A User's Guide to 3DCombine Beta

based on V6.191 (64 bits) Professional

3rd edition

Theo de Klerk

Acknowledgements:

Some illustrations contain scenes from ITV's series "Stingray" and "Thunderbirds" which are the favourite puppet marionation series of the author, created in the early 1960's and definitely only in 2D.

The author of this user's guide is not associated with the makers of 3DCombine in any way.

If by reading this guide, you find inconsistencies or errors, please report them to the author so they can be corrected for the next (online) edition of the guide: theo.de.klerk@gmx.com. Of course praise is also welcomed.

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Part 1: The Setup

Introduction to 3DCombine

To have 3D or make 3D?

3DCombine serves two purposes:

- given any left/right eye pair of images (or movie) combine them to a stereo image (or movie) in a variety of output formats
- given a left channel 2D image (or movie) and an associated depth map, create a stereo image (or movie)
- given a left channel 2D image (or movie), create a depth map and combine the two to a stereo image (or movie)

Most users of 3DCombine will be using the application for the last option as that makes 3DCombine rather unique in the stereo world. The other two options (at least for single images) are also served by other applications, most notably the Swiss knife application "Stereo Photo Maker".

This guide focuses on the third option: create stereo impressions from flat images or movies. But keep in mind that some options offered by 3DCombine are specifically aimed at the first two options where mostvof the stereo information is readily available and used.

In some cases stereo images are presented in an anaglyphic way: it requires a red/cyan pair of glasses to see them as stereo image.

Creating depth illusion

If you have a left and right eye image, the only thing to do (and 3DCombine can do that for you) is to combine the two into some output format giving a stereo impression,

But if all you got is "flat" 2D, 3DCombine can create a stereo image using depth maps or creating them based on information in the flat image.

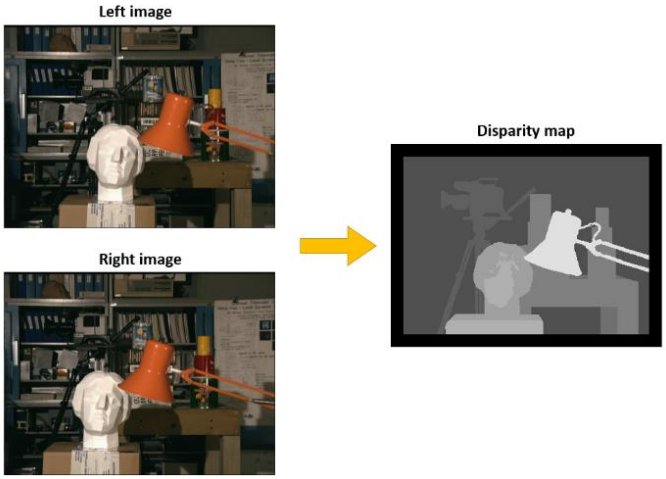

A depth map is nothing else than a grey tone image with distance information turned into a grey shade. White areas indicate "nearby" and black areas "in the far distance". Combining such a map with the colour image the application can construct a stereo image with a left and right eye picture. Both pictures are slightly different, in the same way as your left eye perceives objects from a slightly different position as your left eye. The difference, the parallax[1], provides depth information to your brain. Nearby objects have a greater disparity than

[1] also called "disparity" in 3D image literature

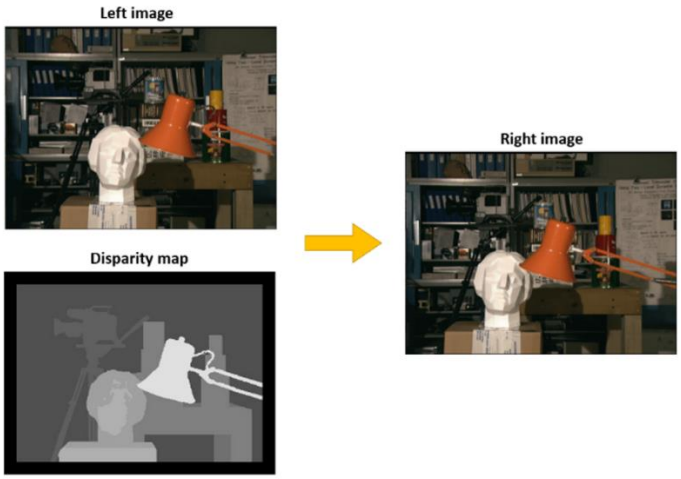
more remote objects. In addition, the available perspective in the 2D image helps to enhance the illusion in 3D.

3DCombine to convert 2D to 3D

If both left and right eye image are present, a disparity or depth map can be created that shows the difference in position of the various objects between both images.



If only a 2D flat image (like the left image) is available, 3DCombine analyses the image and using fuzzy logic routines makes assumptions on what the depth map should look like. Having the left eye image and a depth map, the right eye image can be reconstructed and stereo vision is restored. This is illustrated in the figure below. For a movie it does the same as for an image – a movie is nothing else than a sequence of images: a motion picture.



The assumptions are often quite good but never as good as the depth map made from a left and right eye image. On a single image an object will block other objects that are behind it. But with two eyes the blocked area is slightly different for each eye. Hence the “made up” stereo image must fill in these revealed areas - mostly by assuming it looks like the visible environment and it copies a few pixels from that environment into the revealed area. And that’s where “make believe” replaces reality.

3DCombine can run in two modes to create stereo 3D from flat 2D:

- For most, the use of a “Guides” wizard type conversion will suffice. These are discussed in Part 2: Basic operations.
- For those the want to tweak the input a bit and be in full control, the use of filters and manual steps of the process are available. These are discussed in the other parts of this document.

It all starts by opening one or more 2D images or a movie file.

Producing depth maps and creating a 3D image takes computing power. Therefore converting a movie using the basic methods, may take upto 5 to 8 times its running time[2]: an hour of movie runtime can take 8 hours processing time to produce a 3D equivalent. Using a more thorough approach through manual steps, may take 18 to 30 times as much time as the running time of the movie.

> In this respect 3DCombine takes a different (and more credible) approach than many instant 2D-to-3D converters in stereo tv sets and projectors or offered as “professional” software. They often only apply a horizontal shift of left and right image (disparity), creating a window behind which the (flat) scene is positioned. A standard depth map (somewhat leaning backwards suggests a nearby bottom and remote top of the image) may enhance the depth effect.

Preview the 3D result

Whether you provide a stereo image or have it created by 3DCombine, you can apply filters to it that modifies the stereo image. Certain filters may work well for certain situations but not for others. It is therefore a question of finding the right filters and/or conversion method for a specific image or movie. The “Preview 3D” allows you to see the result of your choice.No need to wait until a lengthy output production process completes.

For single images the “Preview 3D” mode almost immediately (less than a second) shows you what effect certain settings and filters have on the input. You can change or modify these to obtain better (conversion) results.

Movies are done the same way. Each frame is shown the same way as an image but as a movie it seems to run in slow motion. Each image frame change takes almost no time to process but with 24 frames in a second of movie running time, it takes 24 times as long. A 90 minutes movie x 24 frames per second adds up to 129,600 frames. With 0.2 second processing per frame, this still requires 7.2 hours!

For movies there is also an option to use the preview “Save Video” button and create the output file. But rather than running it to completing, taking a lot of time, you may abort the process after a few seconds of output and inspect the resulting movie. If it is not to your satisfaction, use other settings and try again.

[2] See Appendix B: Bitrates on page 100

The ”Preview 3D” button alows you to preview the result in various ways, depending on how you want to use the final 3D conversion output.

Some of the most used choices are:

- Various Anaglyph – differently coloured picture for left and right eye that can be viewed (printed) on paper or screen using a pair of glasses with the right colours (red/cyan, yellow/blue or magenta/green). The true colours are somewhat distorted but the depth effect is easily seen
- Parallel – a popular full colour left and right image positioned next to each other. Also known as “side by side”
- SBS/Sensio – similar to parallel buth with images squeezed by factor of 2. Used for stereo tv sets and projectors to fit the left/right pair together onto the 1920x1080 pixel sized screen. Also known as “Half Size-by-Size”. At projection the two 910x1080 pixel images are horizontally stretched to give a full 16:9 aspect ratio stereo image.
- Above/Below Full – similar to parallel but with images positioned on top of each other. Also known as “Over-Under”.
- Above/Below Half– similar to SBS/Sensio, but left and right image are positioned on top of each other. Only for tv set and projector use. Also known as “Half Over Under”. Each left or right image only has half the height (540 pixels) and full width (1920 pixels).
- Cross eyed – similar to parallel, but images are ordered right-left. You need to train your eyes to look cross eyed to see the correct picture in each eye. Some find this easier to do than parallel viewing.[3]

Examples are shown online at
https://www.3DCombine.com/Formats.html

Save the result

When satisfied, you save the result in an output file, using the selected Preview 3D option described above, by clicking the “Save Image” or “Save Movie” button. The chosen preview mode therefore is also the type of output you choose.

3DCombine normally runs to completion without problems. In my experience it did not fail once for a length of 9 consecutive days converting movies without restarts. But it fails silently when the output device is full. And this may happen if you ignore the fact that the output files can be much larger depending on the type of save you choose. A 22 GB ripped movie could become 220 GB. You need to have that space available.[4]

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[3] Put your finger at the middle of the left/right image. Move your finger to your nose and keep focussing on the finger. Lower the finger and you should see the cross-eyed image.

[4] see Appendix B: Bitrates on page 106 for enlargement factors

Depth map limitations

Depth maps may be very useful but also have their limitations. They are created by inspecting the flat image using algorithms of neural networks and fuzzy logic. It's not perfect and sometimes it makes the wrong assumptions. It is expected that with increased understanding of artificial intelligence and self-learning patterns a number of these limitations will be reduced or eliminated in future.

For single images, the problems can be manually corrected by changing the depth map grey tones for the troublesome areas or editing the final left/right eye images.

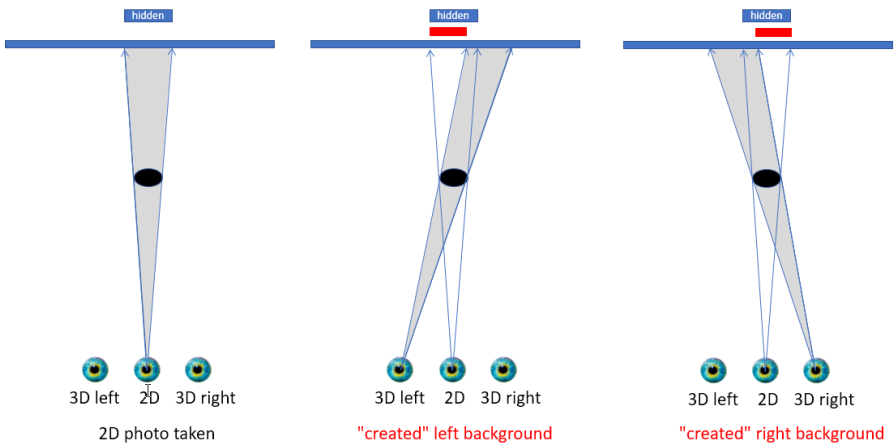
For movies the correction of the depth maps requires a lot of work because of the number of frames involved – or the use of some "average" correction for a whole scene.

An unavoidable challenge posed while creating a depth map is that some information must be added to the background that does not exist in the 2D image. The errors created by the conversion cannot easily be corrected.

Look at the illustration below. At the left it is shown how the picture was taken of a black object against a background. The part of the background hidden behind the object is indicated as a blue "hidden" range.

Creating a depth map, the algorithms try to create two slightly different pictures, as if seen by a left and right eye, revealing some background that isn't present in the 2D image.

The two areas revealed are shown in red in the figure below. To fill this area, the contents of that area has to be "made up" - usually by cloning some information of a nearby area. This may go unnoticed, is very subtle, but if not, it spoils the stereoscopic illusion. Those situations reveal artifacts of the algorithm calculations.



It is up to the algorithms to determine what information is coloned, and where from. Some errors can be reduced or removed by a more accurate depth map. But if that is correct, the final cloning is not

something you correct easily: it will require editing the resulting left and right eye image with an image editor. Frame by frame.

Some of the limitations and problems with depth maps you may see are listed below:

- Some objects are calculated/guessed at the wrong distance. This can be noticeable especially in well known forms like human bodies. The image below shows a body in winter coat lying in the snow. The dark coat seems to be loose from the snow on the coat. This can be repaired by adjusting the depth maps – by different filters or manually on the depth map movie.

In the image below, notice how the remote astronauts cheek is at the wrong distance due to a microphone holder of the astronaut in the front.

The head of Lady Penelope seems to come too much to the front and seems not entirely to fit on the neck.

In stereo movies they give a “this cannot be true” experience where the depth illusion is severely disturbed.

- Backgrounds hidden by an object in 2D are not entirely hidden looking by the left eye or right eye. The revealed area is “cloned” from information nearby. This may result in artifacts. Often the cloning goes unnoticed but on occasion the algorithms produce visible artifacts. In a moving picture many areas become revealed or hidden from frame to frame. The algorithms work on a per-frame basis and do not look ahead or backwards for better cloning between frames.

  The cloned artifacts can be small (see right side of penguin in the middle picture below, taken in Hobart, Tasmania) although the eye quickly picks up on “odd” and “unexpected” edges.

Sometimes they really are disturbingly present such as below with an arm near a window.

The one-time James Bond has artifacts at the back of his head to fill in the missing bits of the door.

or got some extensions to his ears – again in an attempt to fill the door behind him.

- Deformation – algorithms need to clone and reposition nearby objects. This may result in crooked lines that are supposed to be straight. (see flag pole in picture below, taken in Hobart, Tasmania). In movies this may result in a wiggling picture as

the deformation may change from frame to frame. This deformation can be reduced if the calculated depth is not applied only to the right eye frame but distributed ("warped") over the original left eye and calculated right eye frame.

- Harry Potter effect – flat (photo or painting) images are also interpreted as having depth, just like the moving objects in the news papers and wall paintings in Harry Potter's world. The picture below shows some astronauts on a television screen that is not a stereo screen.

In movie frames (and a movie has many frames – 24 for each second) manual correction is a labour intensive work. It explains why hundreds of people are involved in the post-processing of a 2D movie to create a 3D movie. But 3DCombine does allow some work on depth maps of key frames and "tracks" the changes to the next movie frames to the next key frame with a corrected depth map. You can also output a depth map movie first, edit it (per scene with a video editor) and then recombine movie and repaired depth map to output an improved stereo movie.

Some of these artifacts can be reduced when you apply one or more filters on the image before saving the result as 3D output file. Filters are described in Part 4: Creating Or Improving 3D Effects. But ultimately any remaining error can only be corrected on the produced left and right eye images through an image (or capable movie) editor.

This is where the hundreds of post-processing stereo workers come in for commercial movies.

Installation

The installation of 3DCombine is a no-brainer. You copy the installation file from the application web site https://www.3DCombine.com/ . The application is initially free to use for 16 days to see if it fits your needs.

During installation it checks if the required runtime C++ libraries are installed. If not, it offers to install these too.

Registration is done if you decide to purchase the application. After the trial period it reverts to a "free" application with limited capabilities – none of which are allowing you to use what 3DCombine is supposed to do: generate still stereo images or stereo movie frames.

Use your graphics card processor

You may wish to ensure your video card hardware is used in the conversion. See https://www.3DCombine.com/page6.html on the 3DCombine FAQ website on how to do this if not automatically used.

Alternatively you may look in the Task Manager's listing to see if the GPU is used for 3DCombine.

3DCombine (2)	66.9%	294.4 MB	0.1 MB/s	0 Mbps	1.9%	GPU 0 - Video Encode

The 3DCombine FAQ page will tell you the following:

If your NVIDIA GPU supports hardware H265 video encoding it will be enabled automatically when saving compressed AVI or MP4 files. You can check for this in the about box. It will say 'hardware video compression available.'

Certain nVidia GPUs can be used to accelerate the intellgent 2D->3D conversion mode in 3DCombine. Known supported GPUs are RTX2080; RTX3080; RTX4070TI . This should be considered an advanced user operation. These instructions are valid for 3DCombine v6.181

- Download and install https://developer.nvidia.com/cuda-11-4-0-download-archive (to get the right version select Windows, x86_64, 10)
- Download and install https://developer.nvidia.com/rdp/cudnn-download (free nVidia sign up required).
- Select *Download cuDNN v8.2.4 (September 2nd, 2021), for CUDA 11.4* from the *archived cuDNN releases*
- Download the https://storage.googleapis.com/tensorflow/libtensorflow/libtensorflow-gpu-windows-x86_64-2.7.0.zip and replace the *tensorflow.dll* file in the 3DCombine installation folder.
- If uncertain how to install CUDNN, this guide at https://medium.com/geekculture/install-cuda-and-cudnn-on-windows-linux-52d1501a8805 may help. Information on how to edit environment variables can be found in

https://www.3DCombine.com/dload/3DCombine%20GPU%20additional%20instructions.pdf.

- Open 3DCombine and generate an intelligent depthmap. Open the about box. If successful this will report 'GPU acceleration available'. Note that this will disable usage of the GPU for video compression when active.

Quick receipe for images and movies

If you want to use 3DCombine directly to create a stereo image or movie (nothing but a large number of images) first without further ado, these are steps to follow. You can skip reading the rest until you find you want to tweak the program a bit to obtain better results:

1. Load 2D image or movie (File > Open image(s) > 2D (Left)) or File > Open video > 2D (Left))
   Select an image or a movie.
   In case of a movie, for first tries, pick a short one since processing time will be around 20 times the movies running time.
2. (Optional and for movies only) You may want to read the next section to make sure the movie has the right aspect ratio and resolution
3. Click on the "Depth" button on the toolbar ribbon and select
   a. Create Depthmap
   b. Processing Depthmap (option "maximise")
   c. Make 3D (select depth 2.0, yes to high quality, yes to warp left/right)
4. Click on "Preview 3D"
   a. Select type of output (Parallel, Anaglyphic or if aimed at a stereo tv: SBS/Sensio)
   b. Click "Save image(s) or "Save video" and specify output name. Select the type of output – this heavily influences the size of the output file.[5]
5. In case of a movie, sit back and wait for the process to complete (may be 20-30 times the running time of the movie).
6. View the result and read this manual to see what can be improved and how.

Do you need more output versions of the same movie? Consider whether you can convert the output file into the other formats. That's almost always quicker than re-entering the process of making and interpreting depth maps. For example:

- Use parallel output to also create frame-packed SBS, SBS/Sensio (Half-SBS) or anaglyph
- Use SBS/Sensio for anaglyph

If you require several output types, it is best to produce a video output first in an untampered manner, preferably Parallel. From this output

[5] See Appendix B: Bitrates on page 106 for increasement factors

format you can create all other types such as anaglyph or Sensio or Vuzix or other formats that lose information in the conversion.

To create these additional outputs, you first open the Parallel file through the menu File > Open Video > 3D and go straight to “Preview 3D” and select the other output mode and click “Save Video”.. Alternatively, you can do such things through special video editors.

Things to think about with movies

To convert still images with 3DCombine there are no real restrictions: images can be any size. For movies, restrictions apply for the output to be useful for the target devices on which you want to show them.

A 2D movie version must fit aspect ratio

If you want to create a stereo movie for tv set or projector, you need to ensure that the source material fits the current television widescreen aspect ratio of 16:9 .

Old movies are likely to be in Academy format with aspect ratio 4:3. You need to create a new version of the movie that has an aspect ratio of 16:9. This means that the 4:3 image is embedded in the middle of a 16:9 image. It is surrounded by black bars on the left and right side of the image, centering the 4:3 movie picture (known as “pillar box”). Common widescreen resolutions (all 16:9 aspect ratio) are 1920:1080, 1440:810 and 1280:720 pixels. 3DCombine has the Tweak > Smart Pad filter to do this (before any depth filters are used).

Academy Format 4:3

Widescreen 16:9 (added pillar box sides)

Old PAL/NTSC formatted widescreen movies (usually ripped from DVD) are not acceptable widescreen. In fact they are 4:3 movies where the image pixels are horizontally stretched to fill a wider screen (called anamorphic widescreen). For 3DCombine to produce something useful, you must first convert these widescreen images via a video editor to proper 16:9 widescreen where no pixel is stretched. 3DCombine has no such filter to do this for you.

These anamorphic widescreen movies from DVD have 720x576 (for PAL) or 720x480 (for NTSC) pixels and are best converted to the nearest acceptable bluray format of 1280x720 pixels. As widescreen image, they will not have letterbox or pillar box black bars in their frames.

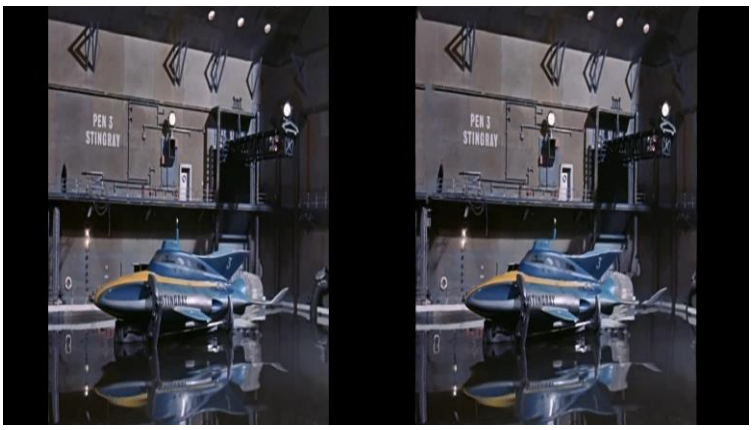
Movie output choice

Clicking on “Preview 3D” allows you to select one of many types of stereo output – from parallel to anaglyphic. The choice you make before hitting the “Save Image” or “Save Video” button, is the type of stereoscopic output you will get. Which one to choose?

SBS/Sensio - Stereo movie or stills for tv or projector

If you want to show a stereo image or run a 3D movie on a stereo television set or 3D video projector, remember that these devices are using an aspect ratio 16:9, often by 1920 x 1080 pixels resolution, in “Full High Definition” size. The width of the left/right images needs to fit the 1920 pixel width.

Use 3DCombine’s output setting “SBS/Sensio” to create a horizontally squeezed image to aspect ratio 8:9 (usually 960x1080 pixels). Positioned next to each other they fit a 16:9 (often 1920x1080 pixels) image. It’s called “side by side” but really is “half-side-by-side”.



The stereo tv set or projector must be set to use the 3D “Side by Side” (SBS) mode to show the image or movie properly.

Parallel - Stereo movie and stereo still images not for tv or projector

Selecting the first Preview 3D option “Parallel” results in two frames where left and right have the right proportions and are positioned next to each other.

