of the data from the pictures depends on the actual lens used.
The software itself calculates which distortion properties the used lens has, but this ability is limited. If an extreme lens is used, like a fisheye-lens, the software needs to be informed beforehand.
It is recommended not to use such lenses, because the chance of success is lower.
The “wide-view”-setting on the GoPro gives no problems.
Zoom lenses have to be used with a fixed focal length. The software itself calculates the focal length for all photos, if this differs between photos the calculation will go wrong. However, it is possible to use series of photos, taken with different focal lengths, but then they must be loaded as separate “photo-groups” in the software.

Computer

Hardware

I have no knowledge about Macintosh-computers, so I will only look at the Windows-platform.
In this chapter it's only about two 3D-photogrammetry-programs, PhotoScan from AgiSoft and RealityCapture from Capturing Reality. In the chapter "Software" we will come back on this.
I use the term "Software" when I mean both programs.

The abovementioned softwaremakers both advise on the optimal computer-configuration. A large part of the calculations is being done by the processors onboard the graphic card, that's why both programs ask for specific graphic cards.
Here follows a summary of the requirements.

RealityCapture

- Minimum:
  - Windows 8 or 10, 64-bit
  - 8GB RAM
  - Nvidia graphic card with CUDA2.0+ and 1 GB RAM
- Recommended:
  - Windows 8 or 10 64-bit
  - Processor with minimal 4 cores
  - 16GB RAM
  - Nvidia graphic card with 1 GB RAM and 386 CUDA-cores.
- For the aligning of pictures RC needs per 1000 pictures (with 40000 features per picture) 8GB RAM, and that increases proportionally.
- By splitting the object in different parts, it is possible to circumvent a memory-shortage.
- Calculating the mesh, colouring and texturing are done without the use of the main memory, so no problem here.
- Without a Nvidia-card it is not possible to generate a mesh or texture.

Agisoft Photoscan

- Minimum:
  - Windows 8 or 10, 64-bit
  - Processor with minimal 4 cores
  - 16GB RAM
  - Nvidia GeForce GTX980 or 1080
- Aanbevolen:
  - Windows 8 or 10, 64-bit
  - Processor with minimal 8 cores
  - 32GB RAM
  - Nvidia GeForce GTX980Ti or GTX 1080
- For the aligning of pictures RC needs per 1000 pictures (with 40000 features per picture) 5GB RAM, and that increases proportionally.
- The amount of RAM needed for calculating the pointcloud is dependent of the resolution of the photos, the overlap, the desired quality and also the shape of the object.
      - Medium quality:
        - 200 photos 6 to 18 GB
        - 500 photos 15 to 45GB
      - High quality:

- 200 photos	24 to 72 GB
- 500 photos	60 to 180GB

- By splitting the object in different parts, it is possible to circumvent a memory-shortage.

It is the general experience that changing the traditional hard disk for a SSD gives an enormous improvement in the total speed of processing data (and a significant setback of the bank account). This not only involves the 3D-software but especially the processing of the pictures themselves. Hundreds to thousands of pictures have to be assessed and eventually improved. The delay involved in loading every single photo from a traditional hard disk becomes irritating very fast.

Software

In Wikipedia you can find a list with almost 100 programs capable to reproduce 3d-models from pictures. On closer examination several programs are not of interest because of the price tag. Programs, specially made for land surveying will cost 10.000$ and more. Other programs work online, which means you send in your pictures and they process them for you. You have no control over the process and you are unable to decide to work with several components for instance. Above that the amount of uploadable photos is often limited.
Some online-programs claim the right of ownership and/or the right to use your model for their own purposes, including sale to third parties! So, it is important to read the user-agreement (the part everyone clicks away) very carefully before using a service like that.
The three programs most used are PhotoScan from Agisoft, RealityCapture from Capturing Reality and VisualSFM. The last one is too difficult for me to use, it uses itself also other programs to build the model. This leaves two programs, which do not differ much in capacity. RealityCapture is still in beta-phase, what means that the developers are still working on it.

PhotoScan (PS) versus RealityCapture (RC)

I tested the standard versions of both programs and the Pro-version of PS extensively. I used pictures taken in our Dutch underwater-environment in freshwater and the North Sea with several cameras.

The following comparison is based on the standard versions of both programs.

PhotoScan

1. Standard version van PS costs once-only 200€. (The pro-version costs 3700€.)
2. The number of pictures is unlimited in principle, but for 2000 pictures PS needs 32GB memory.
3. Makes one chunk of a series of photos and does nothing with the remaining photos.
4. It is not possible to place control points by hand on photos to improve the alignment-process. (Only possible in the Pro-version).
5. Has an easy way to work with masks to remove unwanted parts of a photo.
6. Can not scale the model to the correct dimensions by means of measured points. (Only possible in the Pro-version).
7. Is heavy on the hardware-configuration, freezes at insufficient capacity.
8. Is, in general, slower than RC.
9. Has an excellent user manual.
10. Is very userfriendly.

RealityCapture

1. Standard version of RC costs 120€ per 3 months. (The pro-version costs 9000€.)
2. A maximum of 2500 photo can be processed in one operation.
3. Makes more components from one series of photos.
4. It is possible to place control points manually on the pictures.
5. Working with masks is a lengthy process involving external programs.
6. Is able to scale the model to the correct dimensions by means of measured points.
7. Works with the available hardware, but slows down with limited resources.
8. Is, in general, faster than PS.
9. Has no real user manual, info is hidden in helpfiles.
10. Is not user-friendly, has a steep learning curve.

Planning of the photo session

It is of great importance that beforehand much thought is given over the working sequence. Jumping overboard and crisscrossing the wreck will most certainly not lead to a 3d-model! As already mentioned in the chapter “Practice” we have to deal with very unfavourable conditions. So **thos**e factors, that we can influence, must be optimised maximally.
They are:

- Planning of the activities
- Survey activities
- Arrangements with fellow-divers
- Sharp pictures
- Good lighting
- Adequate overlap of pictures

Planning

It is on your “average” wreck impossible for one diver to photograph the whole wreck in one dive. It’s better to concentrate on one part of the wreck and cover that completely. If this part can be shown on a sketch of the whole wreck, the next part of the wreck can easily be identified by the next diver or on the next visit. Working with parts in this way is very easy. It is very difficult to split the recordings of a whole wreck into parts because something went wrong during the processing.
For the planning of the activities it is very convenient to have a sketch of the wreck available. If not, one diver can be assigned to that task. This diver can, once returned, also point out where he saw the first photographers shooting the wreck. In that way the next divers have a guideline from where to start their activities.

Measurements

In order to record the complete situation of the wreck, only a nice-looking model is not sufficient. The model will have to have the right dimensions. Also, it’s orientation and position will have to be recorded to complete the task.

Dimensions

The wreck will have to be measured to bring the digital model to the right dimensions also. Photographing a ruler of one meter on a 50-meter wreck is not enough! Although for smaller objects it can be a good solution. On the wreck two points need to be found that are clearly recognisable with no obstructions in between them. The further apart the better. Perhaps labels can be put to use. These points need to be marked on the sketch, if possible with a detailed sketch. More of these measurements on different points allow for a good check for eventual mistakes.

Orientation
Hanging on the anchor line, given some visibility, the orientation of the wreck can be measured by compass. As soon as you are on the wreck, the compass readings become unreliable. This info is not useful for the making of the model itself, but should be a standard part of the survey.

Position
In the software a wreck can be positioned in a coordinate system, but in order to accomplish that, three points on the wreck need to be known in X, Y and Z-coordinates. Without specialised equipment this is not a feasible option.
However, it is relatively simple to obtain the coordinates of one known point on the wreck. If the ship is anchored to the wreck, the chart plotter can be used to continually plot the ship's position. During the reversal of the tide the ship will rotate around the anchor point. If that point can be found on the model, all ingredients are available to position the wreck, for instance in GIS-software for further reference.
In inland waters Google Earth can be of assistance. Measuring distances and/or bearings to points visible in Google Earth can give accurate positioning data.

Depth
On the wreck depths of a few significant points can be recorded by means of the depth gauge, which every diver (hopefully) has with him. With these measurements the relative position, the angle in which the wreck rests, can be established. A photo of the dive computer at the spot saves making notes and errors.

On an inshore-wreck it is relatively easy to make a reference to OD (Ordnance Datum). There is often a waterlevelscale on a bridge or a sluice with the required information.

At sea this is a more complex issue, due to the tide. Depending on the location the water level rises and falls to different levels than in a harbour. So, tide tables from a harbour cannot be used. Also, the wind can play an important role. Beyond that there is the choice of reference levels, like OD, Chart Datum (CD) or Lowest Astronomical Tide (LAT). This is beyond the scope of this document. Registration of the water depth, eventually with the mentioning of HW or LW, gives enough information.

Arrangements
As already said it is of importance that a minimum of moving objects get caught on the pictures. We have no control over fish, jellyfish and floating debris. The use of handgrenades before the dive could damage the wreck. Fellow-divers must be told they are not welcome at the shooting-location. It's not only the diver himself, but also his column of airbubbles. Even if they swim along the other side of the wreck in order not to disturb the photographer, these bubbles still appear in the photos. Always keep an eye on the surroundings during the photoshoot!

Pre-dive settings

Film

Sharp pictures are more important than high resolution. Experience gives that filming with 25fps gives much less sharp, usable pictures than using 50fps. Using a higher framerate reduces the amount of light available for each picture, resulting in underexposed pictures. Experiments with a GoPro5Black with 25 fps resulted in lots of unusable pictures.
The GoPro's have a "Low Light"-setting, which means fps automatically is reduced in low-light circumstances. This means that, in a dark corner, filming has to be slow in order to prevent blurry pictures.
"Low Light" does not work while recording in 4K, so then 2.7K is the highest available resolution.
A GoPro 4K-recording delivers photos of 3840x2160 pixels, that is 8,3MP
A GoPro 2,7K-recording delivers photos of 2704x1520 pixels, that is 4,1 MP

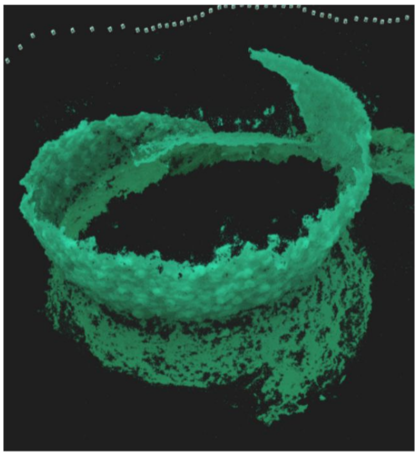
Photo

The camera must be set to the highest available resolution.
Recording in RAW-format has no use, the software will convert RAW to another format anyhow. If the camera is capable to store ***uncompressed*** JPG's, that's the best option. In that format you can store much more pictures on the memory card.
Use the lowest possible ISO-value to reduce artificial noise in the pictures.
Make sure the depth of field is sufficient to get the whole picture in focus.

The photo-session itself

An important skill to master is the ability to visualize, while taking the photographs, the computer program aligning the photographs, so that one can plan ahead and find angles that potentially were missed.
Three hundred photos too much is a small inconvenience, ten photos short can result in a flawed model. You will only find out back at home!
The most important rule: Only that what was recorded on at least two pictures will show up in the 3D-model! Crevices and small openings are difficult to film, take extra material and use much overlap.
During the rounding of a corner more pictures are needed to inform the software "something is going on".
Make sure overlaps are at least 60% horizontally and vertically.
Every photo must come from another camera position, making panorama-photos is of no use. The changing camera-position is necessary to calculate all positions. Change direction slowly, do not change the camera direction more than 30° per photo.
Start with an overview of the area to be covered, then go gradually closer. Going closer in one step gives the risk that the software loses track. It can't find the same details on the far-away and the close-up-pictures. It is important to make close-up-photos to minimise the effect of floating debris.
Do not be afraid the software loses oversight. On the wreck of "De Straatvaarder" in the Dutch Oostvoornelake, more than 700 pictures were made of the ship's bottom. These photos are processed in 11 chunks, witch themselves were successfully combined. Due to bad vis the average distance to the object was 66 centimetre!

Keep in mind that, to assist the software, you must make a "path" of photos which the program then connects. Also, by ending at the same spot you started, helps the software. In the picture you see a section of straight iron hull, with not enough overlap to connect to other structures. The software tries to make something of it….



1Straight section of hull without overlap

The most logical thing to do is to swim lengthwise over the wreck. In that way you end with strips of photos that probably will be processed without problem. However, if the overlap to the left or right is insufficient, you end up with a lot of loose components (see "The Making of the Model"). If you also make sweeps from port to starboard, you will have enough overlap to connect the loose components, manually if need be.
It is natural to pay more attention to interesting parts of the wreck with lots of detail. However, the software has less problems putting together photos with lots of structure! Less details means more pictures!
If you shoot more parts in one session, it is convenient to take a photo of your dive computer in between series. During the postprocessing you can then easily split the series and give them each a proper name.

Pre-processing of the recordings

General

Make sure the different series of photos or films are kept separated per wreck, per datum, per person and per wreck-part by giving them each unambiguous names. Perhaps the wreck will be visited at a later date to make more pictures. Perhaps it will be necessary to make a new 3D-model of the wreck. It is then essential to be able to find your way through the old data.
Remember that because of the different processing of the original material you will end up with different versions of the original material. This costs huge amounts of space in the computer. This is one reason why uncompressed JPG is preferred above TIFF or RAW. An example: a 4MP TIFF is 16,5MB, the same JPG is 2.3MB. A handy (and free) tool to rename all the frames in one go is 'Bulk Rename Utility'. A short manual is included as a supplement at the end of this manual.

Film

The film has to be converted to photos (stills). The Internet has several free programs to do that. There is only one that I could find that can make uncompressed JPG's, Blender. By compressing JPG's, you give away some quality in the beginning of the process, which is unwise. If you already work with Adobe Lightroom, the use of Adobe Media Encoder is free. This program is also capable of making uncompressed JPG's.
Blender is a program with a lot of tools for 3D-work. Converting movies in photo's works great in Blender, and in 100% jpg-quality. Searching for the right settings is unfortunately timeconsuming. To avoid this, a step-by-step manual is added at the end of this manual as a supplement, to simplify the conversion.

There is a choice of cutting one or more photos per second of film. With 20 minutes of film and 5 photos per second you end up with 6000 photos. Choosing the rate of cutting is more difficult than it looks. Looking at the resulting pictures it will become clear that some pictures are blurred. These have to be removed, only sharp pictures are useable!! If, with some bad luck a series of pictures are blurred, we have with 1 picture per second a much larger gap in our sequence than with 5 pictures per second. This can result in insufficient overlap, meaning a hole in our model. The downside is that, with 5 photos per second, you will have to go through a lot more photos.
If circumstances and the camera in use allow it, it's worth a try to start with 1 photo per second. If there is a "gap", this can be filled with a photo from the 5 pictures per second-series.

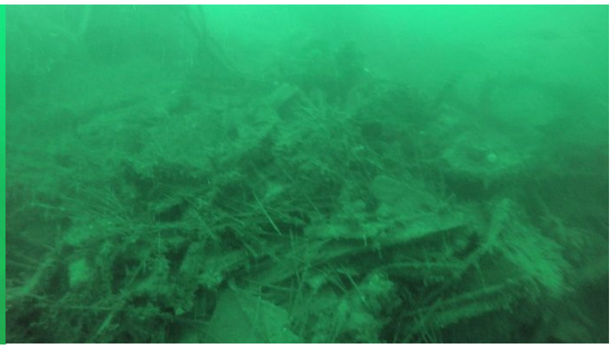
Photo-preprocessing

Before the photos are ready for processing, they have to be selected by hand. Every photo has to be judged for sharpness, and floating objects obscuring important parts. It is of no use to keep all good photos, just make sure the overlap is adequate. If it is crucial to include a "bad' picture in the series, for instance with a diver on it, it is possible to "mask" that picture. This means that the offending part is removed and filled with a neutral colour. In PS is a program to do this built in, in RC you have to use a separate program. To manipulate every photo in this way is not feasible, every effort has to be made to avoid this problem.

The software works only with the original photos, cutting or rotating is not allowed. Noise-reduction programs cannot be used. Remember that the software only looks at the pixels and their mutual relation. Everything that changes the photo at pixel-level causes problems!

The only means to help the software is the "stretching" if the contrast in the photo. In the free software Gimp is incorporated a module called "Stretch HSL". This program tries to maximise the hue, saturation and luminosity of every photo. Most pictures will not get nicer but improve in detail. Fortunately, Gimp has a batch-program available, called Bimp, to process all photos at once.
It is not a miracle cure, but the software selects more points on the treated photos. Experiments with Adobe Lightroom, which has a similar program, gave strangely enough no improvement during processing by the software.

Before HSL



After HSL

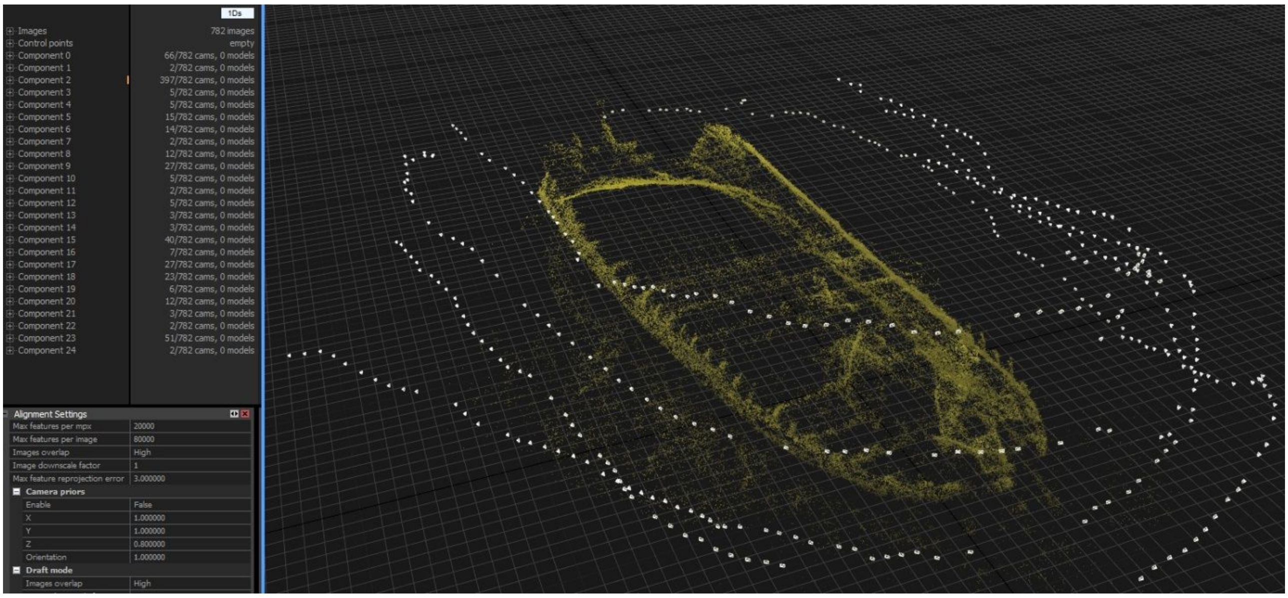
The making of the model

In an ideal world all pictures are all combined in one model. Unfortunately we have to deal with a whole range of problems that prevent this from happening.