This is useful in two situations:

- you have a pc graphics card that can output left and right image to different channels, each connected to a video projector that can play in normal mode. Using polaroid filters you can project both images on a metal screen and watch

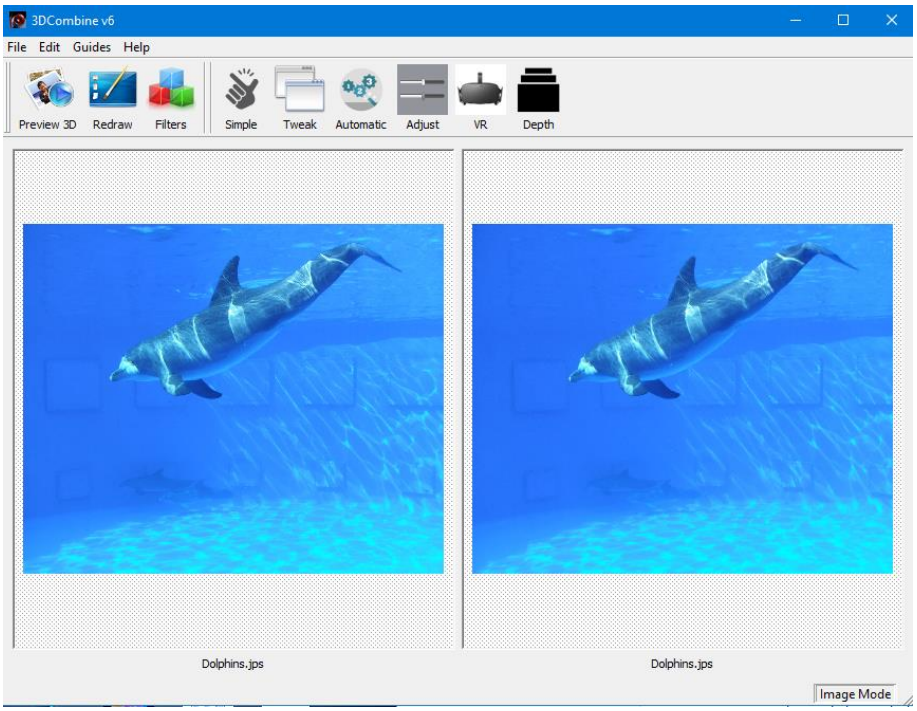
stereo images using polaroid glasses. It's the cinema way to project stereo movies.

- you use the output file to create a full sized .mvc output file (packet framed) through a capable video editor and use those files to create a regular 3D bluray disc.

Part 2: Basic operations

The 3DCombine interface

The user interface shows itself when you start the application from the Start menu or an icon on the desktop.



The two main components are the menu bar (File, Edit, Guides, Help) with button ribbon below it. The largest part of the interface is taken by the two images (dolphins at startup) that show whatever it is you imported into the application or what the application generates.

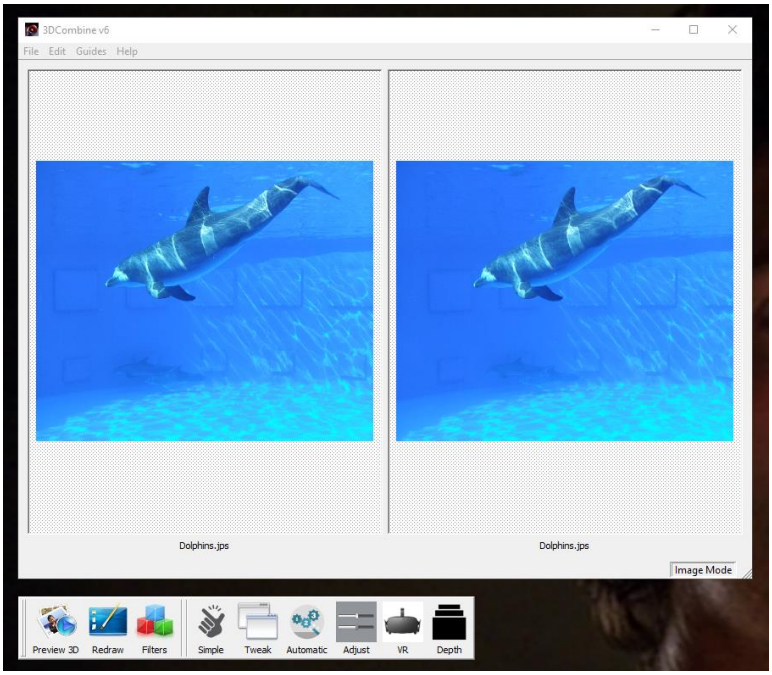
Keep in mind that 3DCombine is suitable for already-stereo (input left/right images, left image/right depth map) as well as 2D to convert to stereo (input just left image).

Whatever you intend to do, such as applying filters to images or using depth maps and applying those to images, always use the “Preview 3D” button in parallel or anaglyphic mode to inspect the result of your conversion and determine if it is useful for you. Go back and change settings if the result is not what you want. Only when totally satisfied, use the “Preview 3D” setting with the “Save Image”/”Save Video” buttons to save image or movie.

Button Ribbon

The buttons ribbon can be unlocked and positioned elsewhere. If you click on its double-lined left edge, it becomes unhinged and you can

position it to another side of the interface or completely separate of it – even outside the interface.

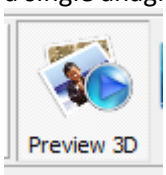


For basic operations, you will mostly look at the “Guides” menu option. The other buttons and menu options are invoking more advanced features that usually also take a lot more processing time. 3DCombine tries to strike a balance between fast (less accurate conversion) and dead-slow (accurate conversion) in the choices between “basic” and “advanced”.

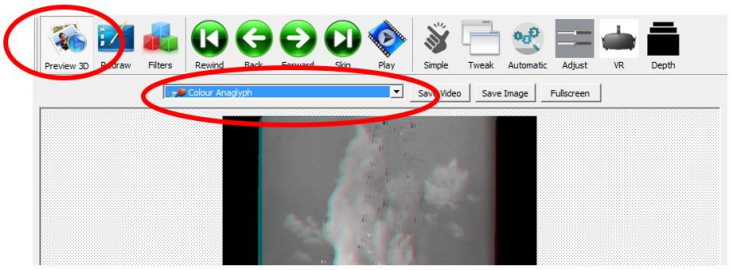
Preview 3D Button

The “Preview 3D” button shows the impact of the chosen conversion filters and also determines the output format Use this preview to modify your settings to make the best possible 3D conversion before you actually save the results.

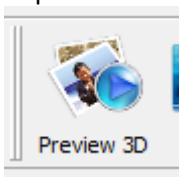
- When clicked (button looks pressed in) the image is shown as the 3D output specified. That may be 2 images side by side or a single anaglyphic stereo image.

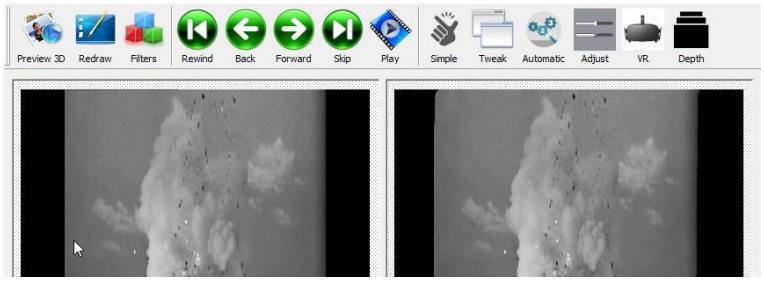
  

  Any filters that are applied are shown in the preview window.



- When unclicked the left and right images are shown separately. There is no processing done and the two images show the "raw material". This can be the opened left and right images or the left image and corresponding depth map (either imported to calculated)





For a closer look you can preview full screen by clicking on "Full Screen" button. Any mouse or keyboard click will revert you to the usual application interface size on the desktop.

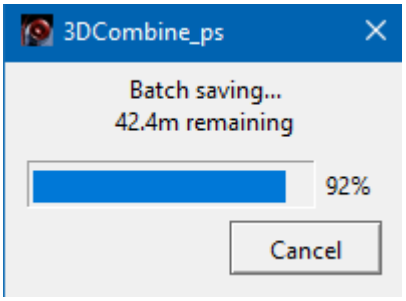
Redraw button

Redraw refreshes the images in the left and right panels. This can be useful if you've resized the window and want to resize the images displayed to match. 3DCombine is not so smart to always resize the images when you change its window size.

Cancel Button

Once you clicked on the "Save image" or "Save Video" button, a small progress window is shown and the preview images move from frame to frame showing the progress.

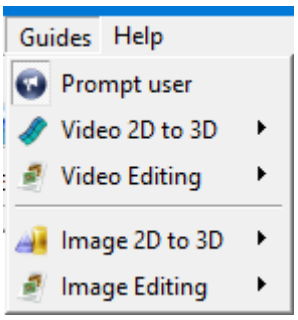
The small progress window has a "Cancel" button. When clicked, the current operation is stopped and the output file closed (but kept with whatever part of the movie or set of images is processed). This button is also useful to have 3DCombine produce a small part of a movie that can then be inspected using a video player.


3DCombine_ps
Batch saving...
42.4m remaining
92%
Cancel

Guides: “wizard” usage

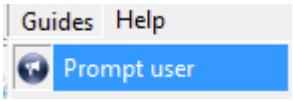
3DCombine makes it easy to quickly start using the software. Once you get more familiar or more demanding you can venture out in using the manual options.

The “Quick Start” method is to use the “Guides” menu option that works like a set of wizards, making some decisions on settings that work well on average. Later you may decide to take things in your own hand and use a more manual process. That process may result in better pictures but in case of movies also prolong the processing times upto 20 or 30 times the movies playing time.

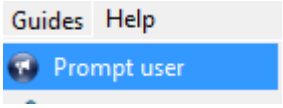


The guides help you to create a stereo movie (video) or still image with reasonable assumptions and balance between processing time and quality..

By default guides prompts are enabled. This is seen by the clicked-in appearance of the Guides > Prompt user menu button.



Disable prompts by unclicking the button (background becomes blue again).



Using the Guides, the final step each time is using the “Preview 3D”button. It shows you what the guide steps will produce.

Restart the guide with different settings if you’re not satisfied. If you are, the “Preview 3D” also has the buttons to “Save Image” or “Save Video”. This starts the 3D generation process and stores the results.

There are Guides for images and video. Basically they do the same thing. A movie is but a large set of images after all. Still, the Guides mention them both separately so we will look at each individually.

Some sample image files are found on the system drive in folder

`C:\Program Files\3DCombine v6\samples`

Still Image 2D to 3D

Open one or more images

Everything starts with the opening of an image file. One or more. This is usually the first step in any “Guide” mode. Otherwise you need to perform this step manually.

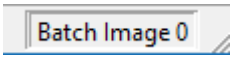
An image is loaded into 3DCombine through its menu File > Open image(s). You can enter the name of a single image file or select multiple files. (as block using the SHIFT key while selecting first and last image, as individual images by using the CTRL key while clicking on each selected image). Multiple images will eventually be processed as batch job.[6]

When in batch mode, two additional buttons appear in the button ribbon that allow you to move to the next or previous image.

If you are on the first or last image the “Back” and “Forward” buttons respectively, remain active but when clicked stay on that first or last picture.

When you use “Preview 3D” and its “Save Image(s)” button to create an output, 3DCombine will either ask for the output file name or for a folder if multiple images must be processed as a batch. Such batch jobs are limited to images stored in a single folder and the results are also written to (another) single folder.

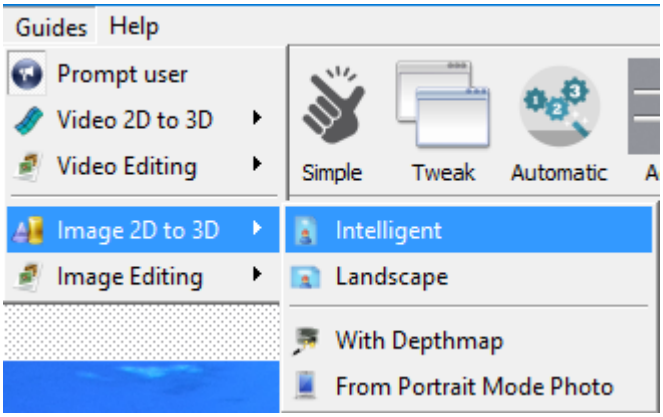
Look at the bottom righthand corner to see which image it is currently processing if you have a batch of images to process.



Use a Guide

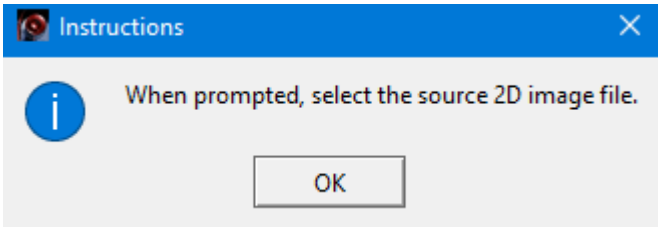
Once an image (or set of images) is loaded in 3DCombine, you use a “Guide” to convert the image to a stereo image There are several Guides available, listed in the menu.

[6] a movie is also an image batch job: each movie frame is handled as a single image

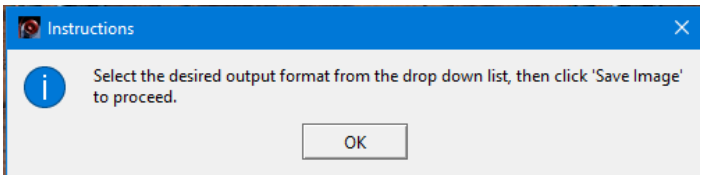


Intelligent

If you select the "Intelligent" process, the application handles all the steps. You only indicate the image file to process.



Next you specify the format for the output file – usually parallel, side by side or anaglyphic.



Next click the "Save Image" button, specify the output file specification and sit back a few seconds for the output file to be created.

(This activates the Depth "Auto 2D > 3D Intelligent" filter)[7]

Landscape

Identical to "Intelligent" but with a different algorithm that is more suitable for wider pictures while still producing eye-pleasing stereo effects. Landscape mode is for photos of landscapes, e.g. mountains, trees, fields etc as opposed to referring to the orientation of the image.

(This activates the Depth "Auto 2D > 3D Landscape" filter)[8]

[7] This guide can be manually be set by selecting "Depth > Auto 2D > 3D: Intelligent" filter. We'll indicate this manual choice with each Guide
[8] This guide can be manually be set by selecting "Depth > Auto 2D > 3D: Intelligent" filter. We'll indicate this manual choice with each Guide

With Depthmap

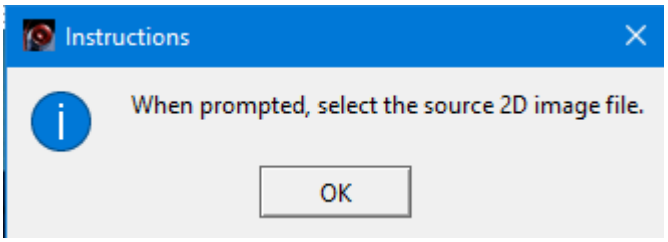
This Guide requires the input of an image and the depthmap for this image. 3DCombine does not create the depth map in this case: you provide it because you made it yourself or got it from some other means. Some smart phones can take “portrait” pictures that have a depth map hidden in the image. Usually because the smart phone can upload such images to a social media platform that allows “3D images” based on (internal) depth maps.

Using a depth map for a stereo image

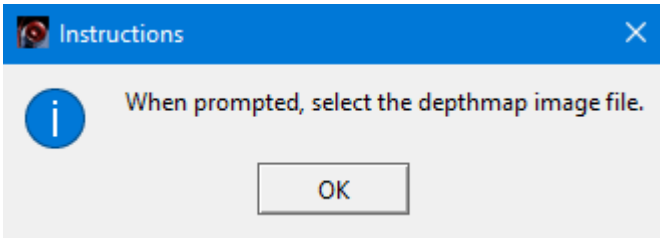
This choice allows you to specify a 2D image as left side image and a depth map as right side image.

3DCombine will use both to create stereo pair by creating right eye image based on the left image to which a depth map is applied. Together the give the stereo depth effect.

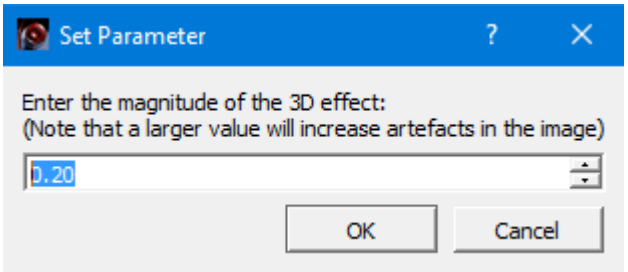
When this guide is selected, it first asks you for the 2D image as left image.



Next it requires another file containing the depth map for this image. If you need to create it, read how to do this further down this section.



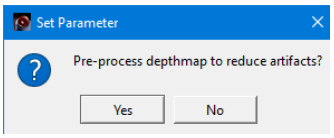
Next you need to specify the depth (disparity between both images). The suggested value of 0.20 is a good one to start with.

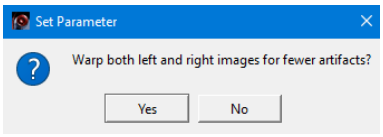


One but last step you need to choose whether to perform some post-processing which may or may not improve the final result. You can skip both options but applying them gives better results but takes a lot more processing time.

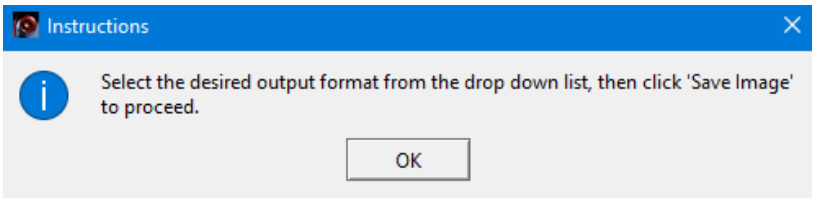
The first question determines the amount of time 3DCombine uses to fill in details not available in the 2D image but needed in the 3D image.

The second question determines whether all depth changes are applied to the generated right image or whether they are distributed over both images. The latter makes for a more believable output where the artifacts created are less noticeable.





Finally, indicate what type of stereo image the final result must be: usually parallel, side-by-side or anaglyphic.These are the options given through the “3D Preview” button.



Click the “Save Image” button and store the result in a file.

(This activates the Depth “Make 3D:02” filter)[9]

Creating a depth map for a flat image

A depth map is a grey tone image overlayed with the 2D image. The grey tones indicate the virtual distance of an object on the 2D image to the viewer. A white area indicates nearby, black means far away. Grey tones are somewhere in between.

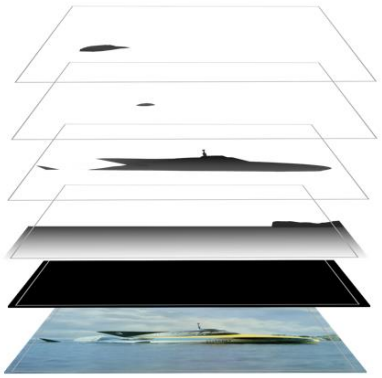
To create a depth map for a 2D image, you need an image editor that can work in layers. PhotoShop, PaintShop or the freeware Gimp are suitable editors.

For Gimp a set of macros has been defined as “DMAGn” (n=1 to 9) by Ugo Capeto. A single grey coloured stroke over an object and the macro will fill the entire object with that shade of grey. For a quick way to make a depth map see appendix Photo editing on page 116 for details.

For the manual method of making one, read on.

An example of the process is shown in the illustration below. At the left you see a stack of grey layers made in an image editor. The white parts in the top layers indicate transparency. Looking from the top down you see a single depth map with shades of grey in each layer, as illustrated at the top right. Because higher levels cover the darker lower levels, those top layers can paint over the lower ones.

[9] This guide can be manually be set by selecting “Depth > Auto 2D > 3D: Intelligent” filter. We’ll indicate this manual choice with each Guide



Combined with the 2D photo at the bottom right, a 3D picture can be created, as shown in an anaglyphic format in the figure below.

The steps to undertake to create a depth map in an image editor, are the following:

- Open the layer-capable image editor for the image
- Create a new transparent layer on top of the image
- Select (almost) white as brush colour and cover all nearby parts of the frame white
- Make the current layer invisible and create a new layer higher up the layer stack. Select a somewhat more grey paint colour and cover all parts that are a little furter away with this grey shade. You can paint over the earlier whiter coloured layers parts – in the end that won't show.
- Repeat this for as many shades of grey as you want to include.

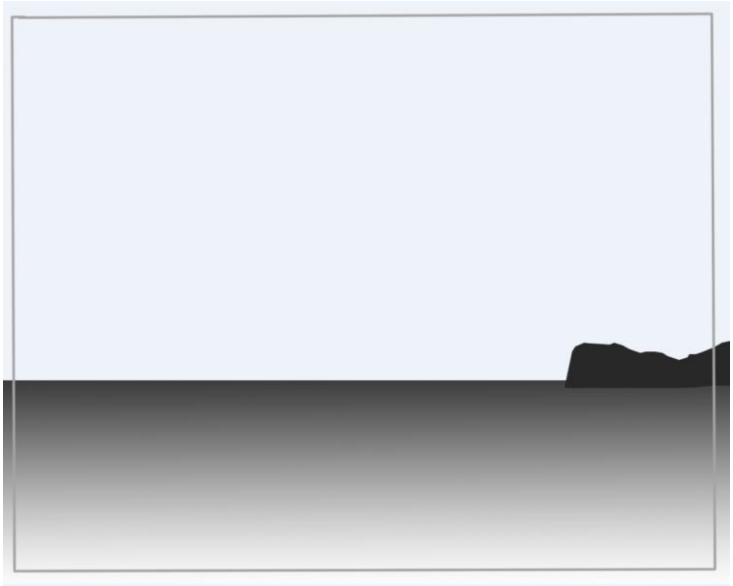
- The final layer is an image-filling black colour
- Enable visibility of all layers.
- Re-arrange all layers upside-down. That is, the first layer (with white) goes on top of the layer stack. The last layer (entirely black) goes on the bottom and covers the entire image.
- The result should be a greytone image, a depth map, of the image while the image itself is totally covered and invisible.
- Save the file with its layers in case you want to correct it later using the image editor by adding layers or modifying existing ones.

If the image is a frame from a movie, 2D Combine has created depth maps for what it considers key frames itself in a folder. You can replace those depth maps by your own:

- Save the image again as a flat "depthmap_*nnn.*bmp" file in the same folder as where 3DCombine stored its own depthmaps. You must adhere to this naming convention. Do not use leading zeroes. So use "depthmap_3.bmp", not "depthmap_003.bmp". Other formats as .jpg are also allowed, but .bmp are lossless and better for accurate depthmaps.
- Repeat these steps for all key frames.

Where areas gradually disappear into the distance (like a sea surface or road), you should not use a single grey tone (which indicates a fixed distance) but rather a gradient running from one lighter grey tone (suggesting nearby) to a different darker grey one (suggesting further away).

The second grey layer in the illustration shows how such a gradient is needed to give the sea level the depth from front to horizon and the rocky shoreline at a fixed distance. It is shown again in the illustration below.



Consult your image editor manual or help files to find out how to do this in your image editor.

From Portrait Mode Photo

Intended for use on photos taken with a mobile phone that has "portrait mode" available. This mode blurs the background around the object. The phone software figures out what the background parts are and has a depth map as part of the picture. 3DCombine neeeds to access this depth map to use it to produce a 3D image.

Using the "Guides" option Image 2D to 3D > From Portrait Mode Photo will perform all steps necessary to produce a 3D image you can preview and save into a file if you want to.

The Guides choice actually performs a number of manual steps as a single routine:

- Open the portrait photo using File > Open Image(s) > 3D.
- This results in the picture at the left and its depth map at the right.
- From the "Depth" button use "Make 3D" on the menu that opens.

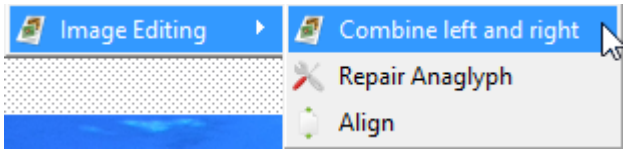
An online tutorial is found at https://www.youtube.com/watch?v=MjqFpKpysDQ&t=1s.

(This activates the Depth "Make 3D:02" filter)[10]

[10] This guide can be manually be set by selecting "Depth > Auto 2D > 3D: Intelligent" filter. We'll indicate this manual choice with each Guide

Image Editing

This Guide is meant for adjusting some of the aspects of an image before processing it to a stereoscopic image. In part this is similar to the manual process of an image.