Components / chunks

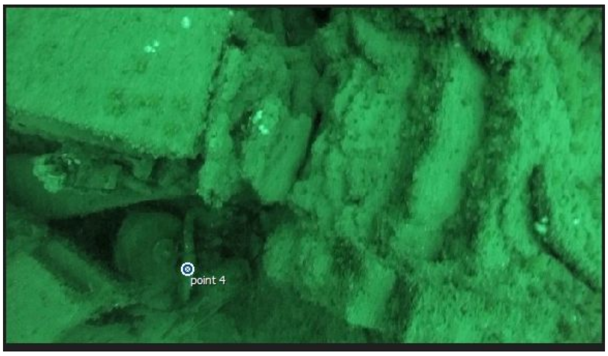
If something goes wrong during the processing of a set of photos, only a selection of these photos is used to make a component. Because of the relatively bad quality of the photos this is unavoidable.
Depending on the used software two things can happen:
- PS makes one chunk and ignores the rest of the photos.
- RC makes more components from this set of photos. As much as possible, photos are combined to produce components. You end up with several components and some loose photos.

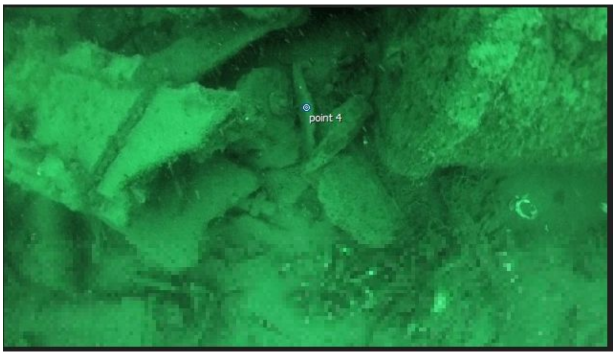
What then follows is the most time-consuming part of the process: connecting as much components as possible to complete the model.

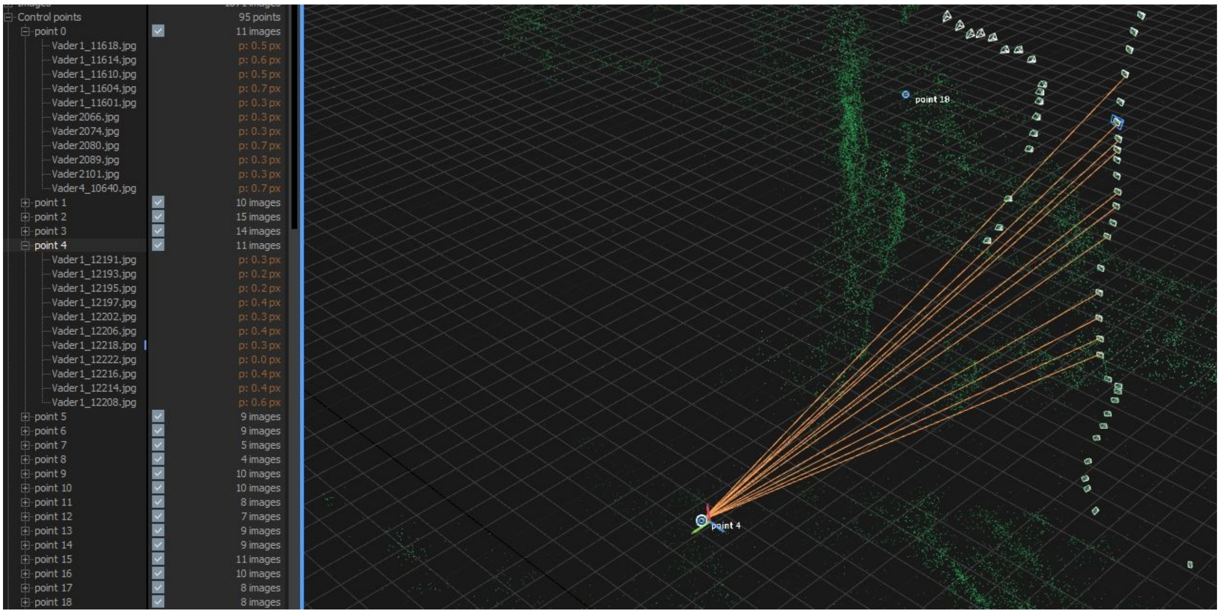


Control points

Combining components is, in principle, very simple:
From component A, a photo is selected on which is also a part of component B is visible. On both pictures a clearly visible point is chosen, on which in both pictures manually a control point is placed. This control point must be placed on at least two photos of each component, for the software to recognise it. So the control point is registered on at least four photos.
You will need at least three of these control points on both components, preferably far apart. Recalculation then brings those two components together to one component.
Repeat until you have a decent model. You will probably end with some components, consisting of 2 or 3 photos. These will not do much to improve the model and can be deleted.







Splitting a wreck in several parts has already been mentioned in ‘Planning’. This system extends into the software. If parts of the wreck have been sufficiently recorded, that part is processed separately. Assuming this worked out well, this results in a component (RC) or a chunk (PS). The software is very good in manipulating these components. If they have an overlap they can be combined to a single component. RC does this in the standard version, in PS you need the Pro-version.

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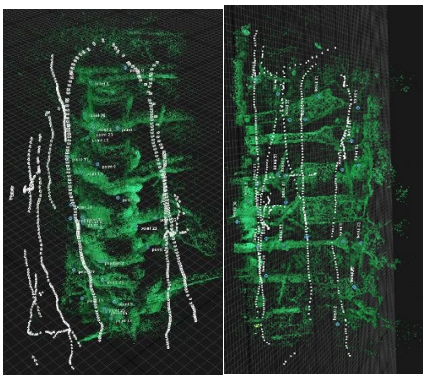
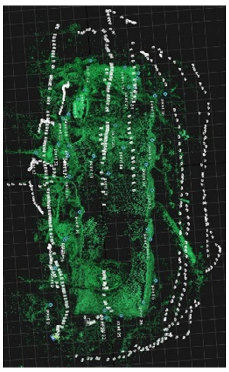
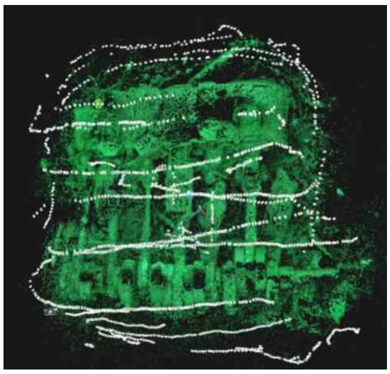






The makers of both programs have, unfortunately, left out the opportunity to exchange components and chunks in between programs. This can be arranged through other programs, but requires a lot of steps.

The process steps

Both programs work in a roughly similar way.

Align photo's
In the first step feature points are selected on each photo and compared with all other photos. If there are, these photos overlap apparently. From the data of these photos the software first calculates the properties of the used lens and then the location from where the photos were taken. From these locations the location of every feature point is calculated to an XYZ-coordinate. Now the basis of every 3D-model, the Sparse Point Cloud, is realised. For who wants to know more about this: search the internet for: 'SIFT-algoritm'.

Build dense cloud (RC combines this step with the following)
Now the original camerapositions as well as the lenscalibrationdata is known, the software can calculate exactly which photos overlap. In first instance the search is for points that appear on three photos, because these can be calculated more accurate. Then the calculation goes on with points that appear on only two photos. In general this is the most time-consuming part of the operation.
Together with the already mentioned Sparse Point Cloud all these points make up the Dense Point Cloud. Basically the model is now ready, what remains is the finishing up.

Build mesh
To give the model a structure it needs a cladding. The separate points in the cloud (called vertices) are connected by lines (called edges) in such a way that triangles develop (called faces). This triangles have a surface and this surface forms the visible shape of the pointcloud. The software fills in small holes in the model, larger holes remain open. The model is now white because the surfaces are painted white for now.

Build texture
In this step the software checks for every face from which photo it comes and it copies that piece of the photo on that face. The endresult is a realistic looking model. This texture is stored in a separate file and is known as 'texture map' or 'texture atlas'. The model itself is now finished.