Combine left and right

Given a left and right image, it is combined to a stereoscopic image. Similar to the manual loading of both images (File > Open Image) and subsequent combining to 3D applying the “Depth” Make 3D filter.

Repair anaglyphic

Similar to “Automatic” Repair Colour Anaglyphic filter. Converts the anaglyphic stereoscopic images back to a full colour stereo image to be output in the desired output format.

(Activates filter Automatic > “Repair Colour Anaglyphic:0”)

Align

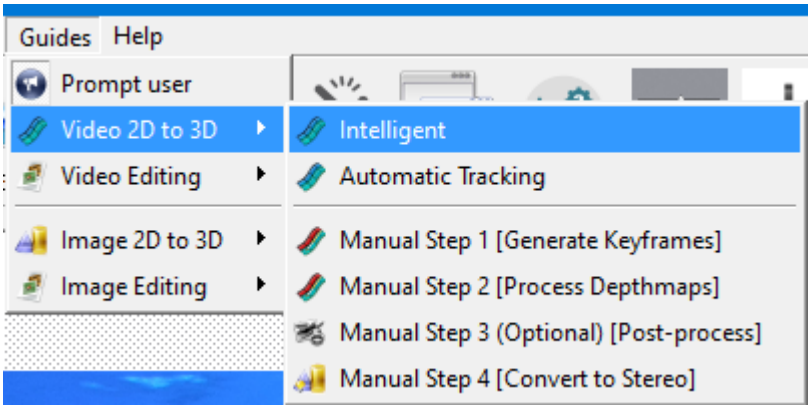
Similar to “Automatic” Automatic Align filter. Corrects misalignment and exposure of both images.

(Activates filter Automatic > “Automatic Align: nn” with nn the number of pixels as align value)

Video 2D to 3D

A “wizard” type approach to create a stereo movie, you follow the menu options listed under “Video 2D to 3D”. If you’re just looking for a receipe to follow, you might jump to section Quick receipe on page 17.

The guide options for creating a stereo movie are listed in the menu.



In fact is movie conversion the same as batch processing of images. The filters used are the same therefore.

The source file must be suitable for its purpose. If a 3D tv set or projector is targetted, ensure the input file has the high definition aspect ratio of 16:9 – and preferably the exact pixel size of 1920 x 1080 pixels. If it is not, you may want to apply a filter first: Tweak > Smart Pad that will change the resolution to (e.g.) 1920x1080 pixels required for HD tv and provide black bars horizontally or vertically where needed.

Online tutorials are found at

Introduction to 3DCombine 6 - YouTube (general introduction)

Convert a 2D movie to 3D in 3DCombine - YouTube (different Guides modes for 3D movies)

2D to 3D video conversion with depth changes - YouTube (depth map tracking)

Keep in mind that output files can be three to ten times larger than the source file[11]. If the output device becomes full, 3DCombine fails without notice.

If you’re ripping movies from DVD or bluray discs, it may be useful to rip each chapter in its own (preferably .mp4) file. That makes the conversion process more manageable and reduces the risk of sudden failure. It may require you stitch them all back together in the end.

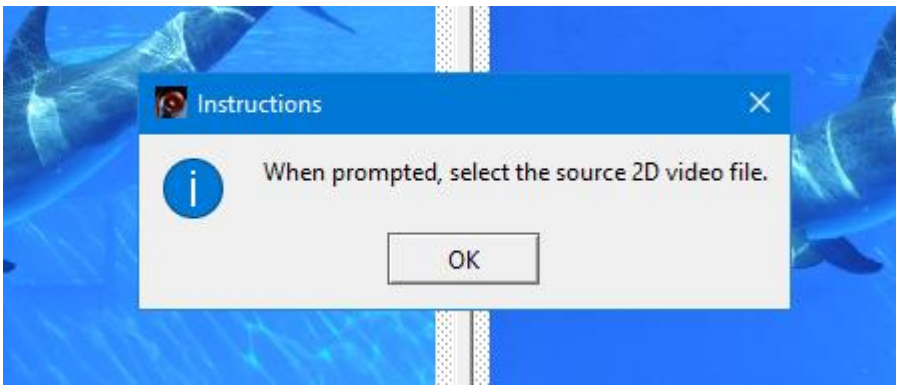
Intelligent

The Intelligent option allows you select a 2D movie, then select the desired output and let the application run to process the entire movie.

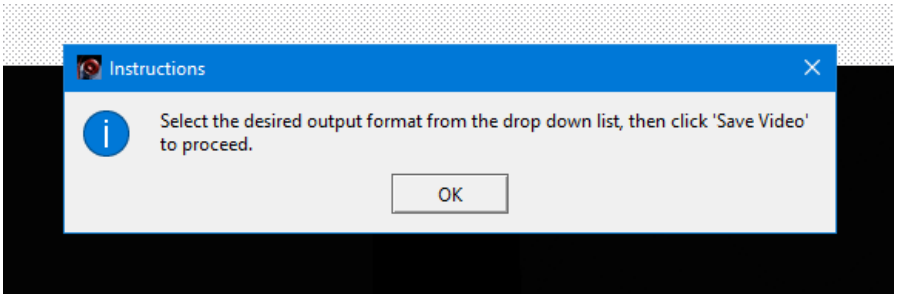
[11] See Appendix B: Bitrates on page 100

All intermediate steps are executed automatically and cleaned up afterwards. No depth maps are ever seen.

When prompted, select the 2D movie (if needed, in 16:9 aspect ratio).

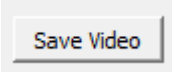


Use the navigation window that opens to select the movie. Depending on its size, it takes a few seconds to load it. When done, it is shown in both preview windows (identical contents) and you're asked to specify the output format required.



The output format is one of the flavours mentioned earlier.

Once specified, click on "Save Video" button and specify the name of the output.



The conversion process starts. Sit back and relax – this may take hours to complete. About 4 to 8 times as long as the movie's running time. The user interface shows the left and right image of the stereo video in the making.

(This activates the Depth "Auto 2D > 3D Intelligent" filter)[12]

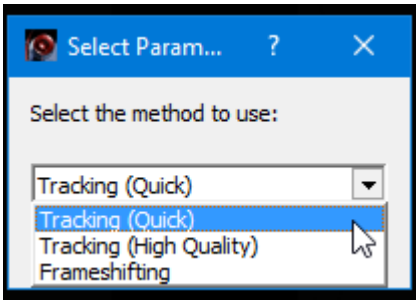
Automatic Tracking

This is a variation of the "Intelligent" process. This method tries to track motion between the frames. Where "intelligent" processes each frame individually, Automatic Tracking uses information from earlier frames to detect movement of the same object between frames. This

[12] This guide can be manually be set by selecting "Depth > Auto 2D > 3D: Intelligent" filter. We'll indicate this manual choice with each Guide

is a much quicker process as not each frame is analysed for a depth map. The result is a less accurate movie and more artifacts.

Once you specified the 2D movie to process, an additional popup window appears in which you select the tracking method.



Once the option is selected, you specify the output format and the output file specification and proceed with the conversion.

(This activates the Depth "Auto 2D > 3D Tracking (xxx)" filter with xxx as the chosen Quick, High Quality or Frameshifting – noe of which can be manually selected)[13]

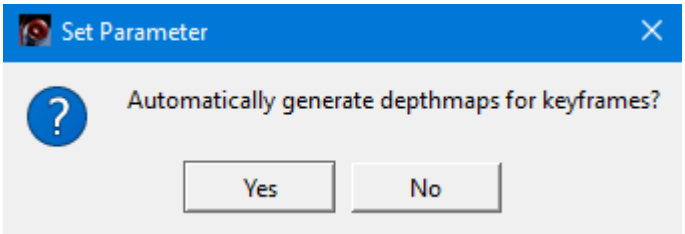
Guided Manual Steps (1 to 4)

The guided method with the most intervention possible, is the manual step process. It is time consuming as it consists of three or four steps, each taking their time to process. The entire process consists of four steps. Each process can be restarted from the previous step.

In the first step key frames are generated. These are .bmp screenshots of major changes in the movie image. Next, depth maps are generated or manually provided for these images. The stereo process then uses the images and maps to create the stereo movie. The better and the more depth maps are generated, the better the final result.

Step 1 Generate Keyframes

Once the 2D movie file has been selected, a popup window asks to generate depth maps for the keyframes. If you do not allow this, only the key frames are generated.



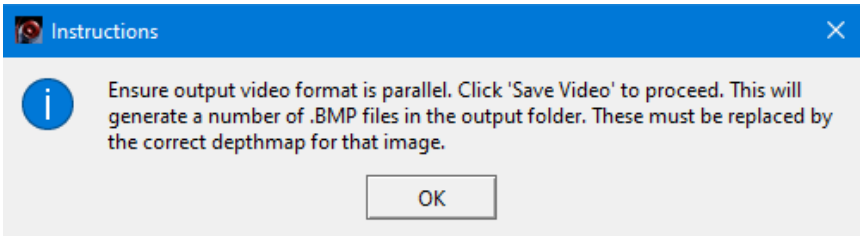
Ideally each scene change should deliver a key frame image. Practise shows a lot of images are skipped and you would need to manually add a lot of keyframes after this step before proceeding to the next. How to do this, is discussed further down this section.

[13] This guide can be manually be set by selecting "Depth > Auto 2D > 3D: Intelligent" filter. We'll indicate this manual choice with each Guide

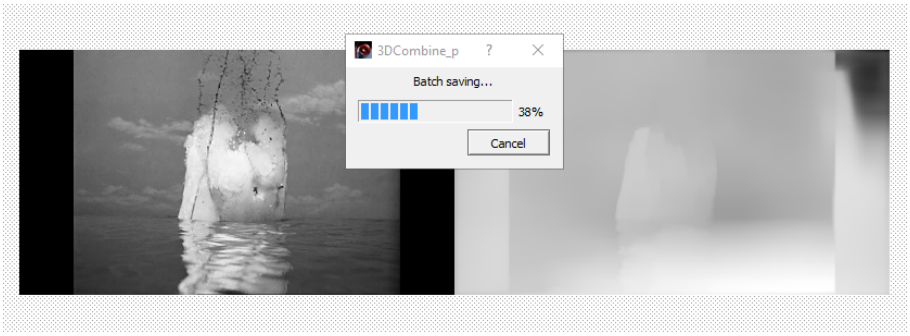
(This activates filter "Keyframes: yes" – that cannot be selected manually)[14]

Whether or not depth maps are generated, you need to use a parallel output file. This is an intermediate step where all the original information is kept and required. The output file is twice as wide as the original source file (e.g. not 1920 but 3840 pixels wide).

The final desired output is specified in the last step. Then the information may be squeezed, coloured, interleaved and changed.



During the processing you see the movie as left image and the depth map as right image.



When finished, this step produced a number of image screen grabs in .bmp format.

[14] This guide can be manually be set by selecting "Depth > Auto 2D > 3D: Intelligent" filter. We'll indicate this manual choice with each Guide

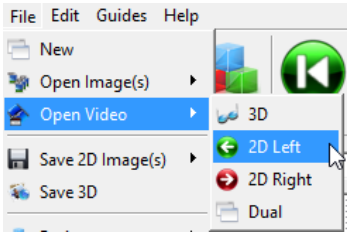
depthmap_0.bmp	2020-12-24 17:52	BMP File	6,076 KB
depthmap_22b.bmp	2020-12-24 17:52	BMP File	6,076 KB
depthmap_23.bmp	2020-12-24 17:52	BMP File	6,076 KB
depthmap_28b.bmp	2020-12-24 17:52	BMP File	6,076 KB
depthmap_29.bmp	2020-12-24 17:52	BMP File	6,076 KB
image_22b.bmp	2020-12-24 17:52	BMP File	6,076 KB
image_28b.bmp	2020-12-24 17:52	BMP File	6,076 KB

They are all named "image_*nnn*.bmp" for screen frame grabs and "depthmap_*nnn*.bmp" for the generated depth maps, where *nnn* is the frame number.

The generated image and depth map files include names that are appended with "b". Those files are "backtrack" image files. For example *_23.bmp and *_28b.bmp are two files covering the entire scene between frame 23 and 28. Depth maps can be interpolated between frames 23 and 28. From 29 onwards, the next scene starts, potentially entirely different from the previous scene.

When you need more keyframes, add them manually. For this perform the following steps:

- load the movie again using File > Open Video > 2D left



- Use the movie play buttons to move through the movie. Either frame by frame (forward/back), playback as fast as the conversion of each frame is completed (play), pause (unclick "play") or skip any number of frames (a quick way to inspect the middle or the end of the movie). The "step left"/"step right" are not useful here since both left/right images are identical.

- For each key frame grab the image by pressing the "Save Image" button. By default the image file is called frame_*nnn*.jpg (or .bmp or other format – the type is selectable). The "Skip" button allows you to go forward by a number of frames (to be specified). The type of format is not relevant: the image is used to create depth maps and is not used later and can be discarded.

For optimum use of depth maps, you should consider a key frame at the start and the end of a scene (the ones 3DCombine postfixes the name by "b" frames). This way 3DCombine can use the depth maps of

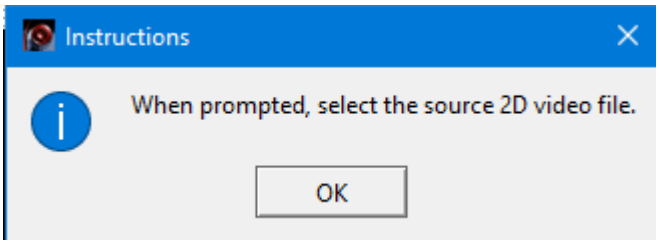
both key frames to generate depth maps for all frames in between (e.g. depthmap_570 and depthmap_610b for depthmaps interpolated for all frames between 570 and 610).

Step 2 Process Depth maps

A time consuming process is to provide depth maps for each of the key frames generated. They can be generated for all keyframes created automatically in step 1, but you may wish to redo all of them.

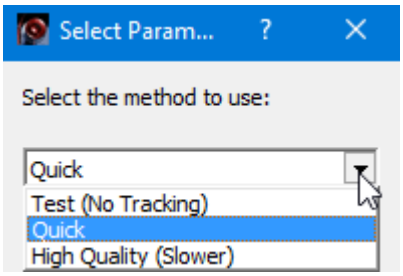
The way to create depth maps for key frames is no different from creating depth maps for images. It is described in section “Creating a depth map” on page 31.

When all depth maps have been created, they must be merged with the original movie file used in step 1.



The output file will be twice as wide as the original source file (e.g. 3840 pixels as opposed to the source file 1920 pixels). The left image will be the original movie, the right image is the associated depth map.

Next, select the way the frames must be processed with the depth maps.



Quick is the usual option. Higher Quality does a more thorough processing of the depth map but for many purposes does not produce a better stereo movie.

(This activates filter "Manual 2D>3D xxx" –with xxx the chosen parameter. This cannot be selected manually)[15]

Next the question is popped to how depth must be created:

- By applying the depthmap of the keyframe to all the subsequent frames upto the next keyframe
- Change the depthmap by interpolating between the depth maps of the current and next keyframe. The latter only works of course if the next keyframe is the last one of a scene (like the ones 3DCombine names "b" files) .

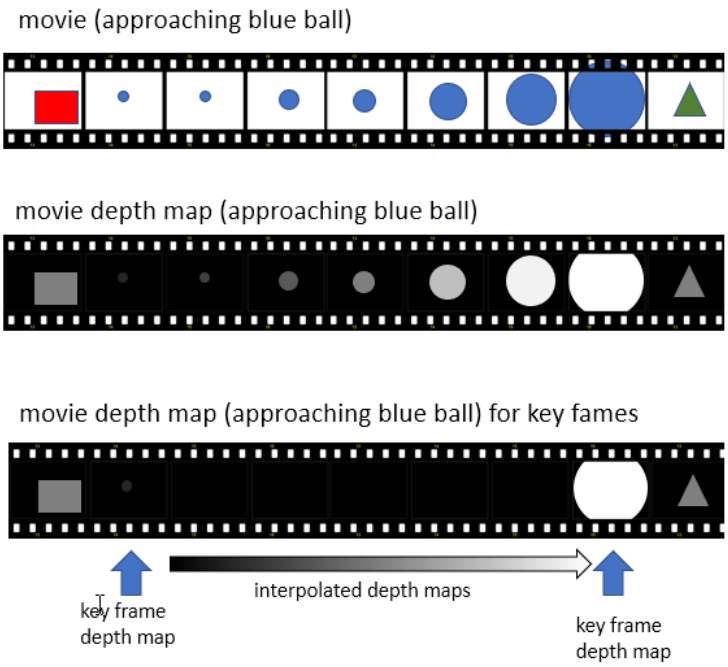
The last option will give a better result. The best would be to create a depth map for each movie frame but this requires a lot of time or many assistants. The solution of using interpolation is illustrated in the figure below.

Between the showing of a red rectangle and a green triangle, a blue coloured circle approaches. It becomes bigger but also comes closer. This means that its depth map representation also becomes larger and less grey with each frame.

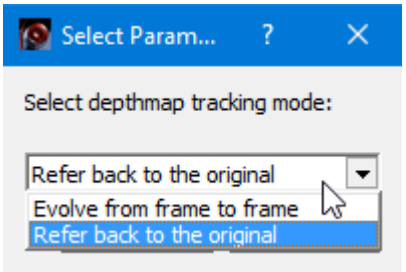
The keyframes are the first frame where the blue circle appears and the last one. The total spans 8 frames. If we create depth maps for each of the 8 frames, the depth maps would look like the series shown in the middle film strip. If we decide to create a depth map for the key frames, only 2 out of 8 frames have a depth map. The frames in between slowly change from the first to the last. They can be calculated as "something in between start and finish".

Depending on the speed with which the blue circle moves, these calculated depth maps may be accurate or not entirely fitting. But they will be better than applying on the first depth map constantly or let 3DCombine make a guess on each frame.

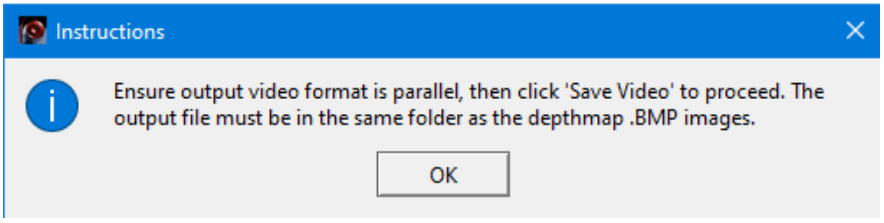
[15] This guide can be manually be set by selecting "Depth > Auto 2D > 3D: Intelligent" filter. We'll indicate this manual choice with each Guide

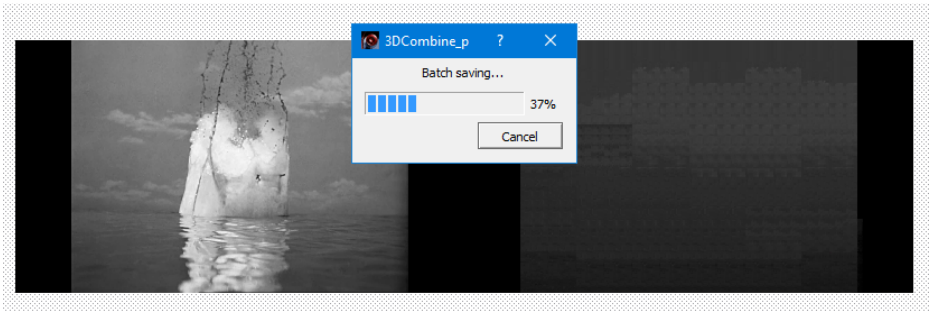


If the next keyframe belongs to an entirely different scene it makes no sense to use it to interpolate.



Finally, a new output file must be generated that combines depthmaps with 2D movie. Each frame has its own hand made or generated depth map.



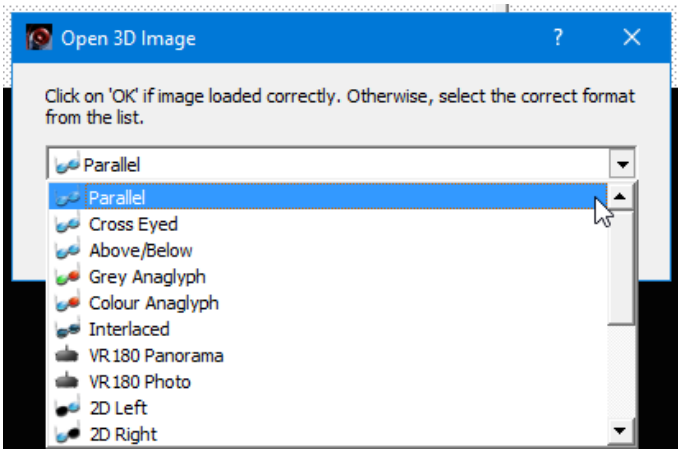


During processing you see the movie as left image and the depth map as right image. This will become the output file contents.

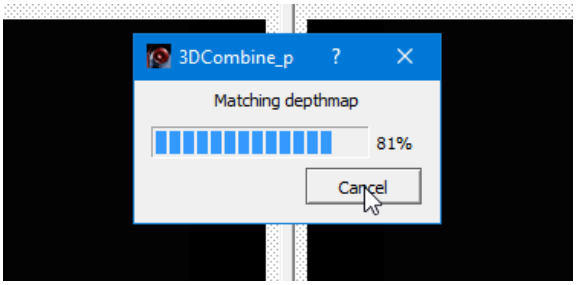
Step 3 (optional) Post Process

The step can be skipped as it optimizes the depth maps in an automated fashion and may bring little or no improvement on the end result, yet takes an enormous amount of time.

This step processes the output file created in the previous step. At the start this file is requested to be opened. It should open properly (in parallel mode) but if not, a different format can be selected.

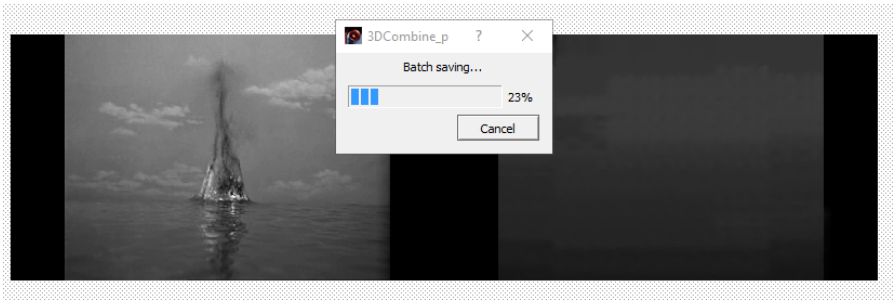


It will then match the depthmaps and ask for an output file specification.



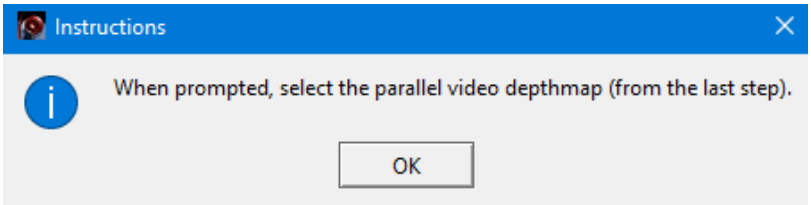
The source file for this step must again be in parallel mode. The processing starts when the “Start Video” button is pressed.

The interface shows the same type of information as in the previous step: movie frame left and depth map right..

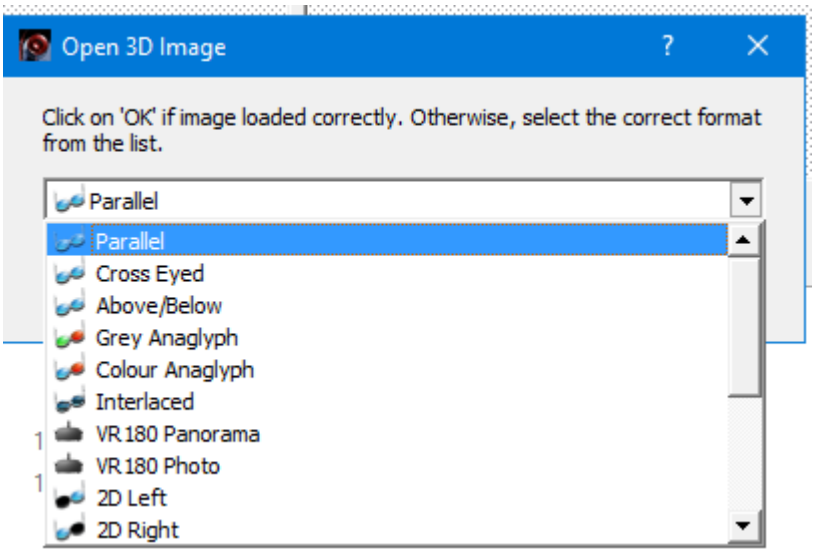


Step 4 Convert to stereo

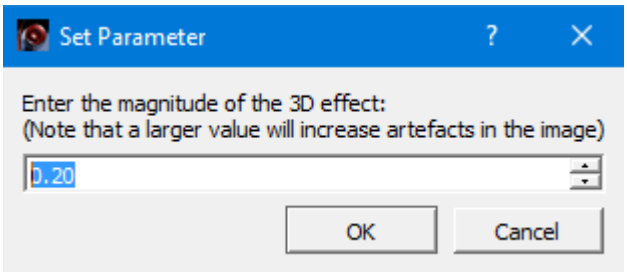
The file created in step 2 (and optionally enhanced in step 3) is now finally processed to a stereo movie. As input you need to specify the file result from step 2 or 3.



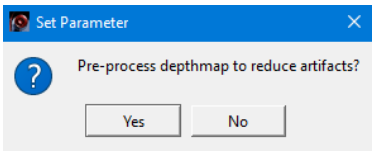
This step 4 combines the flat frames with their depth maps to produce the output file of choice (parallel, side by side, anaglyphic etc).

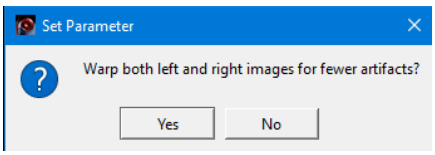


Finally you indicate what the depth must be (disparity between left and right eye image). The default 0.20 seems a reasonable setting.



A final optimalisation during processing can be specified or ignored:

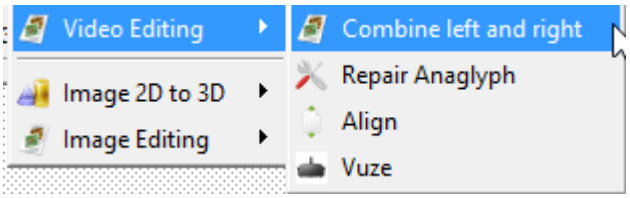




Whether any of the optimzations will result in a better end result depends on the state of the original movie. You may use them or ignore them.

Then the processing can begin, showing the final movie format during the processing. This will take some time again (upto 20 times the running time of the movie), so sit back and relax again.

Video editing



Combine left and right

There already are two movies – one for the left side and one for the right side. You enter them both. 3DCombine then combines both to a single stereoscopic movie in the desired output format.

Repair Anaglyph

Converts an anaglyphic 3D movie into a 2D full colour stereo movie the the output format of choice (other than anaglyphic obviously)

Align

Corrects the video frame images on left and right for misalignment and exposure.Similar to the “Automatic” Automatic align filter.

Vuze

Stitch a Vuze video into a panorama for a Vuze headset.

Part 3 Manual Video Conversion

3D Video conversion manually

Filters

The Guides provide ways to automate the conversion of video files by pre-selecting a set of filters for you. It balances quality and processing time.

If you want to be in more control of the conversion process, you can process a movie by specifying the conversion filters manually – and in what order if you apply several filters at once.

In all cases it is useful to use the Preview 3D option to see (in slow motion) what the effect of the filter is. Alternatively, you use the Preview 3D to save the video output but abort it after a few seconds. This delivers a short converted video file of the first few seconds of the movie. By playing it with a software video player you can decide whether the filters are appropriate or need some further tweaking.

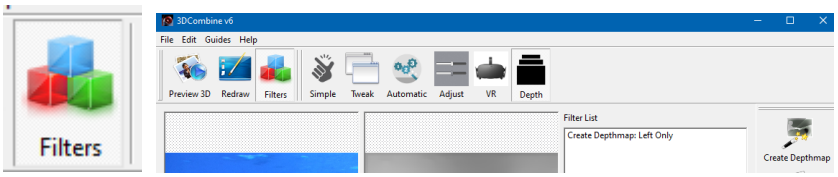
For manual setting of filters to perform the the conversion process, follow the next steps. *Make sure you enter the filters in the correct order. You cannot re-arrange them. When the order is wrong, you need to clear the filter list and start from scratch.*

1. Load the 2D movie

Intially load the 2D movie as a left side movie (File > Open Video > 2D Left). The higher the bitrate (the larger the input file), the more accurate 3DCombine can create a depth map and provide cloning information that remains invisible.

2. Open filters window

To keep track of what options (filters) you activate, it is useful to open the “filters” window that will list all your choices. It also has buttons to edit a certain choice or to delete one or all filters set. (In the “Guide” section we indicated what filters the Guide step automatically set for you). You cannot swap filter order. You need to specify them in the correct order or start from scratch.



3. (Optional) Correct size

If you convert a movie and intend to play it on a stereo tv or projector, the source needs to have a resolution of 1280x720 pixels or 1920x1080 pixels. This automatically also makes it a movie with aspect ratio 16:9.

If it is not the correct size, first use the Tweak > Smart Pad filter and specify one of the two output sizes acceptable. This will give black bars either horizontally or vertically to fill the frame without distorting the image.

4. Create depth map

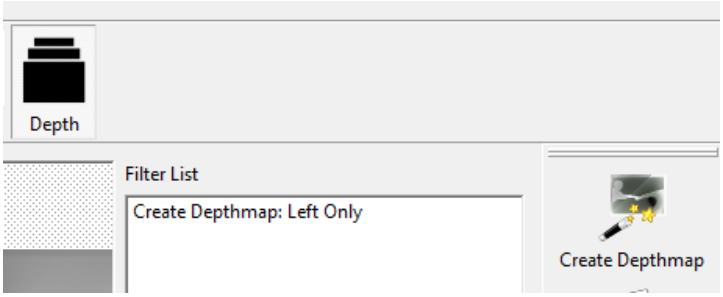
This filter should only be used if no depth map is provided. as right channel image.

On the menu bar, select “Depth” (at the far right – you may need to expand the application window to make it visible). This opens a lot of options to create a depth map.

First you need to select “Create depth map”. Depending on source input you need to select:

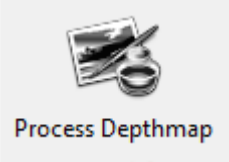
- “Left Only” if the source is a 2D image in the left channel
- “Stereo Pair” if both left and right channel contain the stereo pair of images (from .mpo file or separate left/right images)

For creating stereo from 2D clearly the “Left Only” applies.



5. Process depth map

Next the produced depth map must be processed to create a 3D pair from the left image combined with depth map.

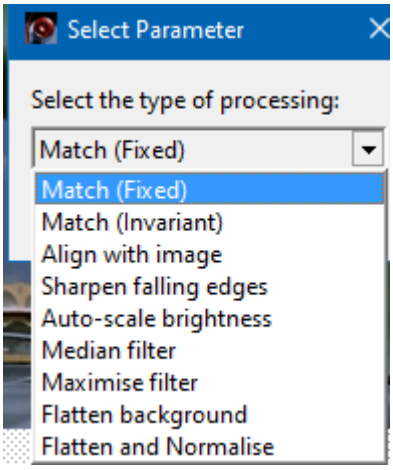


Keep in mind that 3DCombine allows to

- open stereo movies (left/right image in the same file or left/right as two individual files).
- open 2D movie as left eye movie and open an existing depth map movie for it in the right eye channel. 3DCombine will then create the stereo movie.
- open a 2D movie in the left channel and perform all steps to create a stereo movie. This includes generating a depth map for each frame.

The last option is what we discuss here. The available filters work for all left/right combinations but clearly those relating left and right channel are not useful for the 2D to 3D conversion with just the 2D movie as sole left channel input.

Several filteroptions are available:



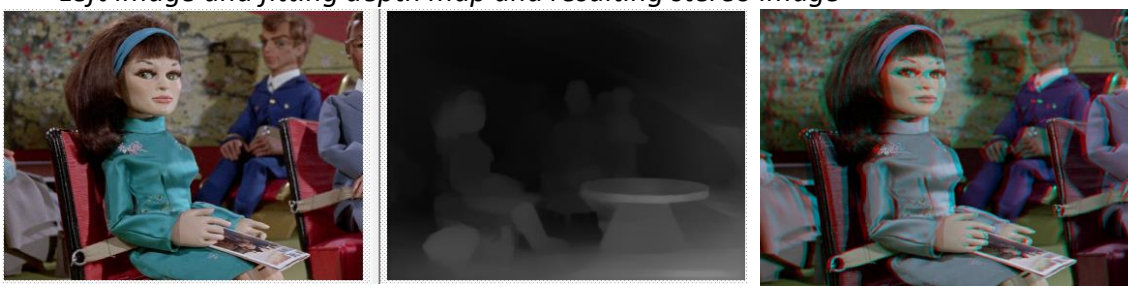
Both '"Match" filters try to make sure that contiguous areas of the image are at the same depth in the existing depthmap. This often sharpens up edges but works on areas within the image too. They are clearly useless if the depth map is created from the image as that always matches and aligns.

- match (fixed) – Left image and depth map must have the same resolution. Left image can be a cropped part of the full image for which the depth map was made (and enlarged to have the same resolution).
  This filter is useful only when an existing depth map is used.
- match (invariant) – same as "match(fixed)" but it will scale the depth map if the left channel image has a different scale and it probably a better choice than "match(fixed)".
  This filter is useful only when an existing depth map is used.
- align with image – this is looking purely at edges in the image and trying to ensure that they line up with the edges in the depthmap. If the depthmap is as little as 1 pixel out that can produce artifacts at the edges. It won't do anything on contiguous areas within the image
  This filter is useful when an existing depth map is used but may also reduce artifacts on a created depth map.

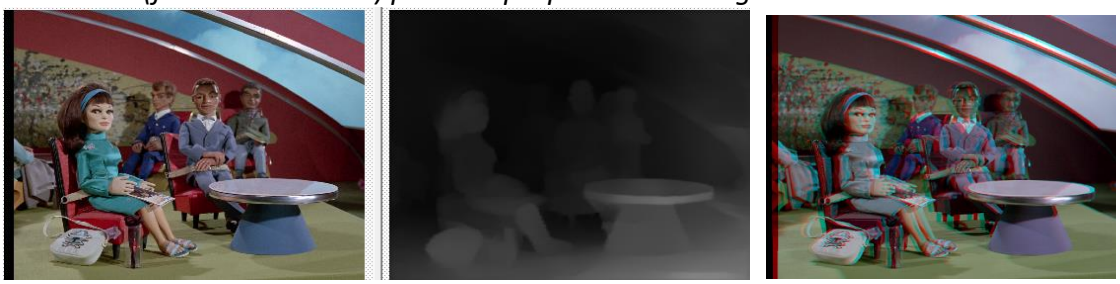
The impact of these filters is shown on the images below.

If needed, any of the depth map matching filters described above must be used before the remaining filters are used.

Left image and fitting depth map and resulting stereo image



Left image enlarged and cropped to same size as original. Depth map unchanged. Match(fixed or invariant) produce proper stereo image

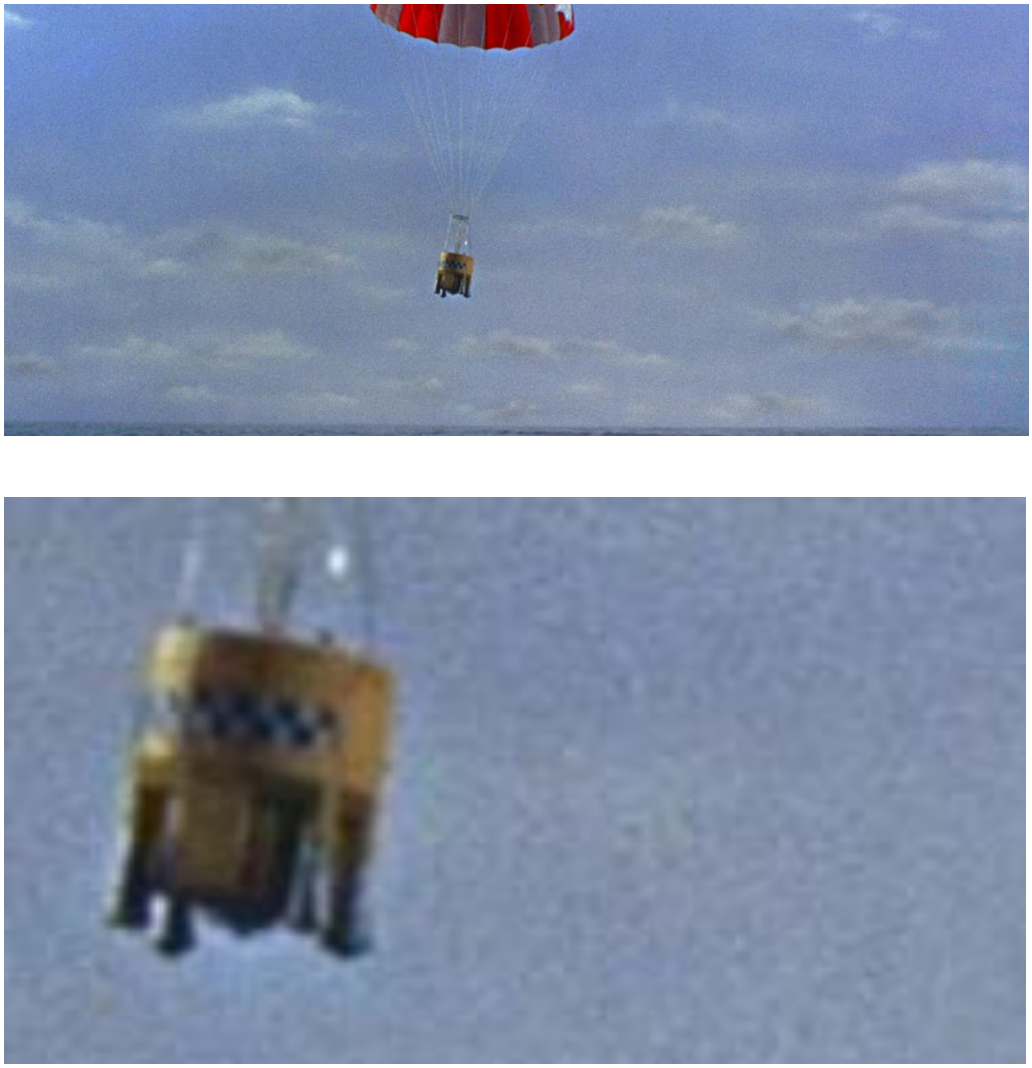


The image has been right-shifted (as seen from black bar along the left side), depth map unchanged, Align with image also shifts the depth map (keeps the black bar at the left) to create a stereo image

- sharpen falling edges – if the depth map has smeared out edges, the conversion is also a bit smeared out rather than have different depths around the edges. This processing will pronounce the edges before you make the actual conversion to 3D using the depth map
- auto-scale brightness – the depth map grey scales are adjusted so the brightest part becomes white and the darkest perfect black. All other shades are scaled in between. This increases the total depth from front (white) to back (black). This usually allows for a smaller depth level (0.2) for the 3D conversion.

Left: Depth map as generated. Right: auto-scale brightness and resulting stereo result

- median filter – if the depth map has some noise in it (result of a grainy looking movie image), this filter will smooth the grey areas for a more even transition in depth. Inspect the depth map first (Preview 3D with the selected frame and Create Depth map filter on) before deciding the use the filter will improve the depth map.



Films in TechniScope only use half a regular film frame – giving a widescreen image without widescreen lenses. As a result, half the film frame must be blown up to full widescreen, revealing the film grain much clearer. Median filter reduces this with a Gaussian blurr in the depth map (leaving the visible image with the film grain).

- maximise filter – it increases the foreground of the depth map. This may be useful for foreground objects that seem to get smeared into the background. Also it may reduce artifacts (on the generated right image) like pointing streaks.

Left: Auto-scale, Right: Auto-scale and maximise and stereo image
Notice how the lighter (nearby) depth map grey tones became whiter
(auto scale is used as without it the maximise modification is too subtle to show in these small scaled images)

- flatten background – if there seems to be too much depth difference in objects that belong in a (flat) background, this filter will bring those parts into the same depth level and flatten the background

Left: Auto-scale, Right: Auto-scale and flatten background and stereo image
Notice how the overall depth map has become slightly darker moving background objects more into a flat background wall
(auto scale is used as without it the flatten background modification is too subtle to show in these small scaled images)

- flatten and normalise -this can help particularly with a depthmap that's been recovered from a stereo pair where the left and right image slightly differ and this influences the depth map created from them. Essentially this filter tries to normalise it so it's consistent scene to scene.

You can specify multiple post-processing options on the depth map and in any order. This order is relevant as each filter works on the results of the previous one.

How to decide on filters

The best way to decide what filters will work best or what depth setting is taking these steps:

1. Move the movie to the frame on which you want to experiment. The “Step right” and “Skip” buttons may be of use here. Alternatively: create a snapshot image of the frame and to experiment apply the filters on this image instead of the movie.
2. Set the filters to your choice
3. Add filter “Make 3D” (select depth, background quality and warp type)
4. Select “Preview 3D” and select output option (viewing from screen often uses Colour Anaglyphic)
5. Judge the result and cycle through steps 3 and 4 with different settings until it is to your liking.
6. Use the found settings for your movie or movie scene (if the movie is cut in pieces)

Clearly this method also works if you made an initial movie but you discover artifacts you don’t like. Then in step 1 select the scene showing those artifacts.

You may save each setting through “Save Image” so you can later compare the sequence of settings in a Windows photo viewer.

If no setting is to your satisfaction, as last resort you can manually modify the depth map.

Manually correcting depth maps

The resulting 3D movie can show noticeable artifacts that can be traced back to incorrectly generated depth maps. Examples are

- solid objects may be split or put at the wrong distance., meaning the grey value of (part of) these objects is estimated incorrectly.
- a flat object seems to wobble as being not flat. Parts of a object seem at different distances and hence different grey values in the depth map. This may be caused by different brightness in areas tgat should have the same brightness.

You may want to try to apply some existing filters to reduce such errors, but you may also want to perform more aimed local corrections on the depth maps. This requires access to the depth map frames generated or supplied as right channel. This approach is very time consuming as you need to go through the slow conversion process three times:

1. Generate a 3D movie using standard 3DCombine methods. This will show the errors in certain scenes
2. Generate a right-image only movie of the depth map created. This movie needs to be corrected
3. Generate a 3D movie supplying left image (the 2D movie) and the corrected depth map (from step 2) as right image

For step 2 you need to generate a depth map following the steps below.Each frame of the depth map movie corresponds with a movie-frame. Using a capable video editor you may correct segments of the

depth map movie by changing the grey scales, using masks and other things your video editor is capable of. The alternative is to modify all depth maps manually (like in the 4-steps Guide mode). Given the amount of work involved, this is likely your last resort.

To create a depth map movie follow these steps:

- Open the movie as 2D Left.
- Set Depth filters “Create Depth Map” (Left only).
- Apply any postprocessing filters that work for you to the depth map
- From menu bar click “Preview 3D” From the many options select “2D Right” to use the depth map images as video movie.
- Click “Save Video” and output the raw depth map movie.

For both an existing or generated depth map, continue to “correct” it for a better 3D movie generation afterwards:

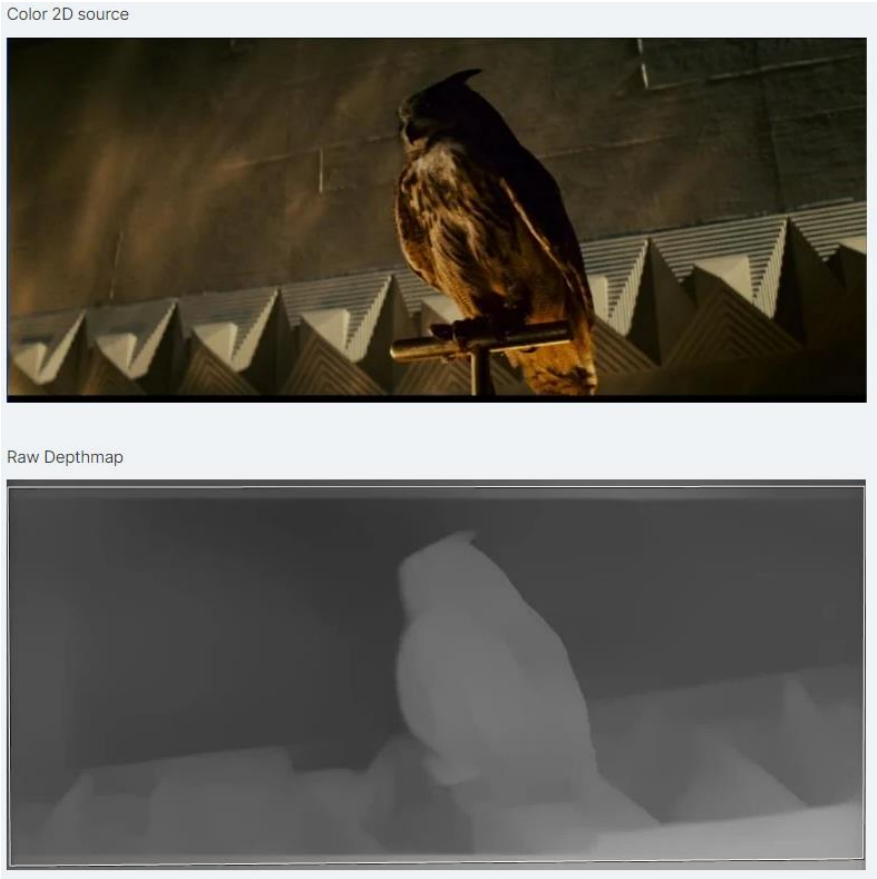
- Edit the raw depth map video. Using the video editor’s frame image tools, apply any corrections required. These may include
    - masking the trouble area in a scene
    - make the too dark areas lighter and too light areas darker so they are less different from with the surrounding.
    - lower the overall contrast and brightness of the depth map.

  You may load the original 2D movie in a separate editing track and make its opacity 50% or less (this may require the stream to be a “picture-in-picture PIP movie). That way you can directly link depth map with movie frame. Remove the movie before you save the depth map movie.