The post-treatment

The only post-treatment the model needs now is to bring it to the correct scale. Scaling is actually not the right term, because the model will get the same dimensions as the wreck itself. This means that the length between the measured points on the model are made equal to the distance of the measured points on the wreck itself. As soon as this is done the model is ready to be used for all kinds of measurements, every part has automatically the right dimensions.
Scaling only works after all components are combined in one model!!

Exporting
As soon as the model is ready it can be saved and exported. There are several filetypes for available, depending on the purpose of the export.
Well-known are: *.obj , *.ply and *.xyz. Texture is included in *.obj, *.ply gives only the mesh en *.xyz gives only the pountcloud.

In Reality Capture the possibility exists to export directly to Sketchfab, a community of 3d-makers. You must first make a (free) account in Sketchfab.

Some programs that are specially made to manipulate 3D-models are, amongst others, Blender, MeshLab, Meshmixer en CloudCompare.
Blender is more focussed on the exterior of the model, manipulating the texture. Beside that it makes JPG's from movies and does a lot of other things.
MeshLab is more focussed on manipulating the model. In MeshLab it is, for instance, possible to connect models and to scale them.
Meshmixer is very useful to 'clean-up' the model. Removal of misaligned parts is very easy. It can also be used to bring the model up to a 3D-printing-quality. Ernie de Jonge wrote a manual, 'Van fotogrammetrie model naar 3D print', in which he describes step by step how to process the model to make it ready for the printer. This manual can be downloaded from the websites of Stimon and LWAOW.
CloudCompare is used to compare two, almost identical pointclouds, and to show the differences between them. Useful for long-time monitoring of the degradation of a wreck, for instance.

For all these programs are instructions to be found on YouTube. They will give you a much faster result than experimenting by yourself. Time spent on watching these movies pays back multiple times using these programs.

From computermodel to printed model

This manual covers only the making of the 3D-model on a computer. In order to be able to physically print this model, a lot of work still has to be done on the model.
Ernie de Jonge has immersed himself in this step and produced the manual "Van fotogrammetrie model naar 3D print". With this you can convert a computermodel to a practical printable model. His manual can also be found on the websites of Stimon.org and LWAOW.

Also not covered: the finishing of the printed model. This really is a separate hobby!
However, there are a few points to consider:

- The most used plastic in 3D-printing, PLA, softens at 60^0 Celsius. Think about that before placing your model in the sunshine behind glass!
- Before any paintjob the plastic has to be degreased. Soaking in cold water with a little bit of washing-up liquid, followed by rinsing in cold tapwater and finally rinsing with demineralized water works well. Wait until fully dried and do not touch with your greasy fingers anymore. The last thing you want is paint peeling off your model because the model is not clean!
- Acrylic paint is almost odourless and is perfectly usable indoors.
- A tablelamp which gives 'daylightcolour' with a magnifying glass is a nice aid while painting.
- Airbrushing is probably the best way to paint your model, because the surface details remain perfectly visible. If you are a diver, there is no need to buy an aircompressor for this, your divetank will do great. In DIY-shops you will find simple pressureregulators, giving excellent service. The regulator in the picture has ¼" female thread, by means of an adaptor you can fit a male inflatornipple. A whole day of airbrushing consumes roughly 30 bar. And the air is perfectly dry! In the picture is shown a 'basic' airbrushset, which (for me) is adequate.

- A good primer as first layer on the plastic will give a good base to start painting. Acrylic primer (and paint) needs to be shaked well before use! Primer wants to be sprayed in minimal three, really thin layers. Only after the last layer the cover needs to be complete. Acrylprimer dries very fast, but the curing time is 24 hours.
- Covering the model with a transparent layer protects the paint against damage. A matt varnish gives a natural looking result. Also the varnish needs to applied in several really thin layers. A thick layer can give a milky appearance.

Some advice

- With the GoPro most of the times a floating grip is used, to find the camera back after losing it. Inshore this is a good solution, but in the North sea, with wind and waves, it becomes invisble. I lost my first GoPro 25 miles from the coast and it beached 90 miles further. The honest finder returned it to me. I do not advise to make a habit of this. Nowadays, when diving in the North sea, I stick a metal bar in the handle. That way the GoPro will remain somewhere in the wreck, with more chance of finding it back.
- With the heavier grip I have more sharp images, it probably helps against small vibrations.
- Take on every memorycard/camera a picture with your name and adress. That helps the finder to locate you in case of loss.

Consulted literature

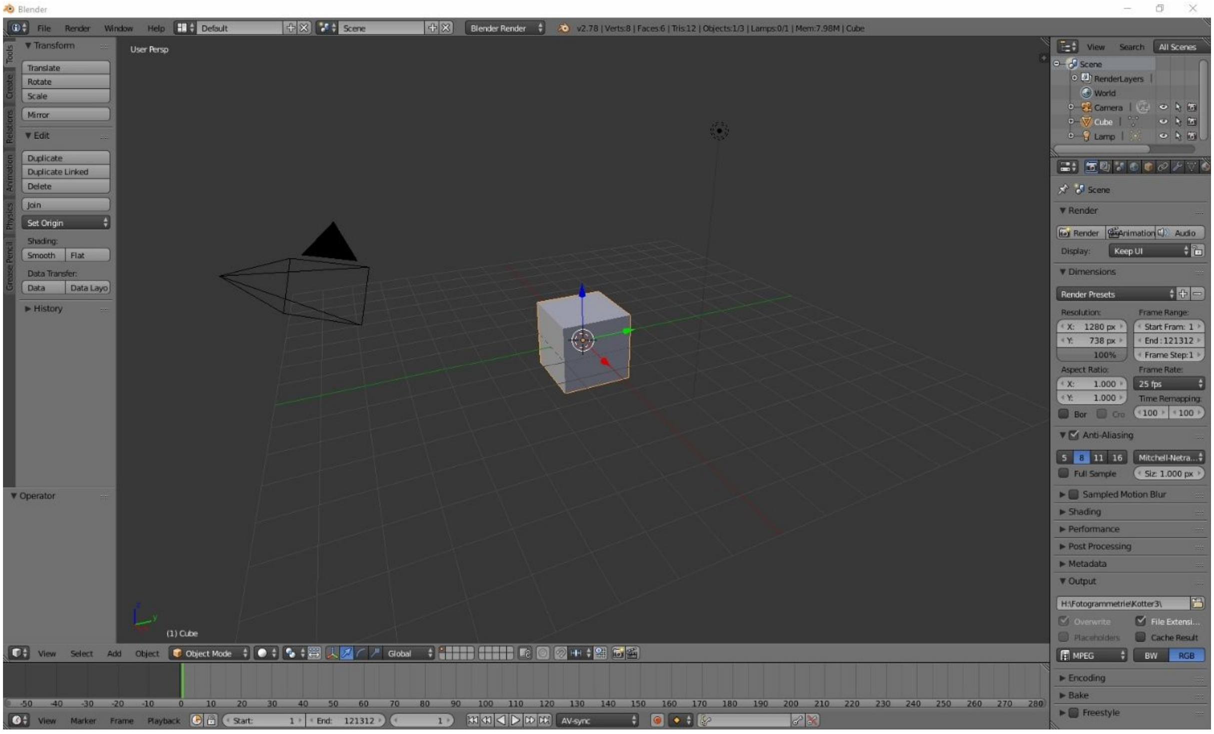
Handleiding onderwateropnamen voor 3d-fotogrammetrie: J. Opdebeeck
Photogrammetry in paleontology: Mallison & Wings
Computer Vision Photogrammetry for Underwater Archaeological Site: T.van Damme
Underwater photogrammetric mapping of an intact standing steel wreck: SM. Nornes et al.
Building 3D-models with digital photographs: K. Hunter
Lots of sources on the Internet, with two especially useful ones:
https://dinosaurpalaeo.wordpress.com/2015/10/11/photogrammetry-tutorial-11-how-to-handle-a-project-in-agisoft-photoscan/
http://adv-geo-research.blogspot.de/2015/06/photoscan-crash-course-v1-1.html