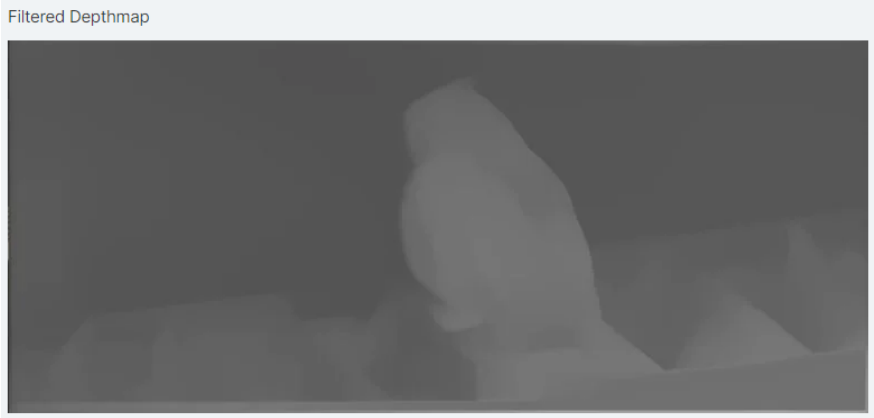
- Save the depth maps as a modified film and exit your video editor.
- Recombine 2D movie with depth map
    - Open the 2D movie through File > Open video > 2D Left
    - Open the depth map through File > Open video > 2D Right
    - From the Depth filters, click Make 3D
    - Click “Preview 3D”, select the desired output mode such as Parallel, SBS/Sensio or Anaglyphic and Save Video

Let’s take an example on how a depth map movie or scene can be repaired by looking at a frame of an owl sitting before a flat wall. The depth map shows a slight variation in grey tone. This produces a wobbly wall in the stereo movie. The wall area needs to be a single grey tone to appear flat at the same stereo depth. An automated repair seems to be reducing the number of grey tones in the wall area.

Two approaches may be in order: one that makes near-black tones entirely black and one that makes near-white tones completely white. Both reduce the number of grey tones and flatten the depth map a bit and in doing so might flatten the wall.



Using the contrast filters to reduce the grey levels in the wall area will produce a flatter wall. Some video editors allow these modified contrast/brightness settings to be saved as a filter for future use.

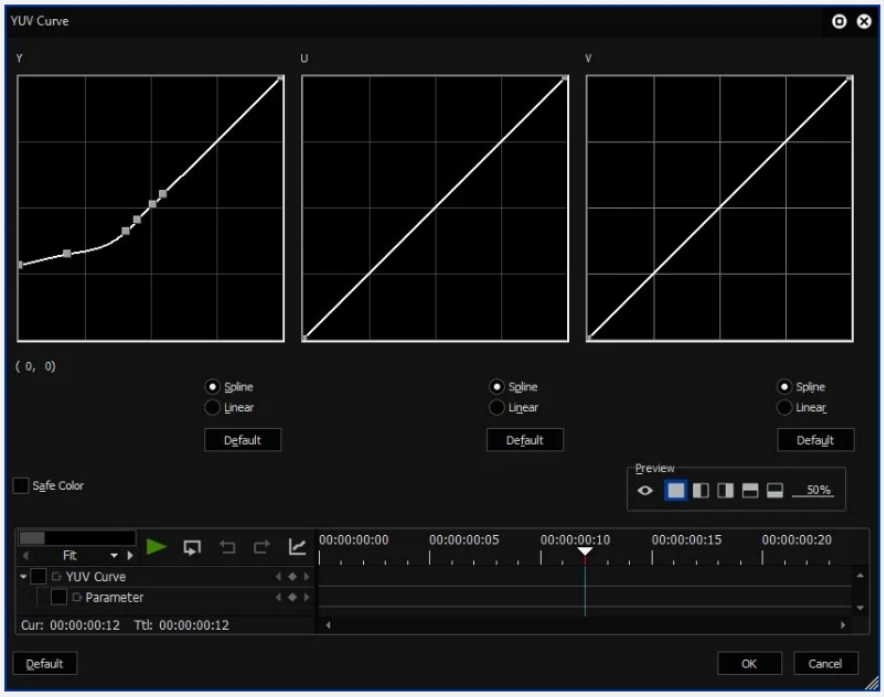


Two such filters can be “make black” and “make white” that modify the Y-channel (luminance) of the YUV setting of the image. (The example is from the Edius[16] video editor).[17]

[16] https://www.ediusworld.com/

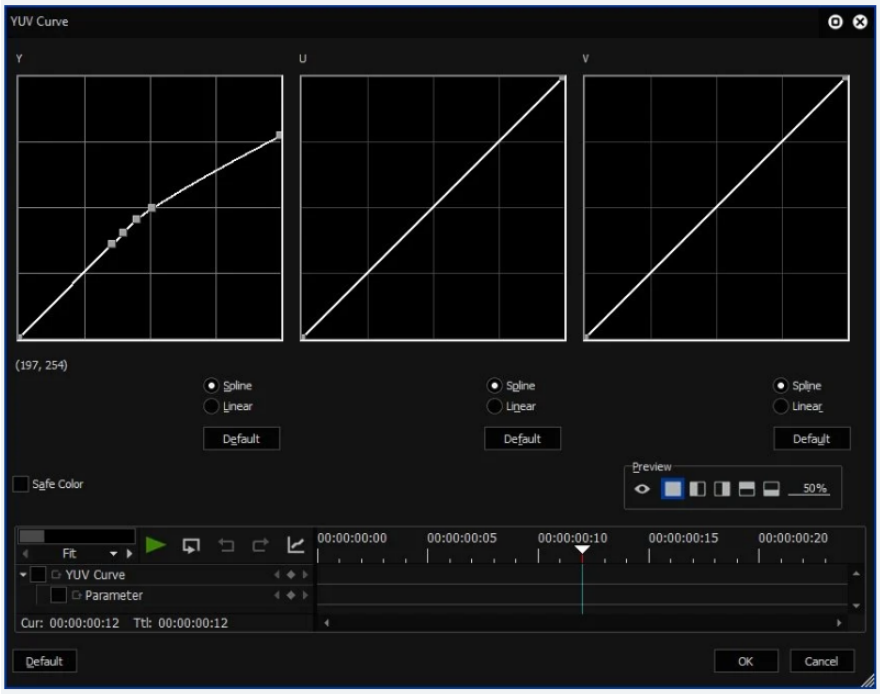
[17] My own experience with PowerDirector: many filters in 3DCombine applied to the depth maps can be done more subtle using the depth map movie and the PowerDirector options hidden behind the “Fix/Enhance” button. The “Tools” button include tracking objects and colouring, the “Designer” button includes masking. It doesn’t have a YUV setting though.

Mask Black Up



The Y curve (luminance) is set to make all near-black grey tones completely black. The colours U (chrominance blue) and V (chrominance red) are left untouched.

Mask White Down

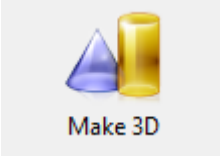


The Y curve (luminance) is set to make all near-white grey tones completely white.

6. Create 3D movie

Finally select the “Make 3D” option. This will allow you to specify the depth (default 0.2 should suffice – higher values create more depth

but also more artifacts – use “Preview 3D” so view the effect of different settings). After that it gives you a choice of whether to use high quality background fill (to add parts in the background that are not present in the flat 2D image). Selecting this does take more procesing time.



The difference between high or low quality backgrounds is most prominent at movies with a low bitrate where there is relatively little background information to clone the missing image bits from. Even at high bitrate the articfacts may persist.

The high quality background does a better job, as can be seen from the images below.

Original 2D movie frame at 3000 bps

3,000 kbps low quality background. Notice the artifacts around the sleeve.

3,000 kbps high quality background. The artifacts at the sleeve are less pronounced

15,000 kbps low quality background. Still artifacts around the sleeve

15,000 kbps high quality background

23,000 kbps low quality background – artifacts still remain even if output file size is the same as when high quality had been chosen.

23,000 kbps high quality background

Original 2D frame at 23,000 kbps

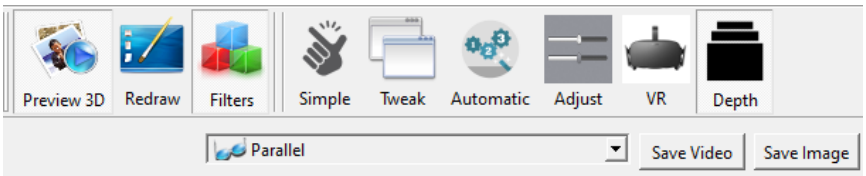
Finally it asks whether you want to divide the left/right artifacts over both images or only on the right image created from depth map. Dividing the artifacts results in a more stable image (otherwise there is some “wiggling” shown where the right image differs from the left).

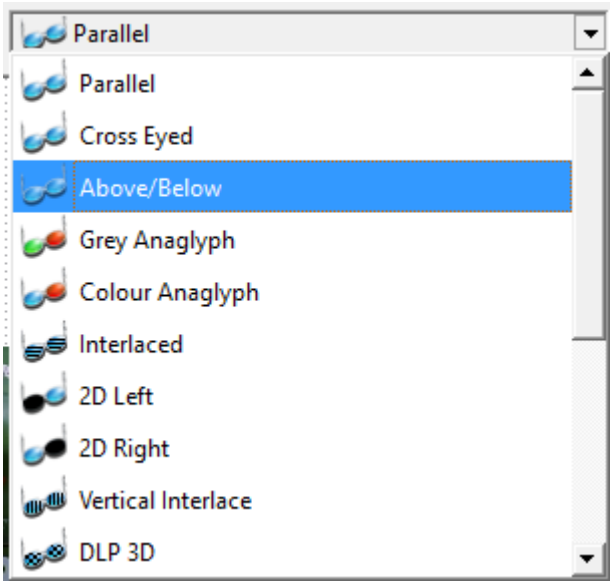
7. Processing

Select the “Preview 3D” button and select the type of output you desire.

For stereo TV or projectors, SBS/Sensio is required, but you can also select anaglyphic for plain viewing using a red.blue coloured pair of glasses. Or any other type of output such as parallel or cross-eyed, above/below, side-by-side, or for various 3D headsets.

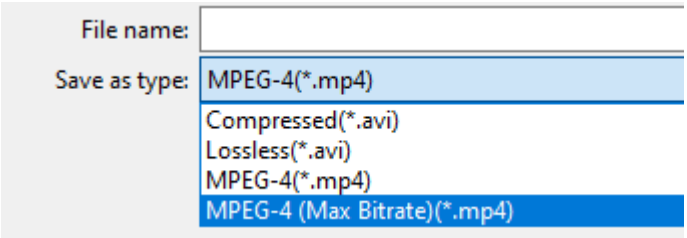
If the output is used in a video editor to create a .mvc (multiview video coding) file that will be used to create a 3D bluray disc, parallel mode is required.





8. Create the movie file

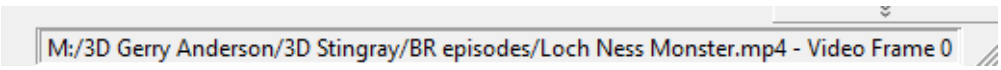
The final step is to click on "Save Video" and specify the output file location, name and type (.mp4 or .avi).



The choice determines largely the size of the output file. The MP4 output is about the same size as the input file. The last one is 7-10 times bigger than the original because it uses a high bitrate, preserving as much as possible of the details in the source file. See Appendix B: Bitrates on page 106 for some experimental comparisons.

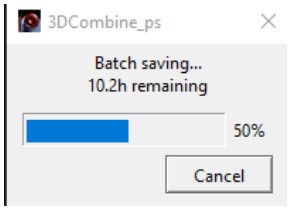
Keep in mind that with output files much larger than the source file that the output device can becomes full. If this happens, 3DCombine fails without notice.

The progress can be seen at the righthand bottom corner of the 3DCombine window. It shows the file being converted and the frame it is currently processing. The expected number of frames at frame rate 24 fps is equal to running time in seconds x 24.



Half an hour corresponds with 43,200 frames.

The progress window also gives an indication of remaining time to go to completion (in hours or minutes). This indication is a prediction that may change if the workload of the pc suddenly changes or the read/write activity to the storage disc changes.



Depending on type of output, the result will mostly be a file using HEVC/MPEG4 as video stream format and MP3 stereo audio output. This is fine if the output can be used "as is". If you intend to use it in a video bluray disc, you need to transcode it to AVC/MPEG4 and LPCM or Dolby Digital to conform to bluray disc standards.[18]

Personal experience

I found using just the "maximise filter" between the create depth map and Make 3D at depth 0.2 and with high quality background and warp both left and right image frames to result in a very slow (upto 20 to 30 times running time)[19] and huge output file (MPEG-4 max bitrate) that is 10 times original size but doesn't compress the original image any further. The audio got distorted.

I use a stereo TV or projector to display the result. SBS/Sense is then the output of choice to obtain a half-side-by-side result. In this case, my input files need to be of resolution 1280x720 or 1920x1080 pixels. This is also true of DVD ripped movies that are 720x576 or 720x480 pixels. The use of a scaling filter like Tweak > Smart Pad (to 1280x720 pixels) is then required before creating a depth map.

Note that the Smart Pad filter does not work correctly for DVD widescreen 16:9 ratio images. These are also 720x576 or 720x480 pixels but are stretched to widescreen: the pixels are not square but rectangular. You need to create a proper 1280x720 pixels image using a video editor that replaces the rectangular pixels by square ones that also make up a widescreen image.

To remove the audio distortion, I open the resulting 3D file in a video editor together with the original 2D version of the file. By using the video track of the 3D file and the audio track of the 2D source and muxing them together I produce an output file with proper sound (check lip sync!). If there are multiple converted files (like concatinating chapters), each part is added and the original file is trimmed at the end to fit the converted video track.

The output of the video editor is set to conform to the video bluray disc standards (AVC/H264 video, AC3 audio).

At the same time I use this video editor to reduce the bitrate of the converted file back the original rate, resulting in an output file of similar size as the original.

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[18] This only applies if you create a video bluray. If you burn the files as data on a bluray or DVD disc, you can burn the results as provided by 3Dcombine

[19] See Appendix B: Bitrates on page 100

Output file type of the video editor can be:

- Half SBS (side by side), Half OU (over/under) – if I keep the files for playback on a stereo image capable device that come with a set of active or passive glasses, allowing full colour viewing
- Anaglyphic - for playback on any flat device but giving a 3D impression with a pair of red/cyan coloured glasses with some colours missing
- Parallel - Required if I want to make a 3D video bluray disc with .mvc (multiview video coding) format. The .mvc contains two video steams (left and right). It needs to be demuxed into both streams and presented to a bluray authoring program that can produce a 3D disc (e.g. using BluDisc Studio, www.blu-disc.net).

Part 4: The 3DCombine menu

Introduction

This part describes the menu bar of 3DCombine. This information is used earlier also, but is collected here in one place.

The “File” menu

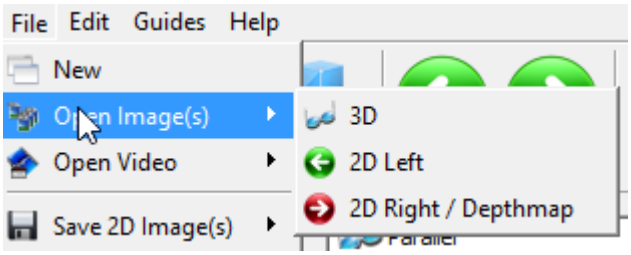
New

The “New” button closes whatever files are currently open to start anew, as if you just started the 3DCombine application. You are warned that any changes will not be saved. If you want that, first save the current filter settings as a project (using File > Project).

Open Images

Using “Open Images” allows you to select what to do. You can open one image pair or a collection. If you use one pair proceed as follows.

- If you already have 3D images (parallel or otherwise) in a single file, you can open that file and thereby opening both left and right side image. Alternatively, you select that file using the “3D” option in File > Open image(s)
- If you have a phone taken image in “portrait mode”, it is actually an image and a depth map. Open such image with “3D”. This results in an image as left image and a depth map as right image.
- You may select left and right images from separate files. Using “2D Left” you select the left side first. Next you click on “1D Right/Depthmap” to open the right side image.
- If you have a left side image and a depth map to produce a stereoscopic image, use the “2D Left” to open the 2D image. Next click “2D Right/Depthmap” to load the depth map that contains the depth information for the 2D image loaded as left image. Ensure that the depth map uses the white colour to indicate the shortest distance. Otherwise you first need to invert this depth map using an image editor.
- If you only have a single image, load it with “2D Left”. Using other tools of 3DCombine you create the right side image.



If you want to process multiple images:

- Click “3D” and select multiple stereo pairs to import
- Click “2D Left” and select all left side images. Next click “2D Right/Depthmap” to load the corresponding right side images. It helps to give left/right pairs similar names so they are loaded in matching order
- Click “2D Left” and select all flat 2D images. Next click “2D Right / Depthmap” to select all depth map files for the

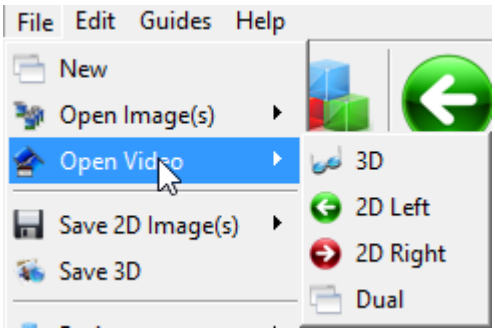
corresponding left side images. It helps to give left/right pairs similar names so they are loaded in matching order

- If you have number of 2D images, load them using “2D Left” and use the 3DCombine tools to generate the right side images.

If you select multiple images you invoke 3DCombine’s batch mode. This is shown by the appearance of two more buttons on the button ribbon.

These “Back”/”Forward” buttons allow you to navigate through your images and apply changes before you hit the “Save Image” button.

Open Video



Similar to opening images, if you use “Open Video” you can specify a single movie:

- If it is already stereoscopic, use the “3D” menu option and specify in an additional question what sort of 3D movie it is (parallel, anaglyphic etc) .
- If it is 3D but as set of two 2D movies (left/right), you can open the left hand side of the video clicking on “2D Left”. Next you need to provide a right eye equivalent by clicking on “2D Right”
- If it is 2D, you can open it on its own using “2D Left” and use other 3DCombine tools to generate the right side frames
- Use “Dual” if you have a MVC stereo file or other video format that embeds two video streams. It will then split both components into their left and right frames. Note that “Side by Side” stereo movies are ***not*** dual movies. They are essentially 2 dimensional with left/right frames side by side in the same frame. Use the “3D” option for this.

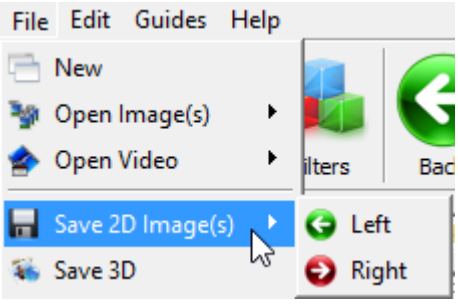
This option is also used in the “Guides” between manual steps 1 and 2 when you want to make more keyframes and depth maps for these frames.

Once the movie is successfully opened an additional set of buttons appear that allow you to move through the movie.

- Rewind goes to the first frame of the movie
- Back goes back 1 frame for both left/right movie
- Forward goes forward 1 frame in both left/right movie
- Skip goes forward a number of frames (you must specify this number) for both left/right movie
- Play simply plays the movie by moving forward through both left/right movie
  This button works as a toggle: when unclicked it pauses the movie.
- Step left – moves the left movie forward one frame. The right movie does not change, If there is no left movie, nothing happens.
- Step right – move the right movie forward one frame. The left movie does not change. If there is no right movie, nothing happens.

Save 2D Images / Save 3D

After manipulation of an image, you may wish to store the result.



Use

- “Left” if you only want to save the left side image
- “Right” if you only want to save the right side image (that can be the depth map if generated from the left image)
- Use “Save 3D” if you want to store the stereo image in a format of choice (parallel, anaglyphic etc). You’re prompted for both choice and file name.

Project

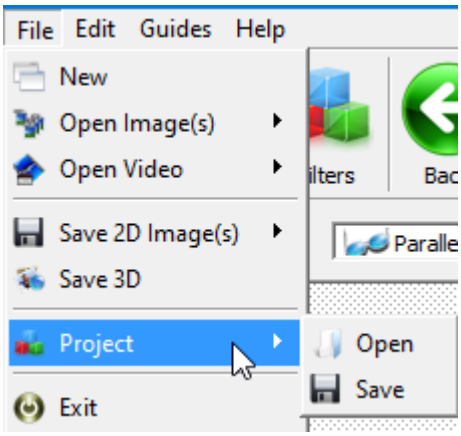
A project is a bit of a misnomer for most people as it does something else than what you might think based on other application’s use of the term “project”.

A 3DCombine project saves the list of operations (filters) performed on an image or movie. All these steps (look at the “Filter” button to get a list) can be saved as a “project” in a .prj file in the current working folder. This allows to have project files with the same name but different filters specified in different folders.

This way you can apply the same modifications to multiple images or movies once these are imported into 3DCombine. Simply open the project and all filters are executed on the open images or movies.

It is not a project in the sense of storing information about the movies or images currently at hand and as a checkpoint of where you've come to. It is not suitable to "save" the current state of affairs to continue at a later time by reopening the project.

With 3DCombine executing specific steps and output results into files, there is less need for maintaining the traditional project information. Input in 2D is always converted to 3D and output. The only configurable information worth keeping in going from opening 2D file to saving a 3D file are the application and settings of the filters.



Exit

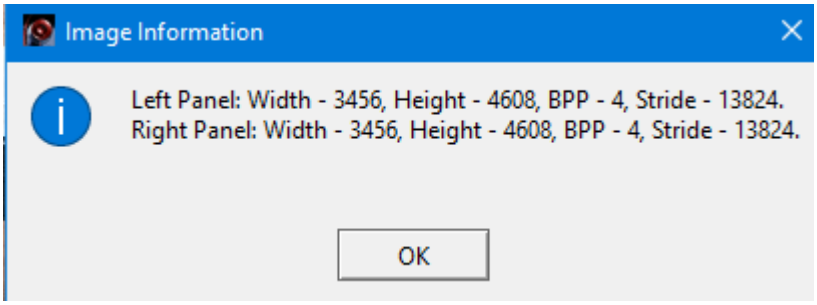
Selecting this option exits the 3DCombine application. If some image or movie save process is active, first cancel this before exiting.

“Edit” menu

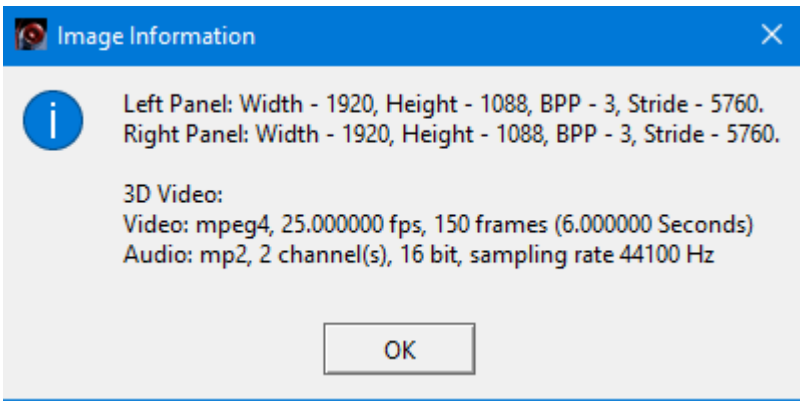
The Edit menu does not contain many useful options – if you expect modifications on images of movie frames, you need to look at some of the buttons and filters.

Details

The “Details” menu option gives information on the current image.



If you’re working on a movie, the movie details on frame rate, frame size and audio type are given. This information may differ depending on the type of movie you’re working on.



Undo

The Undo button undoes the last filter you applied. You can also use the “Filter” button to list all filters applied and selectively remove some or all.

Part 4: Creating Or Improving 3D Effects

The 3DCombine interface

To perform certain steps in the process to create a stereo image yourself, 3DCombine offers a number of filters (their name for “functions”). The settings are applied to all stereoscopic images or all frames of a movie.

The “Guides” also set certain filters for you and balance between speed and quality. The filters used by these Guides are mentioned in small print at the end of the description of these guides.

If the size of the image has changed, its new size can be inspected using the Edit > Details menu choice.

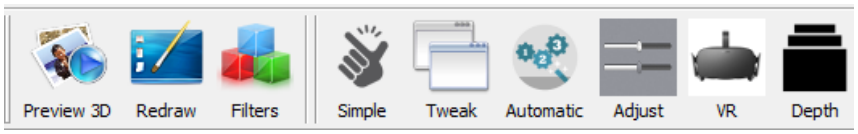
The filters you select are listed in the “Filters” list. This list is shown or hidden depending on the fact whether you clicked or unclicked the “Filters” button.

You can edit or remove any filter by selecting it in the Filters list and then use the “Edit Selected” or “Remove Selected” (or Clear All).

The Button Ribbon

A few buttons on the ribbon are always there, others will be added once an image or movie is opened via File > Open.

All the available buttons only show if the 3DCombine window is wide enough. Otherwise a “>>” mark is shown in the right side margin to show the remaining invisible buttons. You may enlarge the window or click the “>>” button.



Preview 3D

The “Preview 3D” button has been discussed in section Preview 3D Button on page 24. It is used to see the effect of the (filter)operations you perform and allows you to store that result as a file on disc if you select one of the “Save” buttons.

Redraw

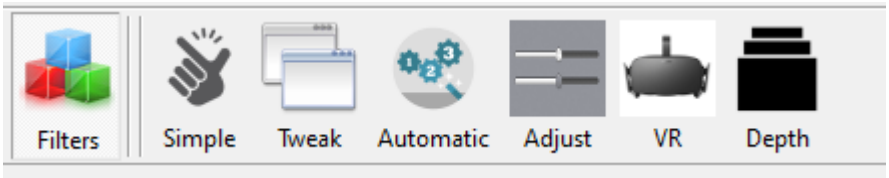
Redraw refreshes the images in the left and right panels. This can be useful if you've resized the window and want to resize the images displayed to match.

Filters

The “Filters” button is a toggle switch. When clicked, it shows the filter list: a list of operations in order in which they are performed on each image. Unclick it and the list disappears.

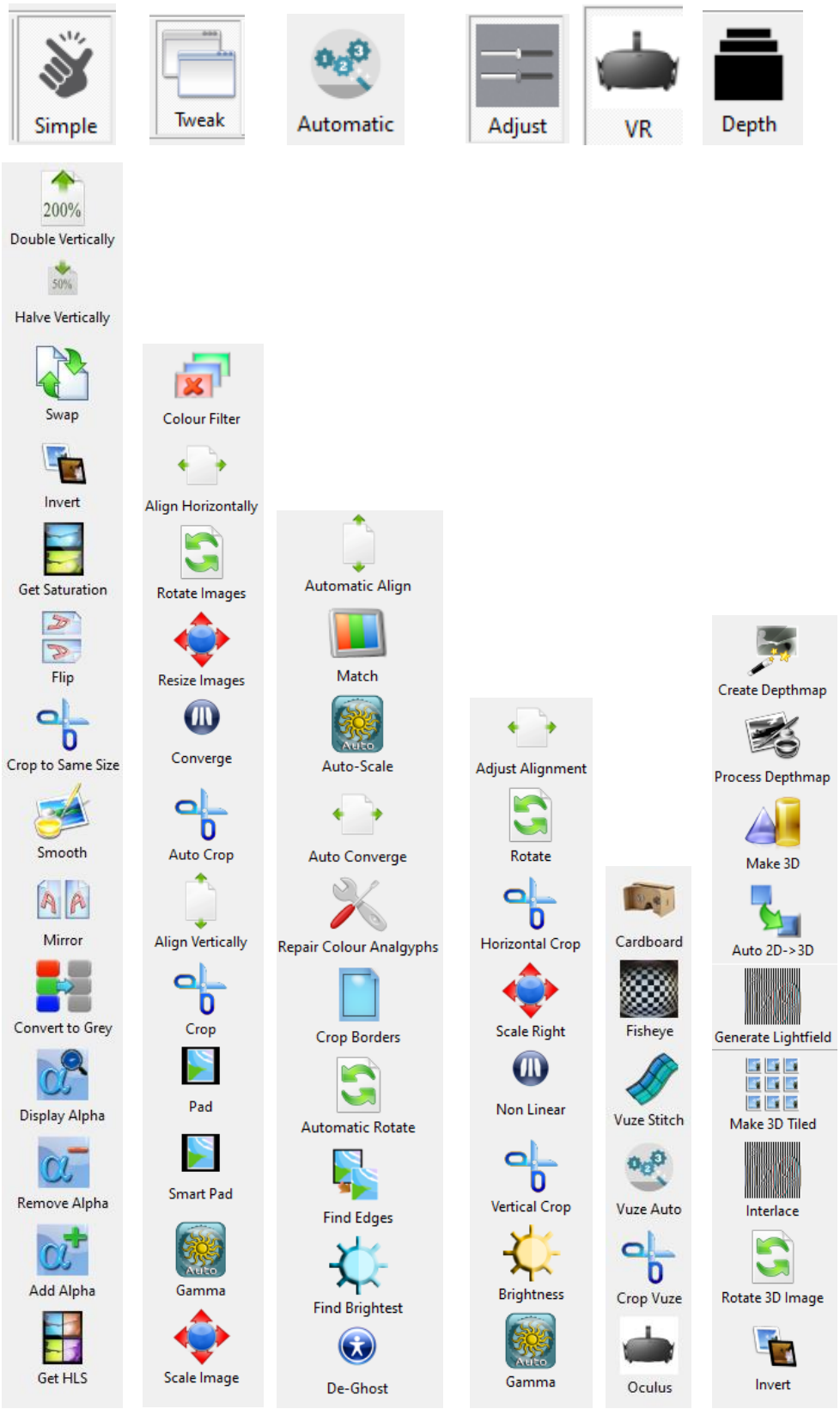
You need to use “Preview 3D” to see the effect of the filters and use its Save buttons to save the image or movie using those filters.

To populate the filter list, you first select what type of action to take (by clicking on a button on the button ribbon, at the right of the "Filters" button).

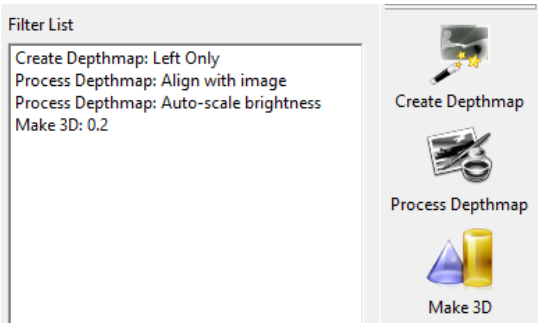


This changes the set of operations you can perform within that type of action at the right of the filter action list. If the 3DCombine window is sert too small, press the button at the bottom of the column for the other filters.[20]

[20] If you right-click you open an almost blank context menu where choices can be made even if no explaining text is given. If this makes part of the GUI disappear, go to the menu bar (File/Edit/Guides), right click there and click on the same blank position to make the disappeared item reappear. Clearly a bug in the GUI.



From the possible actions you select one or several. In case of “Depth” the “Create Depthmap” and two “Process depthmap” actions are selected before the final 3D image is created..



Each of the filters listed can be selected and modified by clicking on "Edit Selected". For example, this allows to change the Depth setting of 0.2 in the "Make 3D" filter to another value. The change is executed on the image in the 3DCombine interface.

In the same way you can undo any of the filters by selecting them and click on "Remove Selected" or remove all filters by clicking on "Clear All". This way you revert to the initial display of the left image or frame. This option comes in handy if you've performed operations you rather undo to start again.

To manually specify how to create or enhance a stereo image or movie, you select a set of filters with "Make 3D" as final filter.

The alternative is using one of "Guide"s: that pre-select a number of filters for you. Not all their filters are available in the filter block lists.

Navigation buttons

Once a batch of 2D images is loaded as left image the menu ribbon with buttons is extended with navigation buttons to move to the next image or back to an earlier image.

They are described in section Open Images on page 70

If a movie is added, there are more buttons, to allow for forward or backward movement or skip a number of frames. And also to simply play the movie (albeit in a slow motion fashion as image conversion is not achieved in real time).

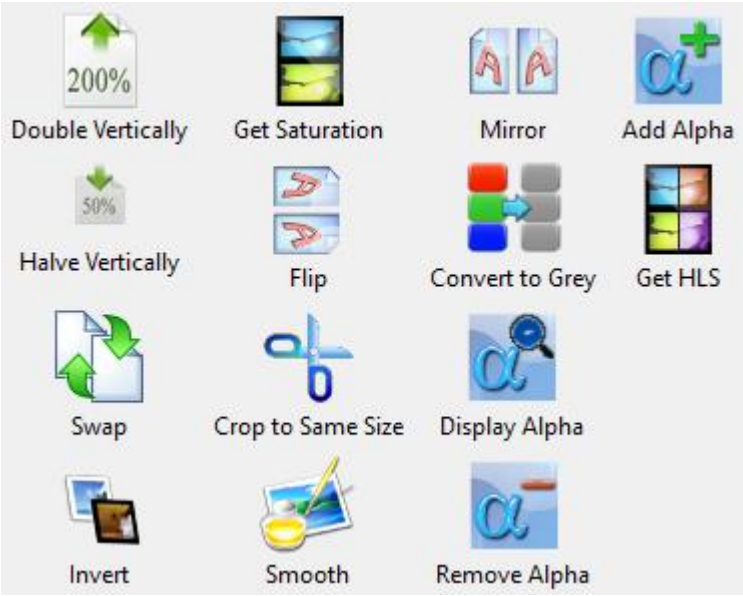
These are described in section Open Video on page 71.

To convert a 2D image or movie to 3D the "Depth" button will contain the most relevant filters for conversion.

A stereo image consists of 2 images. If you want to correct an image, use these filters before creating a depth map and/or select the “Make 3D” filter.

Simple Button

This button opens a menu with buttons that each can perform a “simple” operation on an image or frame.



Most buttons will be self-explanatory. They work on both left/right side images or frames. You use them before using the “Create Depth map” and/or “Make 3D” filter.

Double vertically – Increases the vertical size of the images, stretching all objects vertically. The effect looks similar to squeezing the image horizontally by a factor of 2.

Halve vertically – Halves the vertical size of images. The effect looks similar to horizontal stretching by a factor of 2.

Swap – swaps the left and right image or frame

Invert – inverts the colour of left and right image or frame. The result looks like a colour or b/w negative

Get Saturation – shows left/right image or frame in a grey tone image showing saturation of colour. White is high saturation, black a minimum of saturation. It can be a good starting point for a depth map (possibly inverted).

Flip – mirror the left, right or both images horizontally. The result is a mirror image upside down. This is not a 180° rotation as all objects are mirror-imaged. The vertical flip is called “Mirror”

Crop to Same Size – both left/right images are cropped to the dimensions (in pixels) of the smallest. The larger image is cropped, not reduced in size.

Smooth – a (Gaussian) blur is applied to both frames. Repeated smoothing makes the images more blurred, Useful for images with noise that needs to be removed.

Mirror – In fact a "Flip" along vertical axis. Left and Right side of an image are flipped. The operation can be performed on either left, right or both images.

Convert to grey – colour images become grey tone images

Display Alpha – Alpha channels indicate transparency in an image. If an image has a transparent region, this will show the transparency (as black parts).

Remove Alpha – This removes any transparency and converts the image to a solid image (white instead of transparent)

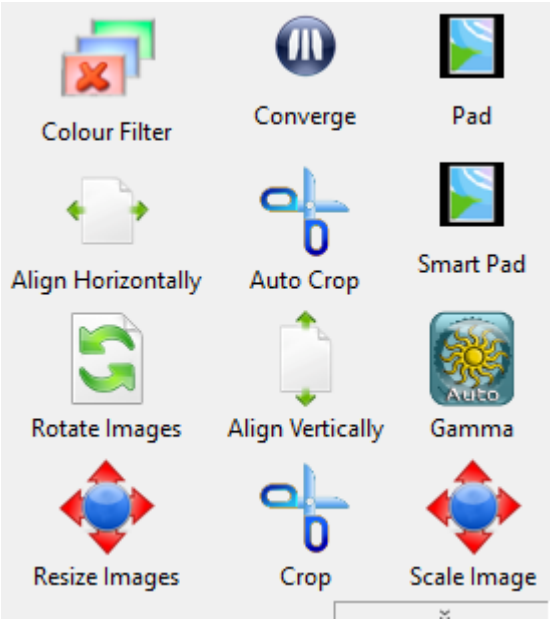
Add Alpha -can duplicate a transparent region in one image (left) to the other (right)

Get HLS – Stands for "hue, lightness, saturation. (Also known als HSL) which are different variations to represent colour space such as RGB (red, green,blue).

Tweak Button

This button opens a menu with buttons that each can perform a "tweak" operation on an image or frame. Examples of the effects are performed on identical pictures in left and right frame. These filters are used before making a depth map and/or use the "Make 3D" filter.

We will show the effect on an image that has a 4:3 aspect ratio and resolution of 1432x1076 pixels. Use the Edit > Details menu option to see the resulting image size.



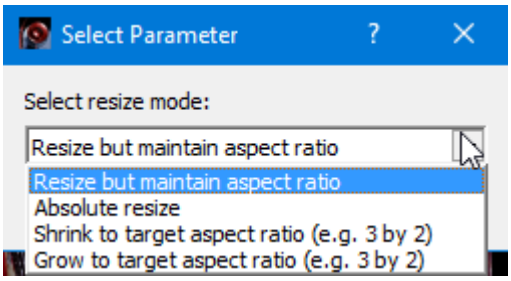
Colour Filter – for each of the three colours red, blue and green as well as for left and right image you can filter on colour. A value of 0 means no filtering for that colour (colour remains). Values upto 255 mean that colour is partly or entirely removed (255). So six questions are asked before the tweak is performed.

Align Horizontally – One of the images is shifted horizontally by number of pixels. Negative values mean shift to the left of the left image. Positive values mean a shift to the left of the right image. The new area (at the right if shifted to the left and vice versa) is "made up" from nearby pixels. Black vertical bars simply bbecome broader.

The example shows a shift of +200 pixels (width 1432 pixels). In 3D it means front objects are pulled before the virtual window or behind it. Positive values moves the image to the front.

Rotate Images – Left and right image can be rotated while the frame border remains the same. Positive values mean rotating clockwise. The example below shows 10 degrees of the left and 50 degrees for the right image. Where unknown areas appear, the information is "guessed".

Resize Images – You are asked whether this has to be with maintaining aspect ratio or not.Usually you want to keep the ratio fixed.



In all cases width and height in pixels is asked for. With kept aspect ratio, one of the settings is ignored to keep the ratio the same.The image is scaled to fill the other size completely. The size that is not completely used is not padded with black bars. Use Smart Pad for that.

Below we resize to 3000x2000 with aspect ratio kept. Notice there is no perceivable difference, but the resulting (right) size has increased its height from 1080 to 2000. The width scaled proportionally to 2660 (which is less than 3000).

The “Grow” and “Shrink” seem to do the same if the same width and height are specified.

Absolute resize deforms the image: height and width become as specified. For example, set to 4000x1000 results in the image below.

Grow/Shrink take the width and height pixel size given and compute the new aspect ratio (r =width/height) and apply it to the actual picture size.

Shrink: the width remains the same, the height becomes r times the width. With new size given as width=1000, height=500 (ratio r= ½) results in same width (1432 pixels) but height ½ x 1432=716 pixels.

Grow: the height remains the same, the width is adapted from the given aspect ratio. Using width=1000, height=500 (ratio r= ½) the height remains 1076 but the width becomes 2 x 1076 =2152 pixels.

Converge – The left and right images are moved closer (positive values) or further (negative values) apart. At the same time the image content is distorted. The example below uses a converge of 5.

Align Vertically – similar to Align Horizontally. Negative values shift the left image, positive values the right image by the number of specified pixels. You need to specify whether the new areas are filled or not.

The example shows an alignment of +200 pixels (with image 1076 pixels high). Missing areas are filled in.

Auto-crop – crops the image to a specified aspect ratio, keeping one size untouched and the other cropped to meet the ratio. Below the

image is cropped to 16:9 (=1.78). Width remains 1432 pixels, but height is reduced to 608.

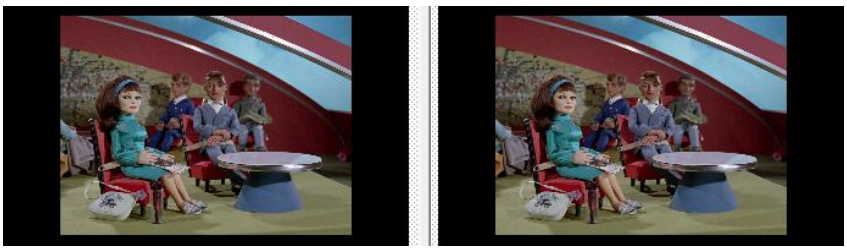
Crop – after specifying where the left, right, top and bottom border must be set, the image is cropped. The example crops 200 pixels both of top and bottom and 300 from left/right (i.e. 1076-2x200 and 1432-2x300 – making the image 832x676 pixels).

Autocrop – you specify a new aspect ratio (16:9 would be 1.78) and the image is cropped accordingly. The original image is not distorted but like “resize – keep aspect ratio” one size fills the entire width or height, the other side is chopped and information is lost.

An autocrop of 1.78 (=16:9) makes the image widescreen retaining its width but losing information on top and bottom.(1432 x 604 pixels)

Pad – this has nothing to do with an iPad or tablet and is all about the verb “to pad”.It creates a new image to the specified size. The original image is positioned in the center, surrounded by whatever black bars are needed to pad the image to the final size.

The example shows how a 1432x1076 image is padded to 2000x1200 by adding black all around the frame. The image remains 1432x1076 itself, the added black bars make it 2000x1200.



When padded to a smaller size the entire image may become black. Use the Smart Pad instead.

Smart Pad – similar to Pad but it will change the size of the original picture. It keeps the aspect ratio but one side will fill either height or width. The other side is padded with black bars. The image below is padded to 1500x800 pixels. The pillar box bars appear.

If the new size is smaller than the original image, it is shrunk, retains its aspect ratio but is scaled smaller. The example below uses a width of 1000 pixels (where the image has 1432) and height 1500 (larger than 1076).

Gamma – specify a different gamma value to make the image brighter or darker. You specify what the darkest colour is and the lightest colour. Regular images run from black towhite from 0 to 255. Effectively this divides all 256 values each colour can have in a smaller than 256 interval – reducing the number of colours (increase contrast).

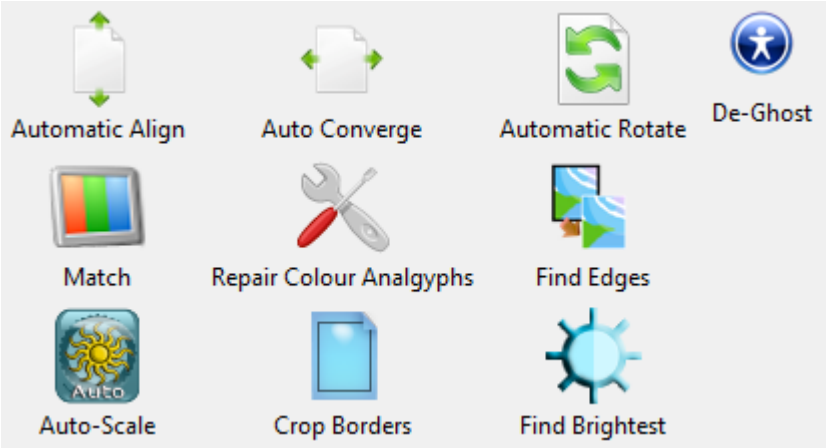
Entering value 50 (dark) and 200 (lightest) results in the image below.

Scale Image – the image is scaled in proportion by a percentage. The new size can be seen in Edit > Details. In the interface the image appears to remain unchanged since the interface scales it in the opposite direction to show it. Edit > Details however shows the new dimensions of the image.

A scale of 150% makes the 1432x1076 pixel image 2148x1614 pixels.

Automatic Button

This button opens a menu with buttons that each can perform an "automatic" operation on an image or frame. Automatic is just that: you invoke a filter and it works to preset conditions, not requiring any user settings. If you want to be involved, use the Simple or Tweak filters. Most of the automatic button options are applied on a 3D made image – so after the "Create 3D" option in the depth map options.



Automatic Align – important for proper stereoscopic output is that homological points are the the same height in both images (horizon at the same height). This function repositions the two images to make them align (by shifting them vertically). This step is taken after the 3D image is made.

Match – inspects both images and adjusts brightness and contrast so both left and right look the same. This avoids strange stereoscopic effects when the brain sees differently by each eye.

Auto scale – wrong name. It does not scale the image but its brightness. The brightness of each image is re-scaled from 0 to 255 even if the actual interval is smaller (e.g. 20-130). It adjusts the brightness to maximize contrast in both images.

Auto Converge – left and right image are moved closer together or further apart (to do this manually, use the Tweak menu) for better stereo effect. The number of pixels shifted is indicated. It aligns the images more correctly, avoiding eye strain in watching them – particuarly in head sets. This step is taken after the 3D image is created.

Repair Colour Anaglyphs – adjust the red/cyan colours that separate both images in a stereoscopic view in an attempt to produce it as good a colour image as possible.

Crop Borders – remove black bars at top and bottom of the image. Important if you want to vertically align the images without the bars misfeeding information)using "Automatic Alignment")

Automatic Rotate – rotate one or both images to reposition them to be in alignment. Important if you want to use "Auto Converge"

Find Edges – shows the edges round objects in the picture. Useful as a temporary result to be previewed in 3D to perform alignments. Not useful as permanent output (unless you feel very artistic) but useful to see edges and know where a filter like "Sharpen edges" will operate on.

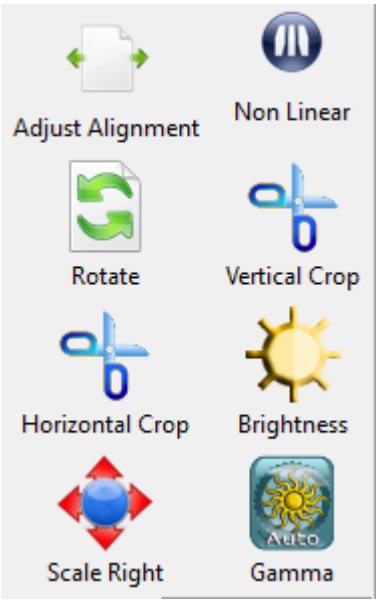
Find Brightest – find the brightest pixels in left and right image and copy them into the left image. This may cause a less sharp left image.

De-ghost – only relevant for imported interlaced or anaglyphic images to remove ghost effects they may have.

Adjust

The buttons behind the Adjust button are meant to adjust the two left/right images to give a better 3D effect. Some buttons also occur in other button menus. Adjust is a manual operation and the user decides on the setting values – unlike the "Automatic" filters.

In most options, one or two slider bars are shown below the left or both images and you can shift these sliders rather than entering values in a text box.



Adjust Alignment – allows to adjust the left image either horizontally (left slider) or vertically (right slider). When the mouse hovers over one of the sliders the help text underneath explains what shift applies.

The example below shows a horizontal shift over 294 pixels. See how the right side image is padded with a black bar. (Shifting -294 pixels shows the bar on the left image).