Supplements

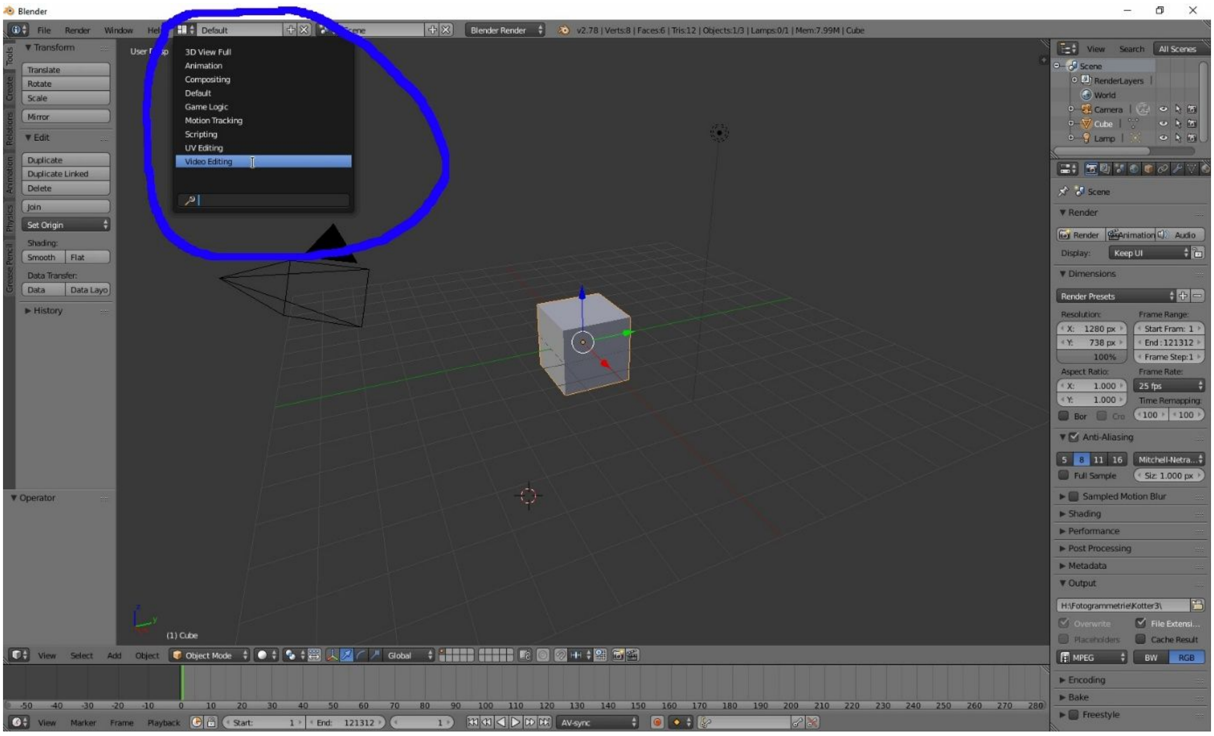
- **Producing photos from video in Blender**
- **Short manual for Batch Rename Utility**

Producing photos from video in Blender

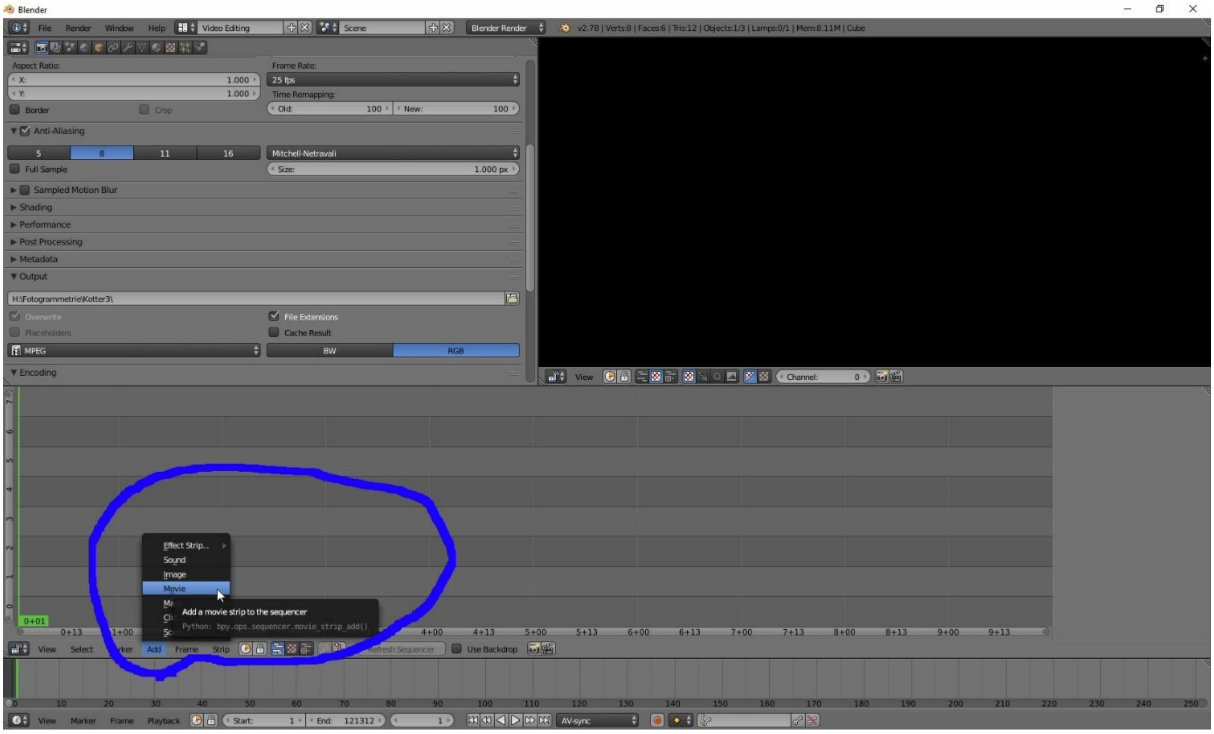
Hans van der Weide 25-02-2018



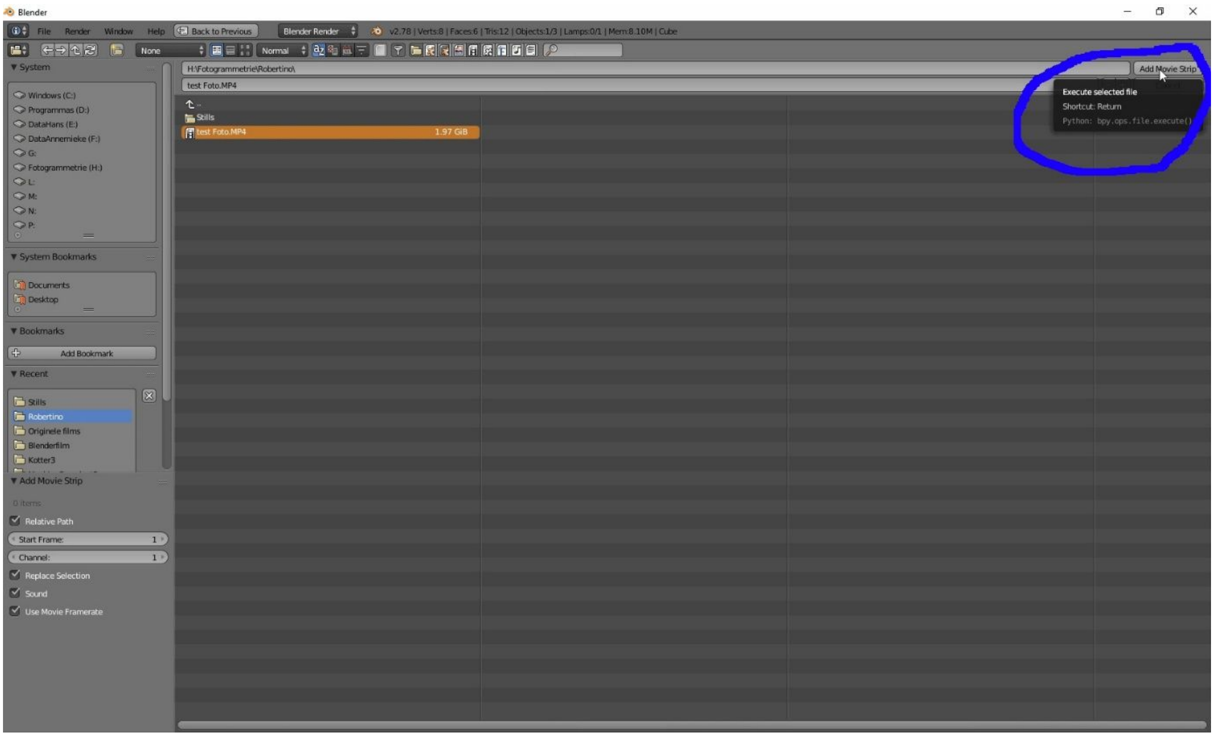
1. This is the startupscreen in Blender.



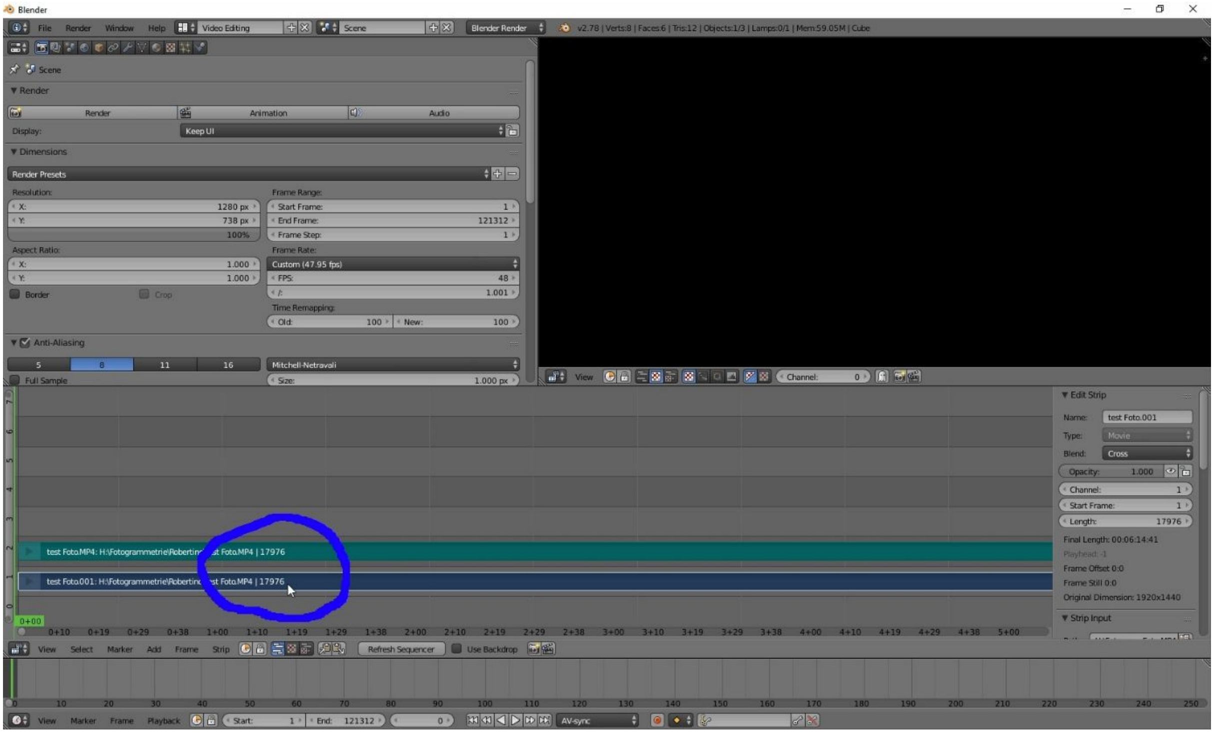
2. Choose here: ‘Video Editing’