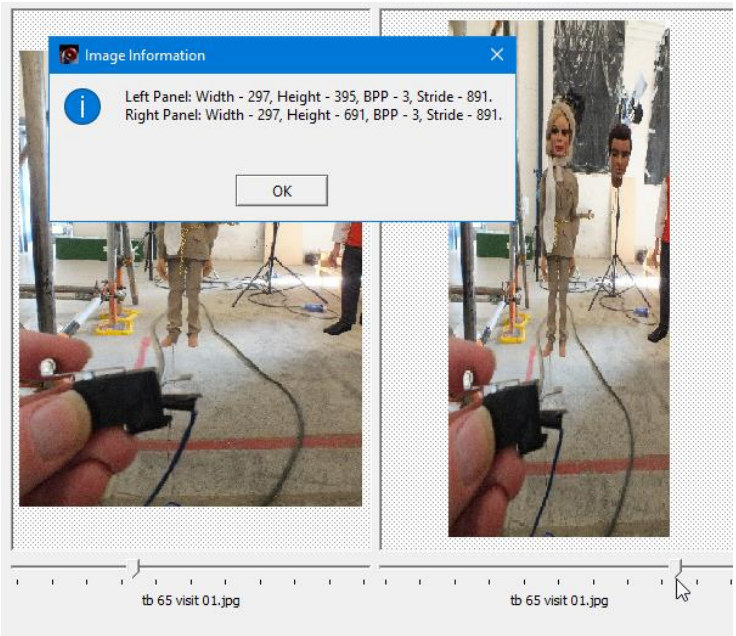
Rotate – rotate both images in opposite directions in values between -450 and +450 units (0 being upright).

The example shows a rotation of 271.

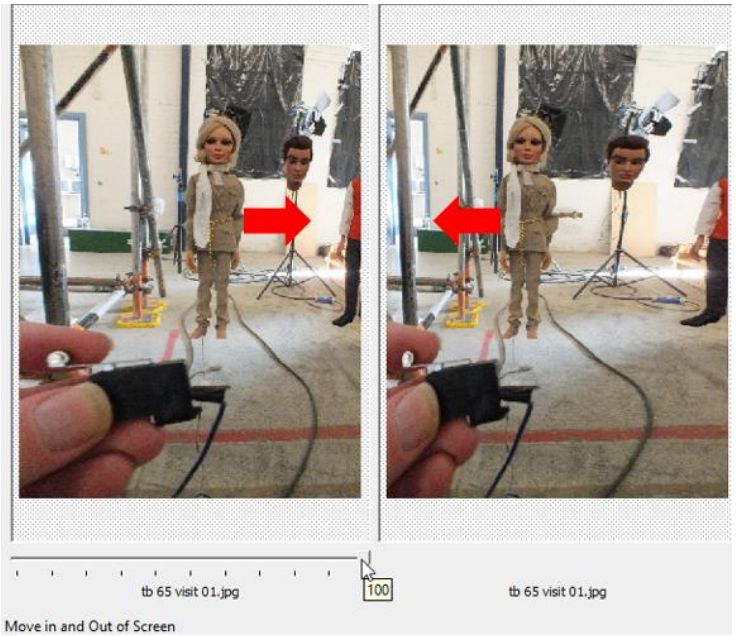
Horizontal Crop – crop the left and/or right side of the image between a value of 0 and 107. The example shows maximum crop on both sides.

Scale Right – modifies the right side frame by reducing or enlarging it vertically or horizontally, causing a squeezed or stretched picture. The left slider adjusts the horizontal scale, the right slider the vertical scale. Note that although the interface tries to show the entire frame, the unscaled side remains the same size.

The example shows a vertical scale of 997 and the resulting sizes of left and right image (from Edit > Details). Initially both left and right had values that only left has maintained.

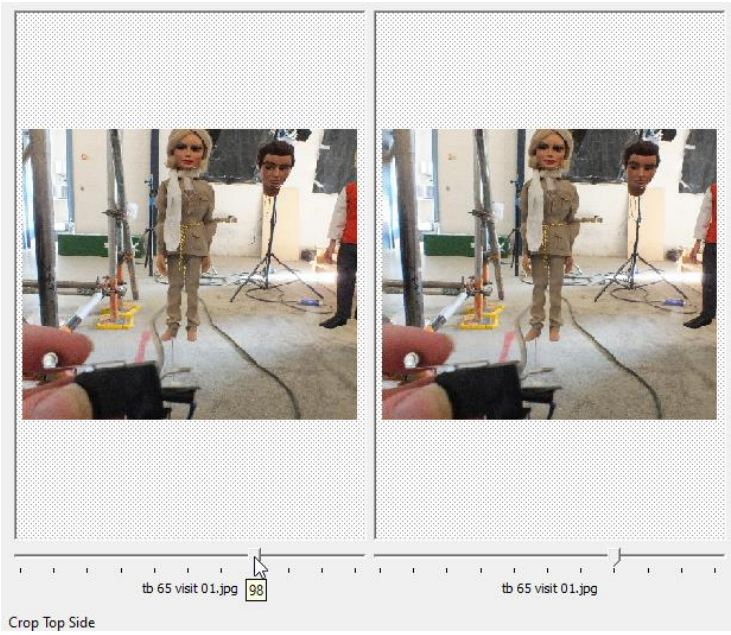


Non Linear – the entire frame contents remains, yet the middle part is moved to in opposite directions inleft and right frame. The side contents is squeezed or stretched.



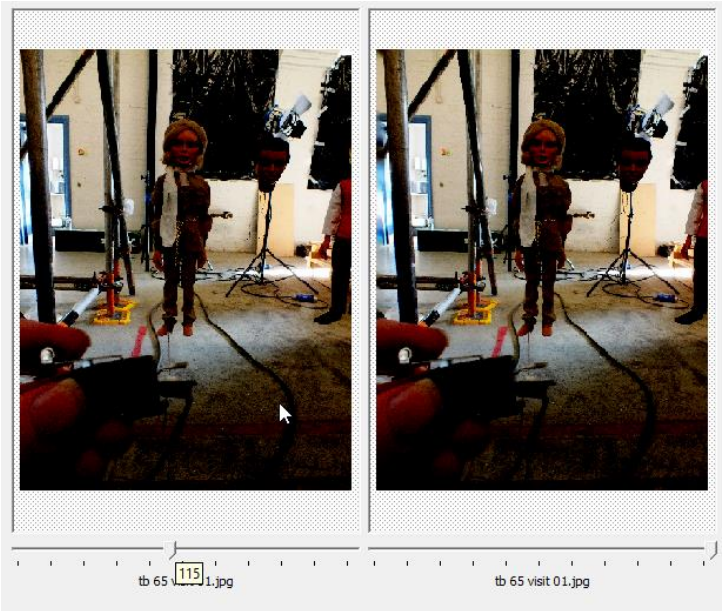
Vertical Crop – similar to horizontal crop. Each slider crops either the top *left slider) or bottom (right slider) of the frame.

The example shows a crop on top and bottom by 98.



Brightness – adjust levels of darkness and brightness. The proper lit picture has levels between 0 (black) and 255 (white). Reduce the interval and several shades of grey become a single shade, causing the overall picture to have fewer shades. In the extreme case where darkness is moved from level 0 to 255, the entire frame becomes black. In reverse, if the bright 255 is reduced to 0 the entire picture becomes white.

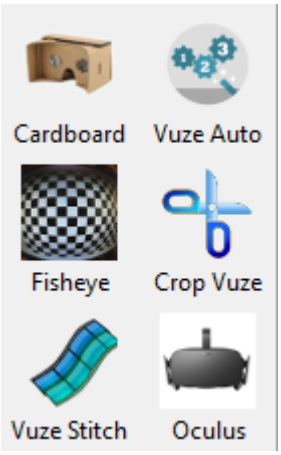
The example shows the darker level 0 to become 115, leaving only 255-115=140 levels available to cover black to white rather than 255 levels.



Gamma (also in Tweak) – change the gamma level of the frame from 0 (dark) to 100 (bright).

VR Button

This button opens a menu with buttons that each can perform an operations on an image or frame for use in Virtual Reality glasses of particular types.



Cardboard – Modify the stereoscopic image to fit a cardboard or similar viewer. Used for parallel view on mobile phones.

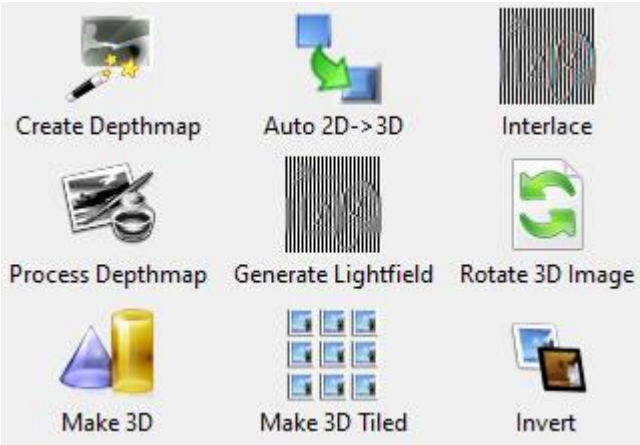
Fisheye – use 3D movies from fish-eye movie cameras (such as Lucid, which is one of the output file options) to create a 3D panorama in any format you want for use on a regular 3D tv or projector or anaglyphic on a pc screen. An online tutorial is found at https://www.youtube.com/watch?v=V1mwwp3fwfQ&t=158s

Vuze Stitch, Vuze Auto, Crop Vuze – Create panoramas for Vuze camera. They are discussed in the same tutorial as the Fisheye.

Ocultus – Modify the stereoscopic image for use in Ocultus viewers.

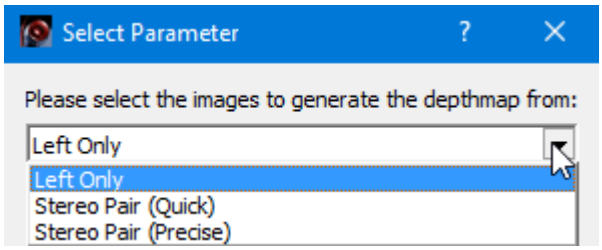
Depth Button

When you click on the Depth button it opens a sliding window revealing a number of buttons associated with depth in the image or frame.

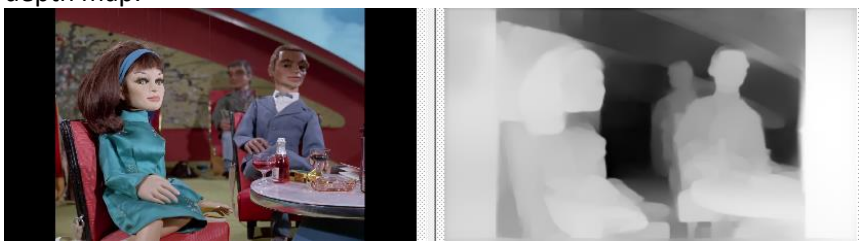


Any result can be viewed by clicking the “Preview 3D” button and click the “Save Image” or “Save Video” button after the desired type of output has been selected (See section Preview 3D Button on page 24).

- **Create Depthmap** creates a depth map of the current frame or image. It needs to know which side to use for depthmap creation or if a stereo movie or image is loaded how to create it from the difference between both images.



In case of a 2D image or frame, the right image becomes the depth map.

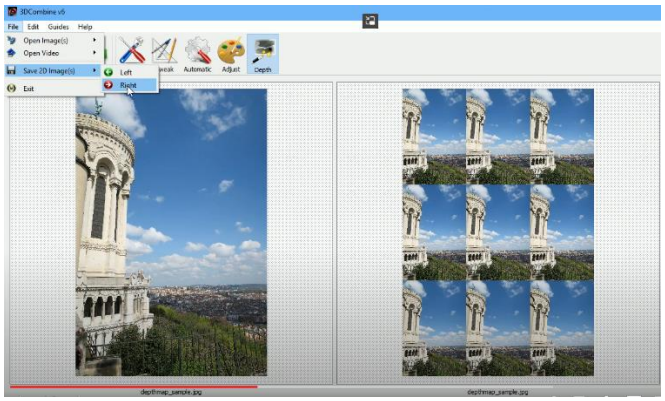


In the example above you see some manual correction is needed for the background at the left that is positioned too far in the foreground (too white compared with the much darker other part).

- **Process Depthmap** uses the depth map as right side image to create a 3D frame. This processing can occur in various ways and you must specify how you want it done.
  The various options here are important for the final outcome. They have been discussed at length in section “5. Process depth map” on page 50.
- **Make 3D** - creates 9 images from different viewpoints from one stereo image. This allows a lenticular monitor to display the same image but looking slightly different from different viewing positions. 3DCombine can generate these 9 images but the algorithm to apply is monitor dependent.
  - You are asked for the depth or disparity between left and right image. The suggested 0.20 value normally suffices but you can experiment.
  - It also asks if you want a high quality conversion. This takes more time but can provide better fill ins for the areas that are now revealed but which are not part of the flat 2D left image
  - Finally you are asked whether you want to warp both left and right image. If not, the left image remains the same and all difference is created in the right image.

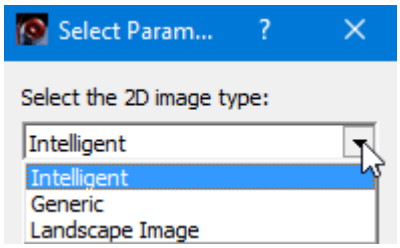
This therefore may display more artifacts. Dividing the left/right differences over both images (warp left and right) may give a more stable image

The resulting 9 images are created as right eye image and you can save this right image separately in (for example) .jpg format.



You can use the "Preview 3D" button to display the result in the way you want it (see Preview 3D Button on page 24). Using the Edit > Undo reverts to the left side 2D image and right side depth map. Create a new 3D image with a different depth value if you wish.

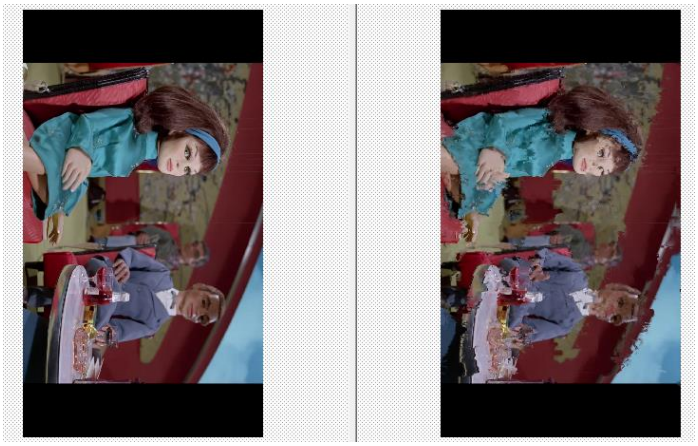
- **Auto2D > 3D** mimics the Guides "Intelligent" behaviour. When you click this button, you're asked what type of 2D image is available in the left frame.



Next all steps of creating the depth map and creating the stereoscopic image in Make 3D are performed in one sweep. If the right image already contains a depth map, that one is used.

- **Generate lightfield** This creates a set of images of the left image and stores them as files in the last used folder.The middle one is the unchanged left image. The other ones are modified 3D with a view more from the left (via middle) to the right and also show where 3DCombine had to fill in missing information – which may be very visible. It allows you to decide on what depth of field value you want to use with minimum artifacts.
- **Make 3D Tiled –** output type for certain 3D viewers
- **Interlace -** output type for certain 3D viewers

- **Rotate 3D image** rotates the left image clockwise, generates depth map and creates a right image (also rotated) The generated right side looks bad as looking through a bathroom window.
  If you already generated a stereo pair, it is simply rotated without distortion.



- **Invert** inverts a depth map in the right image. White becomes black and vice versa. This may be useful if the depthmap is used in other applications that use black-to-white instead of white-to-black depth maps.

Part 5 Correcting depth maps

Introduction

The depth perception in the end depends on how good the depth map is that creates the right image from given depth information on objects in the left image.

Using most of the “Guides” options, the depth maps remain invisible to the user. But where you want to influence the results, you need to manually change the depth maps. This must always be the case where the automated procedures make the wrong guesses about the depth of certain objects, causing some of the depth map limitations discussed earlier in Depth map limitations on page 11.

3DCombine normally runs to completion without problems. In my experience it did not fail once for a length of 9 consecutive days converting movies without restarts. But it fails silently when the output device is full. And this may happen if you ignore the fact that the output files can be much larger depending on the type of save you choose. A 22 GB ripped movie could become 220 GB. You need to have that space available.

In case of a movie conversion, you may use the “Guides” option for performing the process in 4 steps. After the first step, you can enter as many keyframes and associated depth maps as you wish before proceeding with the second step where these maps are used to create depth maps for each and every frame of the movie.

This part discusses how to create, modify and use the depth maps. Much of it is already covered in section Creating a depth map on page 31.

Create and save a depth map

Create depth map for image

You can create an entire depth map from scratch for an image using the layer approach discussed in section Creating a depth map on page 31. If you do not have the original image anymore, recreate it using File > Save 2D Image(s) > Left.

Use 3DCombine generated depth map

If you intend to improve on a depth map that 3DCombine created, you need to output this depth map as a file and then modify its grey tone contents to reflect proper distances. This can be done in any image editor that supports layers as your changes can then be stored in separate layers. Each of these layers can be adjusted without disturbing any of the other layers. You may select a certain grey tone using a wand tool and copy the selection as a new layer and adjust that layer.

To create a depth map for an image perform the following steps:

- Load the image in the left frame
- Click on the “Depth” button on the button ribbon
- Click the “Create depth map” button on the menu that opens
- Select the “Left Only” option as source for the depth map
- The right frame now shows the generated depth map
- Save the map using File > Save 2D Image(s) > Right

Editing a depth map

The depth map is adjusted using any layer supporting image editor. The final result must be stored in a flat file grey tone format such as .jpg or .bmp.

Do save and keep the original editor file format that has all the layers present. For Adobe Photoshop this is the .psd file.

This may come in useful if you need to make further adjustments if the result shown in 3DCombine is not to your satisfaction.

Recreating the stereoscopic effect

Recreating a stereo image

With the depth map created, it must be processed by 3DCombine into a stereoscopic image.

Perform the following steps:

- Import the flat image as left image using File > Open image(s) > 2D Left
- Import the depth map as right image using File > Open image(s) > 2D Right/Depth map
- Allow processing the depth map by clicking on the Depth button on the button ribbon of 3DCombine.
- Process the depth map clicking on the “Process Depth map”
- Create the stereoscopic image clicking on “Make 3D” button
- Preview the result clicking on “Preview 3D” button on the button ribbon in the format of choice such as parallel or anaglyphic.
- Repeat the steps above each time you revise the depth map
- Save the final 3D image by clicking on “Preview 3D” button and next on the “Save Image” button.

Recreating a stereo movie

Creating the stereo version of a flat movie is essentially identical to creating a lot of stereo images that suggest movement. After all a “movie” is short for “moving pictures”.

Here most of the work is done using the “Guides” manual steps described in section Guided Manual Steps (1 to 4) on page 38.

In essence, you create key frame images for each first and last frame of a scene and create depth maps for these. Either by creating them from scratch using the key frame images or by using the generated depth maps for these frames.

When a movie is imported, a number of play buttons appears on the button ribbon. Navigate to the specific frames and handle them as you would a single image:

- Save frame using File > Save 2D Image(s) > Left
- Import frame into image editor
- Create depth map by adding layers of grey tones
- Save depth map as flat .jpg or .bmp file
- Close image editor and save original file plus layers in case you need to edit it further

The resulting depth maps must adhere to a standard naming, being “depthmap_*nnn*.bmp” (other formats as .jpg are also allowed, but .bmp are lossless and better for accurate depthmaps) for the scene opening frame and “depthmap_*nnn*b.bmp” for the last frame of the scene.

The postfix “b” indicates “backtrack” . You use this if in the production of the 3D movie you want to use interpolation of the depth map between first and last frame of the scene.

All depth map files must reside in the same folder as where the 2D flat movie is stored for the “Guides” manual steps to work. If you saved the frame images in that folder too: they are no longer needed. Next you continue with Guides > Manual Step 2 and further.

Appendices

Appendix A: Errors occurred: possible causes

3DCombine sometimes doesn't seem to do what you intended and may give a clear reason or not. Some of these unclear reasons are discussed here.

Unable to save file. As indicated by the message, this may be because the output folder cannot be written to. Perhaps the folder is set read-only, perhaps you need administrative privilege to write to it. But the same message also occurs when, during operation, the disc of the output folder has become completely filled.

Sudden abort of application. This seems to happen during movie conversion in any sort of "Guides" use. Reason unclear. Currently only workaround is divide the movie in smaller parts and process them individually, reducing the risk of losing work. Recombine parts using a video editor. Because the output is SBS or anaglyphic most of the time, any 2D video editor will work.

Because the converted output file can be ten times larger then the source file, make sure the output disc has sufficient storage space. When 3DCombine requires more space it will abort when the disc is full.

Output can not be opened in video editor. This may be due to the output being produced with variable bitrate and the editor only accepting fixed bitrates. Convert the output file to fixed bitrate using any movie converter.

Files or folders won't delete – This may happen when you used 3DCombine for a long time without rebooting your pc. It should not happen but it seems sometimes a link is kept to files created and because of that you cannot delete the file (Windowx Explorer seems to go in "no response" mode. Reboot to release any link to the application.

Rendering is slow – rendering of movies is not fast (and takes about 20 times the running time of the movie). If it is far slower than that, either your pc has a slow processor or a reboot may release any resources held by whatever application has run earlier.

Wobbly movie conversion result A wobbly picture with the images vibrating left and right might be caused by a low bitrate source file. This delivers not a lot of information for the converter to clone for areas that have no information. Use sufficiently high bitrates for a more stable picture.

Audio out of sync – This may happen if you use the original movie's audio track as opposed to the one created by 3DCombine. The 3DCombine output seems a few frames short of the actual movie.If several parts are spliced together while the original audio track is not

trimmed to the same length, a synchronisation problem occurs and gets worse with every additional spliced in segment.[21]

[21] See Appendix B: Bitrates on page 98

Appendix B: Bitrates

Composition of a movie file

If video is converted from 2D to 3D, the quality of the conversion very much depends on how much source information of a frame is available to convert and to clone information that is missing in the 2D image.

Consider a single high definition frame. It has resolution 1920x1080 pixels. Each pixel has a colour made from red, green and blue (RGB). Each colour can have 256 shades – an 8 bits or 1 byte number between 0 and 2^8-1 = 255. That means a single frame requires 1920 x 1080 x 3 x 8 = 49,766,400 bits. And there are 24 frames per second in movie, totalling to 1,194,393,600 bits/second, 1,2 Gbps or 150 MBps (b for bit, B for byte=8 bits). There are few if any households that can stream movies over internet at that rate. A current bluray disc of 25 GB capacity would be completely filled in 25/0,150 = 167 seconds – less than 3 minutes.

It took some time, but one started to compress images. From "complete" lossless images (like BMP and TIF) they invented lossy formats like.JPEG under the assumption that irrelevant details could be left out. This reduced the image size a minimum factor of 10 but with more compression and more loss upto 20 or 30 times smaller.

Filling a bluray disc with JPG images as movie frames would allow 10 to 30 times 3 minutes. Better, but still a short running time.

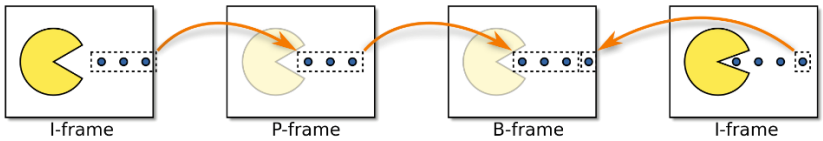
Based on the knowledge of compressing images, moving images could be compressed even furter. The "complete" but lossy image would become a what is known as an I-frame. These full images would only occur every so often. In between were new frames, P- en B-frames. Both do not have a complete (lossy) image like the I-frame but only contain the changes from objects between two I-frames.