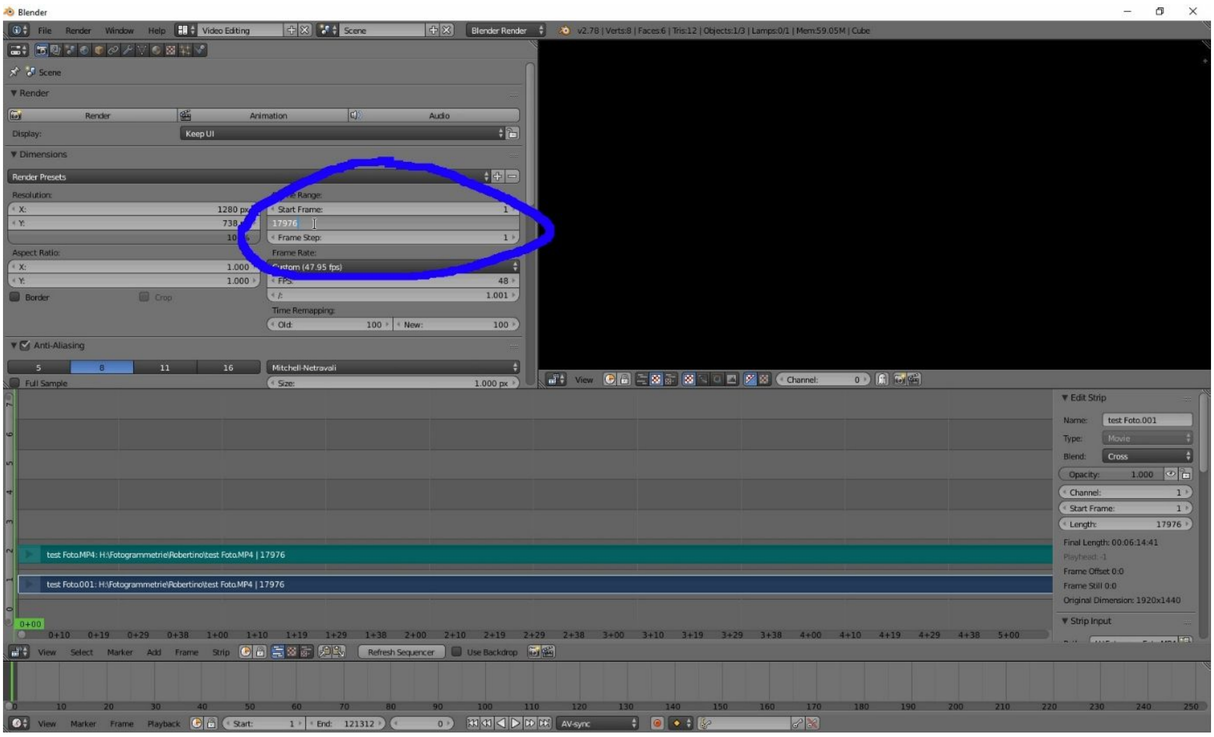
3. Choose here: ‘Add Movie’



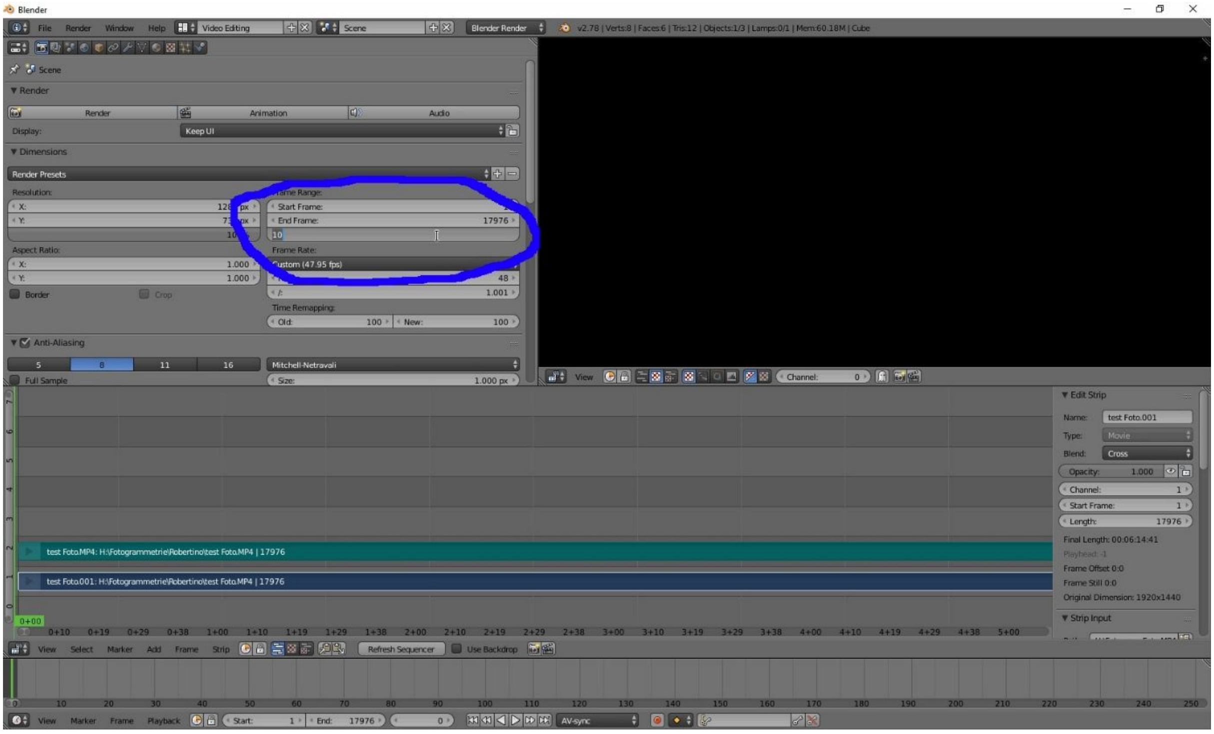
4. Select the film and choose: ‘Add movie strip’



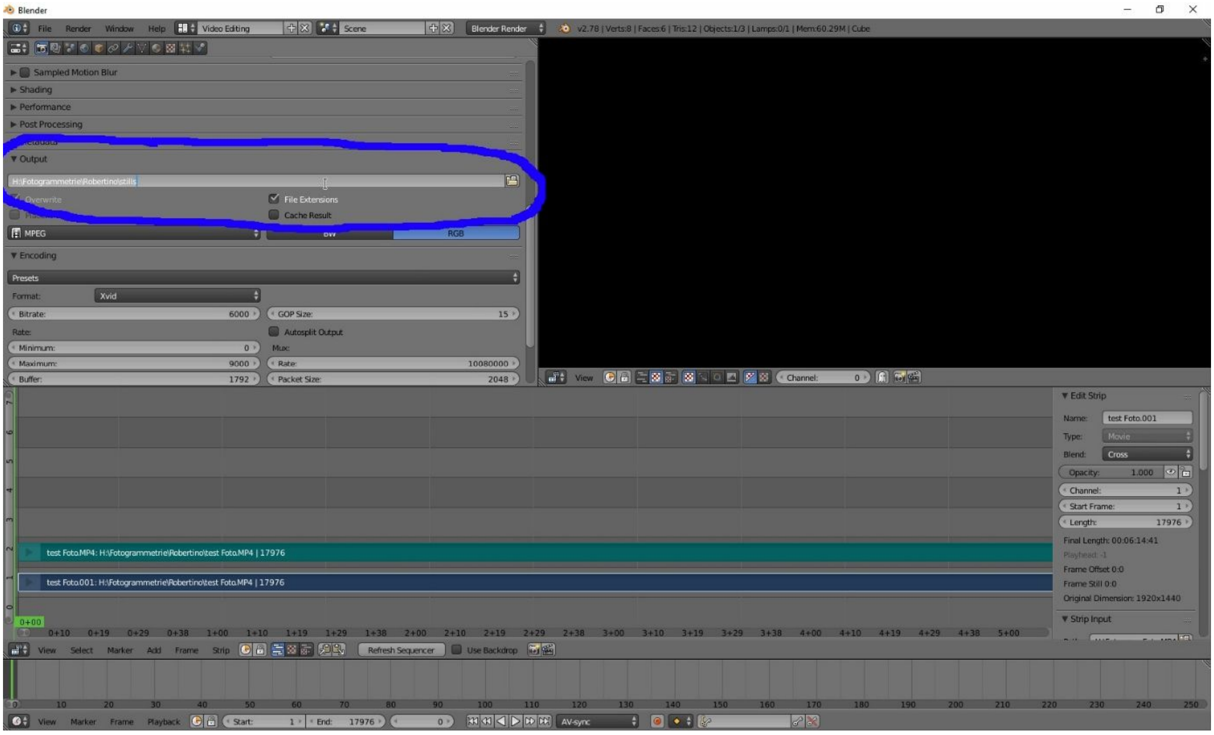
5. This is the size of the video (number of frames), write this down



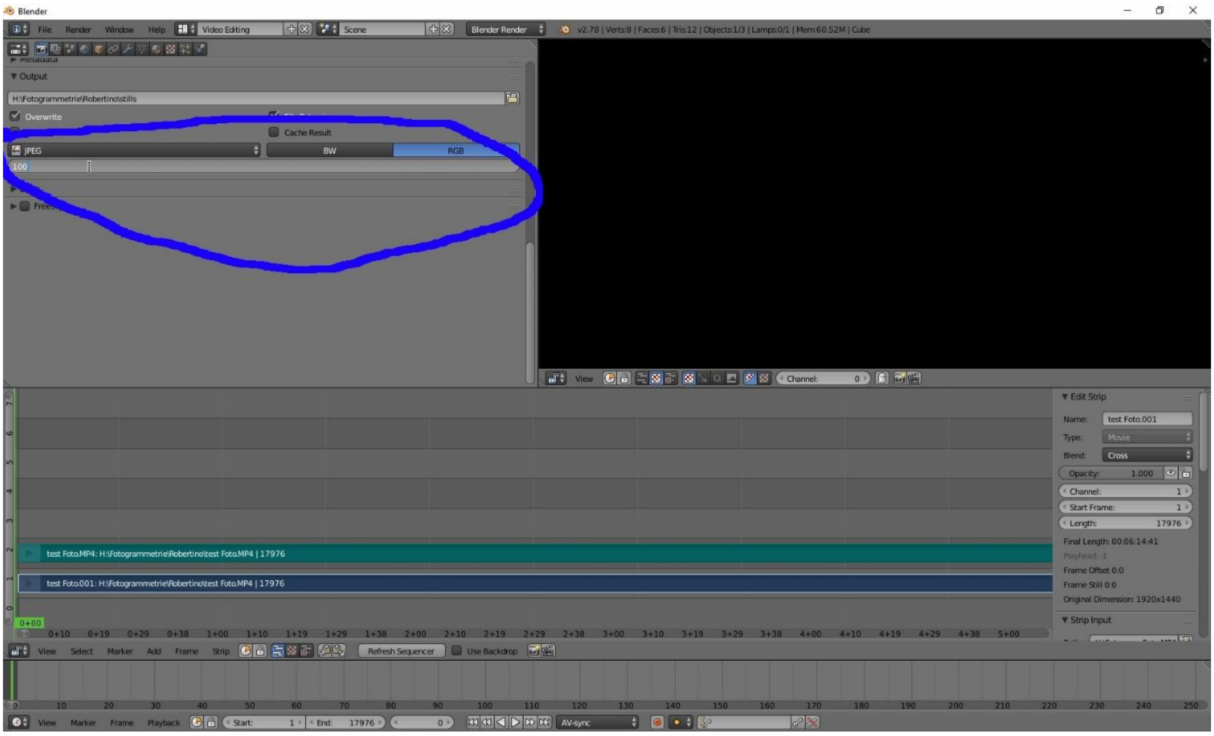
6. Fill in the right size here



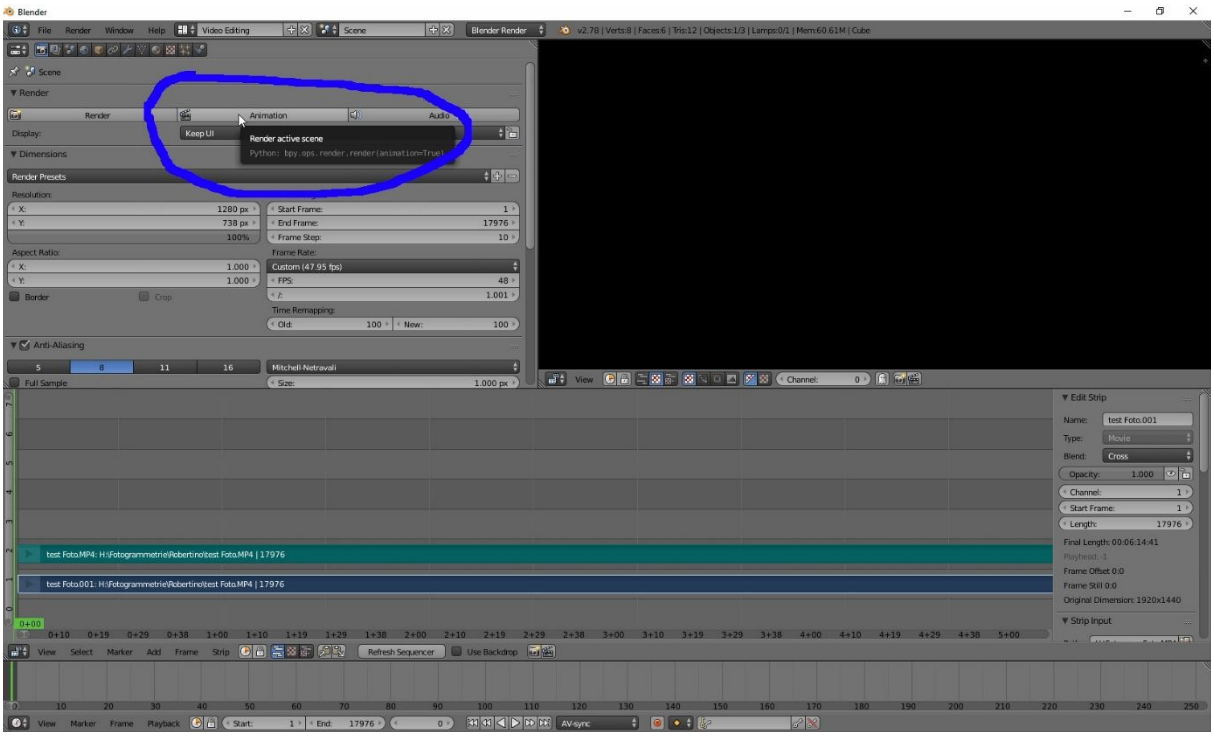
7. Fill in the required stepsize, in this case every 10th frame is grabbed



8. give the path, where the photos have to be stored

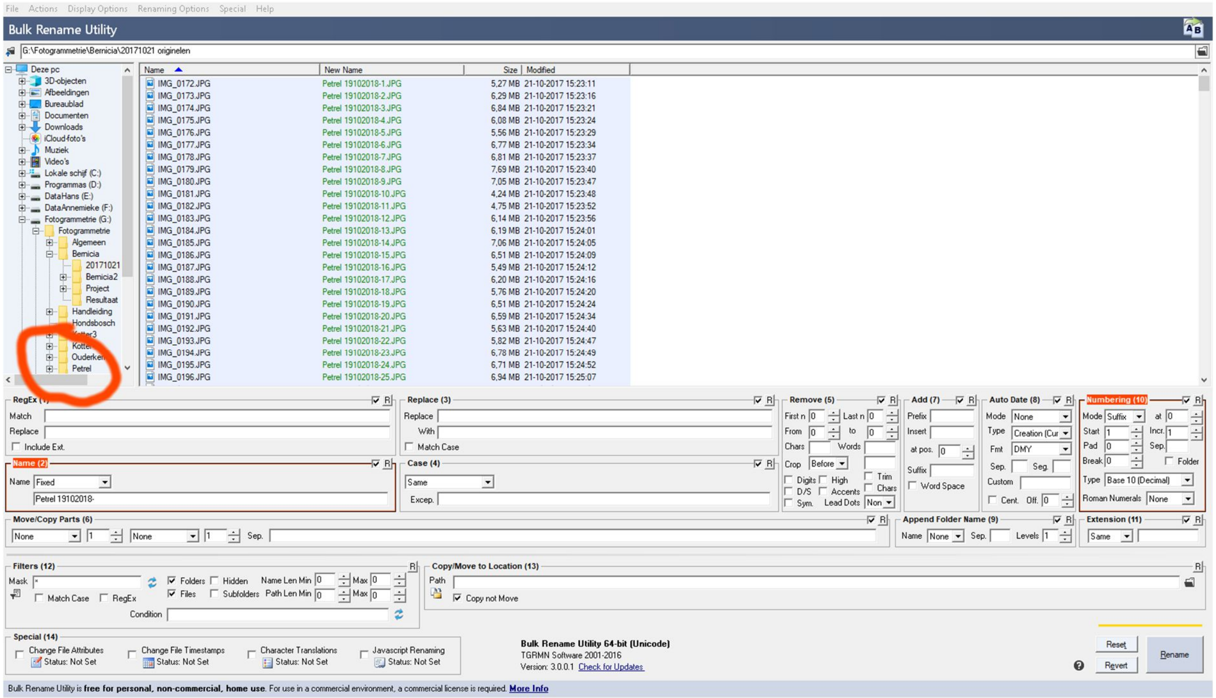


9. give the type (jpg) and the quality (always 100%!)