Some shop talk:

- An **I-frame** (Intra-coded picture) is a complete image, like a JPG or BMP image file.
- A **P-frame** (Predicted picture) holds only the changes in the image from the previous frame. The encoder does not need to store the unchanging background pixels in the P-frame, thus saving space. P-frames are also known as *delta-frames*.
- A **B-frame** (Bidirectional predicted picture) saves even more space by using differences between the current frame and both the preceding and following frames to specify its content.

P and B frames are also called Inter frames. The order in which the I, P and B frames are arranged is called the Group of pictures (GOP).

It is shown in the picture below. A cookie monster eats cookies coming in from the right.



At both ends there is a complete I-frame. The P frame shows the movement of only the cookies part of the image. The subsequent B-frame shows how a fourth cookie comes in (seen in the next frame) and the three existing cookies move further to the left.

DVDs used MPEG-2 as a standard for creating I,P and B-frames. Later developments came with MPEG-4 (also known as H.264) that deliver a similar quality at ¼ of the bitrate. Clearly this compression technique is used on blurays. The 4K discs use an even more efficient compression, H.265.

It is clear that using I,P and B-frames the amount of data needed to show one second of film decreases and thereby the bitrate. They can come down to a manageable level and increases a bluray disc capacity to contain a movie of 2 hours (high bitrate) to fill up the disc or it can contain the movie, a lot of extra's, additional audio and subtitle tracks and elaborate menus. It all fits the same 25 GB disc capacity but requires a lower bitrate. Of course the playback software on computer or as part of a standalone player, must be able to process that amount of data and recreate full frames for display.

If you use the tool MediaInfo to inspect a movie file, you will encounter their mention of GOP groups as (for example)
Format_Settings_GOP: M=3, N=13
Here M means the size of of BP groups (first one is always a single I frame) and N the number of BP groups (existing of B frames and always ending with one P frame).
M=1, N=5 means I P P P P – I P P P P
M=2, N=5 means I BP BP BP BP – I BP BP BP BP
M=3, N=3 means I BBP BBP – I BBP BBP
M=3,N=13 means I BBP BBP BBP BBP BBP BBP BBP BBP BBP BBP BBP BBP – I BBP BBP etc
The more B and P frames, the smaller the video file.

Bitrates for bluray and HD Television

The lower the bitrate, the fewer details can be provided to the frames of the movie. This is no different from compressing a photo still more and more.

Common maximum bitrates are:

- a bluray disc object like a movie can have upto 40 Mbps. Maximum set by the Bluray Disc Association, BDA.
- HD television transmissions can be upto 19 Mbps (either use the bandwidth or for a half-HD 1280x720 pixels picture sent in full (720p - progressive) rather than a full-HD image of 1920x1080 pixels in halves: first the odd rows and then the even rows (1080i - interlaced)).

- 4K UHD (3840x2160 pixels also known as 2160p) has 4 times as many pixels as ordinary bluray has upto 128 Mbps

The higher the bitrate of the source files for 3DCombine to convert, the more information about the frame is available. The more there is, the better 3DCombine can clone information into areas it has to “make up”.

Lower bitrates give less detailed pictures but also coarser cloned items that show up as visible artifacts.

Experiences with 3DCombine

Because 3DCombine creates large output files with mostly I-frames, you may consider cutting long running, high bitrate movies into several pieces and process each in sequence.

Essentially the output is targeting a high bitrate so as not to lose any quality in the process of converting. As the source video itself is also using higher bitrates, the difference between input and output becomes smaller.

I did some experiments on the same movie segment but different bitrates to see the difference in results. The following data was measured on a 1 minute segment of a film:

The input movie was

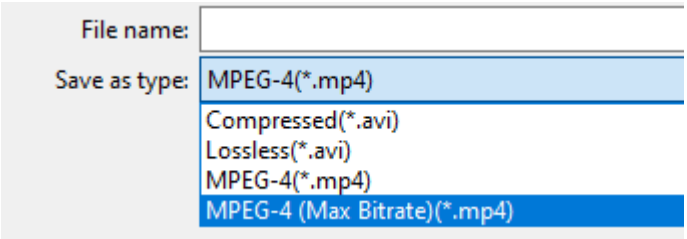
- in full HD 1920x1080 pixels, 2D.
- original .m2ts rip from bluray at 15,500 kbps was converted to .mp4 with 15,500 kbps
- same segment was edited in Cyberlink PowerDirector to save in bitrates 15,500 kbps down to 3,000 kbps
- input files had video format AVC (MPEG4), 24 fps, progressive, audio format Dolby Digital 5.1 at sampling 48 kHz, 448 kbps

The 3DCombine processing consisted of

- Create Depthmap (Left Only)
- Process Depthmap “maximise” filter
- Make 3D (depth 0.2 (default), high quality background fill, warp both left and right images for fewer artifacts

No other user-activated processes were running during the test to minimize their influence on the performance.Slight differences may still occur because the Windows system itself runs services now and again.

The output files in SBS/Sensio format were created for each bitrate in all output types “compressed”, “lossless”, “MPEG4” and “MPEG4-maximum bitrate”.



The results can be seen in the two tables below – identical but sorted on either bitrate of the input file or on the type of output 3DCombine can create. The column used for sorting has its header printed in red.

Some general information on the output formats[22]:

- compressed:
  - video: MPEG-4 Visual with profile Advanced Simple@L1
  - audio MPEG2 at 44.1 kHz sampling, 256 kHz bitrate, 2 channels L/R
- lossless:
  - video: HuffYUV
  - audio: PCM, at 48 kHz sampling, 16 bits depth, 1,536 kb/s bitrate, 2 channels L/R
- MPEG4:
  - video: HEVC with profile Main@L2@Main
  - audio MPEG2 at 44.1 kHz sampling, 256 kHz bitrate, 2 channels L/R
- MPEG4 max bitrate:
  - video: HEVC with profile Main@L2@Main
  - audio MPEG2 at 44.1 kHz sampling, 256 kHz bitrate, 2 channels L/R

In all saved formats the audio quality is inferior to the source. DTS or Dolby Digital multi-channel get replaced by MP3 quality.

Potentially you also lose in definition in the output types “compressed” and “MPEG4” as the bitrate is lower than the original bitrate.

[22] information provided by the MediaInfo tool

output type	bitrate input kbps	input file size kB	conversion time mm:ss	video bitrate output kbps	output file size kB	file size factor	video bitrate factor
compressed	3000	25,434	22:22	3,346	27,920	1.10	1.12
lossless	3000	25,434	22:45	301,000	2,273,590	89.39	100.33
MPEG4	3000	25,434	22:10	5,345	41,912	1.65	1.78
MPEG4 max bitrate	3000	25,434	21:06	62,300	467,823	18.39	20.77
compressed	6000	49,962	21:00	3,405	28,368	0.57	0.57
lossless	6000	49,962	21:10	306,000	2,307,573	46.19	51.00
MPEG4	6000	49,962	20:48	5,541	43,378	0.87	0.92
MPEG4 max bitrate	6000	49,962	20:36	69,400	521,252	10.43	11.57
compressed	9000	70,141	20:57	3,442	28,643	0.41	0.38
lossless	9000	70,141	21:22	309,000	2,333,151	33.26	34.33
MPEG4	9000	70,141	20:33	5,692	44,506	0.63	0.63
MPEG4 max bitrate	9000	70,141	20:38	69,400	521,252	7.43	7.71
compressed	12000	91,433	20:57	3,467	28,830	0.32	0.29
lossless	12000	91,433	21:12	311,000	2,347,207	25.67	25.92
MPEG4	12000	91,433	20:34	5,811	45,398	0.50	0.48
MPEG4 max bitrate	12000	91,433	20:38	79,600	597,344	6.53	6.63
compressed	15500	117,865	21:19	3,491	29,009	0.25	0.23
lossless	15500	117,865	21:24	313,000	2,363,006	20.05	20.19
MPEG4	15500	117,865	20:56	5,928	46,275	0.39	0.38
MPEG4 max bitrate	15500	117,865	20:53	84,200	631,966	5.36	5.43
MPEG4[23]	32200	30808362	2687:00	4,939	4,947,891	0.16	0.15
MPEG4-max bitrate[24]	20200	13,533,720	2340:06	230,000	154,461,915	11.41	11.39

[23] complete feature film of 2:06:20 running time
[24] complete feature film of 1:29:20 running time

output type	bitrate input kbps	input file size kB	conversion time mm:ss	video bitrate output kbps	output file size kB	file size factor	video bitrate factor
compressed	3000	25,434	22:22	3,346	27,920	1.10	1.12
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lossless	12000	91,433	21:12	311,000	2,347,207	25.67	25.92
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MPEG4[25]	32200	30808362	2687:00	4,939	4,947,891	0.16	0.15
MPEG4 max bitrate	3000	25,434	21:06	62,300	467,823	18.39	20.77
MPEG4 max bitrate	6000	49,962	20:36	69,400	521,252	10.43	11.57
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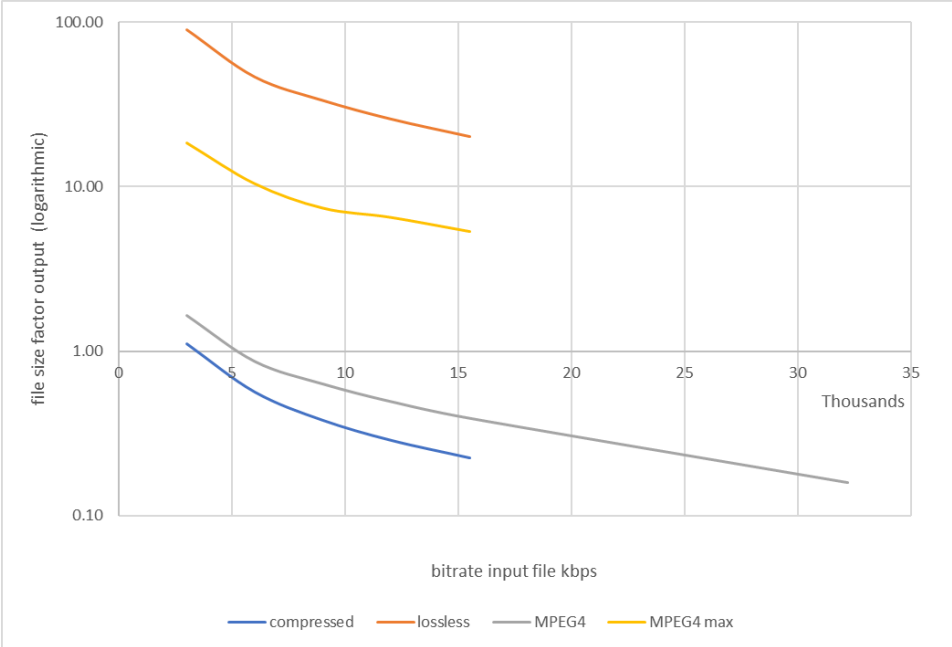
MPEG4 max bitrate	12000	91,433	20:38	79,600	597,344	6.53	6.63
MPEG4 max bitrate	15500	117,865	20:53	84,200	631,966	5.36	5.43
MPEG4-max bitrate[26]	20200	13,533,720	2340:06	230,000	154,461,915	11.41	11.39

[25] complete feature film of 2:06:20 running time
[26] complete feature film of 1:29:20 running time



The data in the table has also been plotted in the graph above. The file size factor corresponds with the bitrate factor[27]. The MPEG4 graph is shown for bitrates upto 33,000 kpbs.

Higher input bitrates provide more detail in the frames. This results in more detailed images. This potentially allows the conversion routines to clone more accurately. Inspecting conversion results from high and low bitrates did not show much difference. The output frame remains of better definition at higher bitrates.

Some conclusions from these measurements:

- the larger the bitrate, the smaller the output file increase factor (but larger bitrates produce larger files). For MPEG4 and compressed it becomes even smaller than the input file size[28]
- the input bitrate seems not to make much difference in conversion time regardless of output type. The time required is about 20-22 times the running time of the source file.
- the conversion is not visually better at higher input (or output) bitrates
- the audio might have problems on output: loss of synchronisation or crackling effects.
- the output audio is inferior to most input audio: multichannel DTS, Dolby Surround or LPCM are reduced to MPEG2 (better known as MP3) audio at 256 kbps.
- The output file is 5-7 frames shorter than the source file.

[27] In the table both differ slightly because the output bitrate only contains the video bitrate, ignoring the audio part. The input bitrate is of both.
[28] Another bluray ripped file of 34 Mbps and size 30 GB (182464 frames) using MPEG4 resulted in a bitrate of 5.2 kbps and file size 4,8 GB – after almost 45 hours of processing.

This leads to the recommendations to:

- Use MPEG4 maximum bitrate to keep all information from the input source frames.
- Use a suitable video editor to mix two movie files:
  - use the 3DCombine produced video stream
  - use the original source file audio stream
- Create an .mp4 (AVC/MPEG4) for general use or a .m2ts (AVC/MPEG4) (if subsequently used for bluray authoring) using the bitrate and audio options of the source file. This also takes care of any required transcoding to conform to bluray standards.

Processing speed for various output formats

From the measurements you can see there is little difference in processing performance for different bitrates – it takes about 20 times the running time of a movie to convert it to SBS/Sensio in 3D format regardless of the original bitrate.

The same is true to a large extend for the various output format types you can select such as Parallel or Anaglyph, as the table below shows. The processing time takes 18-22 times the running time of the movie.

The big difference is in the size of the output file. This is not only dependent on the output type ("compressed", "MPEG4" etc) but also on the output format {such as "parallel"). The size change is caused by a different bitrate for these formats.

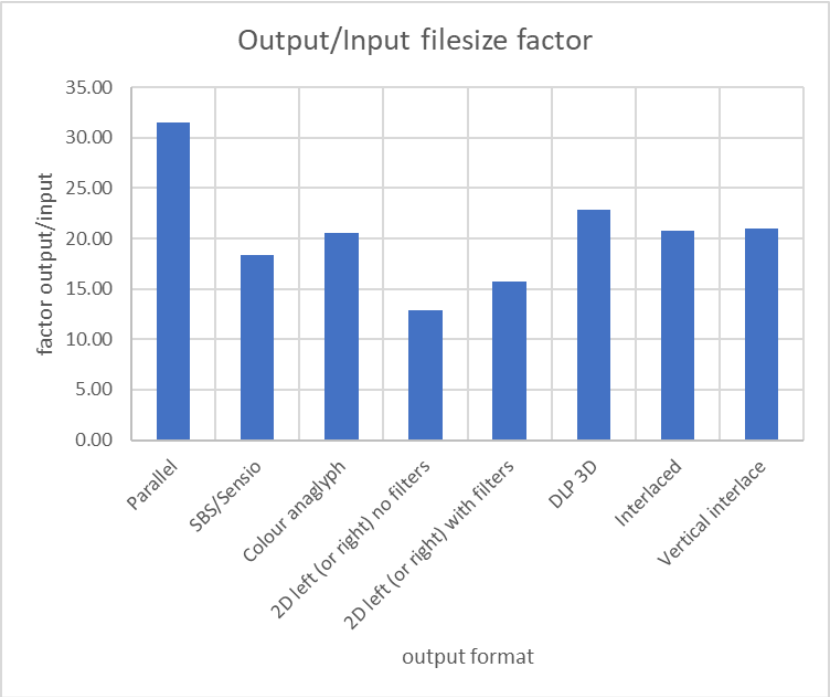
Some measurements made are listed in the table below. The same test movie was used with the same conversion filters as before:

- 1 minute full HD 1080p source movie, 3,000 kbps bitrate, video MPEG4, progressive, audio Dolby Digital 5.1, file size 25,434 kB
- Processed with filters "Create depth map", "Maximise" and "Make 3D" (depth 0.2, high quality background, warp) for various output 3D types.
- Output type choosen "MPEG4 maximum bitrate"

It may come as a surprise that simply copying the source (2D Left) without any filters, still produces a larger output file. When the filters are used, 3DCombine goes through the motions of changing the flat 2D frame into a left side image of a stereo pair.

output format	processing time mm:ss	output file size kB	output bitrate kbps	file size factor to source 25,434 kB	video bitrate factor to source 3,000 kbps
Parallel	22:16	800,131	107,000	31.46	35.67
SBS/Sensio	21:06	467,823	62,300	18.39	20.77
Colour anaglyph	21:58	522,886	69,600	20.56	23.20

output format	processing time mm:ss	output file size kB	output bitrate kbps	file size factor to source 25,434 kB	video bitrate factor to source 3,000 kbps
2D left (or right) no filters	01:23	328,430	43,600	12.91	14.53
2D left (or right) with filters	18:19	400,734	53,300	15.76	17.77
DLP 3D	18:24	581,737	77,500	22.87	25.83
Interlaced	17:24	529,067	70,500	20.80	23.50
Vertical interlace	18:28	532,440	70,900	20.93	23.63



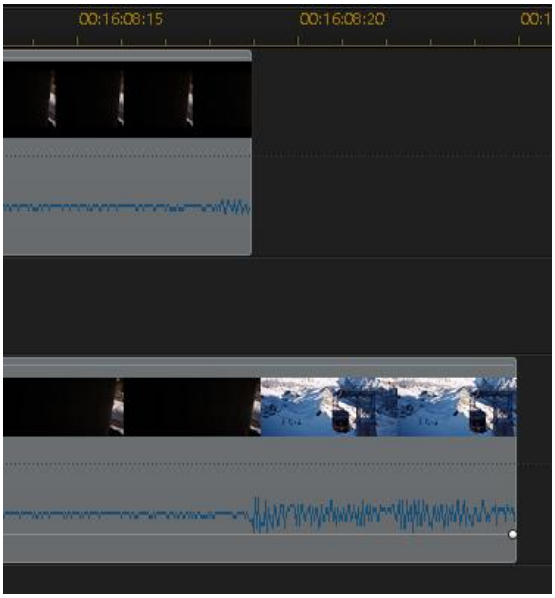
Some conclusions:

- The output type ("compressed" a.o.) is more important for file size and bitrate than the output format ("parallel" a.o.)
- For specific devices, only one output format will do so the only influence is the choice of output type.
- if you can use various output formats, select one and convert the result into another format (like "parallel" into "Half SBS" or SBS/Sensio) using a video editor or converter. This saves lots of time.

Audio sync

The output file synchronises frame-to-frame with the input file. Hence muxing the video of the output with the audio of the source input will provide lip-sync results. The output file is 5-7 frames shorter than the source file.

And that's where the problem starts. If multiple output files are concatinated to a longer movie and muxed with as many input files the source movie is longer in every chapter. When 10 chapters are concatinated, the end of the converted file will be 10 x (5 to 7) = 50 to70 frames short of the original, causing synchronisation gap to become bigger with every new chapter.



Different lengths: the converted 3DCombine ends at 16:08.19 (top row) but in reality the source ends at 16:09.00 (bottom row) (time indication starts at time marker): 5 frames are chopped off.

Conclusion:

- Each conversion is always 5-7 frames shorter at the end (typically fewer than 24, less than 1 second duration).
- Source and target are identical frame-by-frame except for the missing final 5-7 frames in the converted file.
- When editing converted chapters together using the original sound, trim the original audio at the end of each chapter.

Appendix C: External Tools

Searching for 3D tools on the internet quickly makes you realize a lot of tools are not meant for stereo viewing but to assist in creating objects to print in a 3D printer. A whole different ballgame therefore.

In this section a number of tools are mentioned, freeware as well as commercial software, that may assist in your quest to produce stereo images and movies from flat 2D files.

As with most freeware tools: be careful on what links you click as most of their webpages are loaded with irrelevant adverts that try to redirect you to other commercial tools. The installation files may also lure you to "also install our recommendation" and before you know it a lot of bloatware gets installed also.

Blu-ray and DVD ripping

- AnyDVD HD (https://www.redfox.bz/en/anydvdhd.html) continuation of the Slysoft AnyDVD software that removes all encryption and allows a disc (DVD or blu-ray) to be played regardless of region or encryption. And files can be copied unencrypted.
- DVDFab (http://www.dvdfab.cn/) software to rip DVDs and blu-rays completely or only some titles and shrink them to size if needed. Trialware.
- MediaInfo (https://mediaarea.net/en/MediaInfo) – freeware tool to inspect video files characteristics like are they interlaced or progressive, what is their resolution, framerate and other useful information. Integrated in Windows Explorer. Use the "Tree View" for exhaustive information.

File joining/splitting

- HJSplit (www.freebyte.com/hjsplit or http://www.hjsplit.org/) – a program that either joins files together (all with added filetype <name>.<type>.001 to 00*n*) or splits one in a set of files of specified length (output <filename>.<type>.001 to 00*n*).

Photo editing

- **Adobe PhotoShop** (www.adobe.com) – expensive photo editing program, currently only on "365" annual subscription. Affordable version as "PhotoShop Elements". "Mother" of all image editors.
- **Corel – CorelDraw Graphics Suite** (www.corel.com) – similar to PhotoShop but far cheaper image editor, based on their purchased "PaintShop pro" application. Comes in flavours "Suite", "Standard" and "Essential". The latter two only on Windows.
- **GIMP** (http://www.gimp.org) – GNU freeware cross platform image editor (amongst which are Windows and Linux)
- **3Dconverter DMAG1-9** (http://3dstereophoto.blogspot.com/p/software.html) – set of macros that work with GIMP to create depth maps of images. Created and maintained by Ugo Capeto. He maintains a blog with

lots of information on 3D creation on
http://3dstereophoto.blogspot.com/

Video editing and format converting

- **Adobe Premiere Pro and Elements** (www.adobe.com and https://www.adobe.com/products/premiere-elements.html) – commercial movie editor. The "Elements" version is a trimmed down (cheaper) version of the full-fledged Premiere Pro.
- **Cyberlink Power Director** (https://www.cyberlink.com/index_en_US.html) – a movie editor (both picture and sound). If you intend to work on an output file, do not chose its AVC/MPEG-TS output stream as it has difficulties reading its own output in this format.
- **Wonderfox HD Video Converter Factory (Pro)** (https://www.videoconverterfactory.com/dvd-video-converter/) – free and paid (Pro) versions of a HD video converter from one format into many other formats. You may need to disable the "hardware acceleration" if your video card doesn't work with this converter (producing 0 bytes sized files).
- **Xmedia Recode** (https://www.xmedia-recode.de/en/) – free video format converter from almost any format into any other.

Stereo Photo Editing

- **Stereo Photo Maker** (SPM). http://stereo.jpn.org/eng/stphmkr/ Freeware program made in Japan. It has become the "de facto" application to manipulate stereo images. You can create or add depth maps, align images and a lot more. It is Windows based but can run on Apple Mac and Powerpc's if run in a Windows emulator. In part it duplicates or complements 3DCombine's features. It can make depth maps only after downloading Google software.
  It can also make stereo slide shows from stereo images.

Photo and Video players

There are lots of software video players on the market. We only mention two.

- **VLC Media Player** (https://www.videolan.org/). Freeware movie player by the Video Lan Community. Capable of playing most video formats. It can play SBS movies (Tools > Effects and Filters > Video Effects > Advanced > Check "Anaglyphic 3D"). The Side-by-side capability started implementation but I don't think it ever came to anything.
- **PowerDVD** (https://www.cyberlink.com/products/powerdvd-ultra/features_en_EU.html) A commercial player that seems rather strict in obeying BDA rules about preventing unintended types of use like refusing to play bluray discs if your monitor is not digitally connected (uses VGA connections) as well as disallowing screen captures if it is. Plays many movie and photo formats and automatically switches to SBS if such a medium is

inserted into its media library. Manually use Photo/Video > Change to 3D Format > Side by Side

Appendix C: Discussions on the web

By searching on the internet on keywords like “3DCombine review” you may find several experiences by users and ways they work.

Some that you may find useful are listed below (no guarantee any link will be there forever).

https://www.3DCombine.com/documentation.html

https://www.avsforum.com/threads/a-new-software-allows-proper-2d-to-3d-conversions-using-depth-maps-and-ai.3228063

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