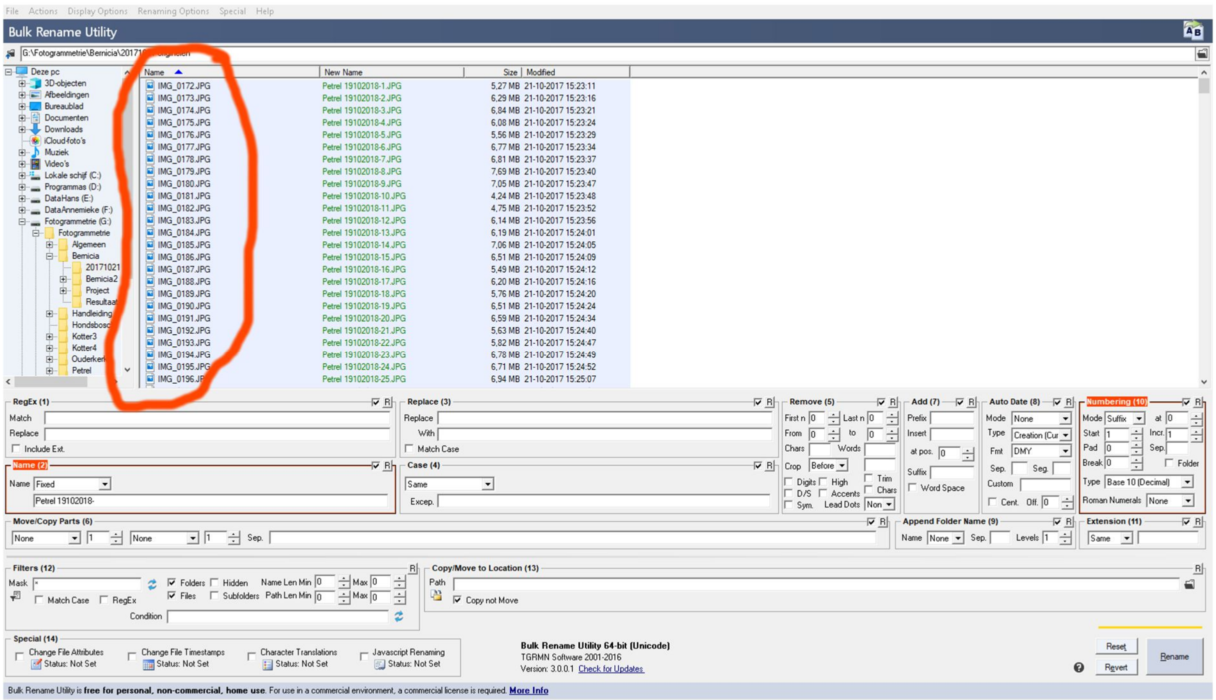


10. Go back up and select ‘Animation’

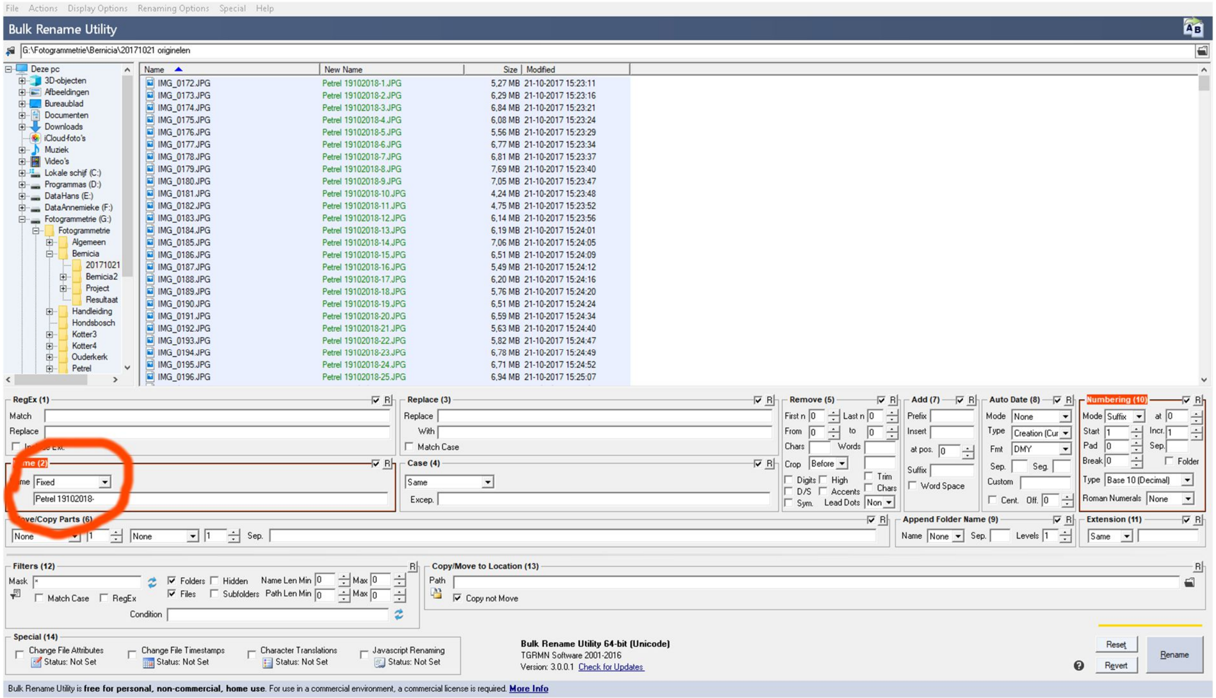
Short manual for Batch Rename Utility



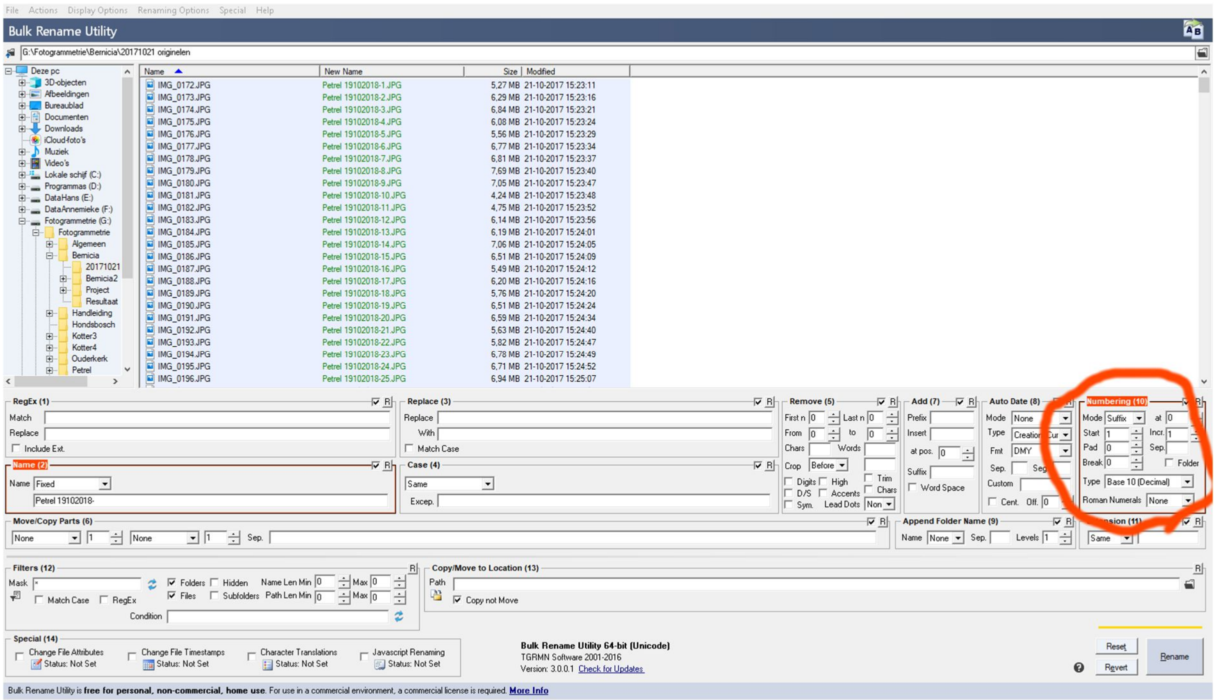
1. Select the map with the photos.



2. Select the photo's.



3. **Give the photos an recognizable name and perhaps date.**



4. **Add a number to each photo**

At each step you see the result in the second column.
Press 'Rename' bottom right and ready!